Reducing the costs and impacts of bushfires

A report by the Independent Bushfire Group
after the Black Summer fires of 2019-2020

July 2020

The **Independent Bushfire Group** is 12 non-aligned bushfire practitioners, fire managers, land managers, fire researchers and ecologists with over 400 years of collective experience in bushfires, land management and fire ecology across a range of fire landscapes. We focus on practical firefighting issues. A version of this report was submitted to the NSW Independent Bushfire Inquiry in June 2020. This report may be updated from time to time.

Table of Contents

Preamble 3

Summary and Recommendations 4

Introduction 11

Part 1 – Causes and Contributing Factors 15

1.1 Summary of Fire Studies 15

Part 2 – Preparation and Planning 17

2.1 A Risk-based Approach to Bushfires 17

2.2 Aspects of Bushland Management 24

2.3 Community Fire Planning 36

2.4 Critical Fire Incident Management Skills 44

2.5 Research 52

Part 3 – Response to Bushfires 55

3.1 Initial Attack for Remote Fires 55

3.2. Fire Behaviour Modelling 64

3.3 Suppression Strategies for Large Fires 71

3.4 Fire Incident Management Arrangements 85

Part 4 – Other Matters - Recovery 91

4.1 Post Fire Review of Operations 91

4.2 Environmental Recovery 105

4.3 Community Education 116

Part 5 – Detailed Fire Studies 120

Fire Study 1 131

Fire Study 2 136

Fire Study 3 140

Fire Study 4 145

Fire Study 5 150

Fire Study 6 155

Fire Study 7 160

Fire Study 8 166

Fire Study 9 170

Fire study 10 175

Fire Study 11 177

Appendix A 179

Report Authors 179

Preamble

The extraordinary bushfires of 2019-2020 present an historic opportunity to recognise the best in bushfire management and to drive improvement.

The fire environment has changed with respect to climate, community exposure, fire intensity and size. Costs to communities, health, environment and government are escalating. The costs in NSW alone of suppression, recovery and the broader economic impacts of the 2019-2020 fire season will run into billions of dollars. Then there are the less tangible but no less important effects on individuals, firefighters, communities, physical and mental health, ecosystems, catchments and wildlife. The community, media and governments have never been so interested or receptive.

All these factors create the opportunity for change to fire management practices that will:

- better protect communities
- reduce costs
- reduce the overall risk and trauma to firefighters
- conserve our natural heritage.

It is also important to counter simplistic solutions that could lead to less effective fire management with even greater impacts. Firefighters deserve to be supported with the best possible systems and strategies.

Fires no longer behave the way they did 40 or so years ago when some of the authors commenced their professional and volunteer roles as fire managers, but over that period we have experienced the gradual, yet predictable, change that culminated in the 2019-2020 fire season. In this report we share our concerns, thoughts and recommendations from the 2019-2020 season and highlight new opportunities that this season's experiences can offer firefighters.

As a group of dedicated fire practitioners, we have a strong interest in seeing sensible changes adopted in response to the 2019-2020 experience. Whether this is a thorough rethink on fire prediction modelling, a review of the effectiveness of the current ways assets are given protection on the bush/urban interface, a new focus on supporting key firefighting roles such as Divisional Commanders or improving community resilience; all these and other priority initiatives are addressed in the report.

Managing bushfires is a whole-of-community project. Fire agencies can do their best, but they need the support and commitment of the community, government, independent experts, scientists, non-government organisations and other agencies.

> *This crisis represents a once-in-a-generation opportunity for genuine reform.*
>
> Editorial, *Sydney Morning Herald*, 6 January, 2020

Summary and Recommendations

This report has been prepared by a collaboration of 12 bush fire practitioners, fire managers, land managers, fire researchers and ecologists. Together we have over 400 years of practical, professional experience in bushfires, land management and fire ecology across a range of fire landscapes. The report has a pragmatic approach to, and operational focus on, issues within our expertise. It applies our collective knowledge to close observation and analysis of the recent NSW bushfires. Detailed studies of particular fires form part of this analysis.

We believe firefighters deserve to be supported with the best systems and strategies. We are putting forward comprehensive recommendations for improved operational performance, systems development and research priorities for bushfire management in NSW and beyond.

We recommend changes to fire management that will:

- better protect communities
- reduce costs
- reduce overall risk and trauma to firefighters and,
- conserve our natural heritage.

We suggest the greatest gains can be made from improvements to risk-based strategic thinking, research, initial attack, suppression strategies, critical skills and operational reviews.

Current practices have been tested during the 2019-2020 fires and amongst many 'wins', they have not always been successful. Multiple difficult fires and resource shortages as in the 2019-2020 season, make the best systems and processes even more important to achieving the best outcomes. Many challenges are a product of how fire suppression is thought about, organised and resourced. Others require stronger evidenced-based and new-thinking approaches to meet the challenge of climate change and a changed fire environment across Australia's bushland.

Issues are grouped into three phases of disaster management: Preparation and Planning, Response and Recovery. Each issue includes a statement of the issue and the opportunities for improvement, followed by a summary of the issue, recommendations and finally a detailed analysis. Most of the issues are connected to each other, demonstrating the complex, integrated nature of bushfire.

This report also includes 11 detailed studies of the 2019-2020 fires. These fire studies use analysis, maps and text to illustrate some of the issues discussed in other sections. The studies are 'first cut' analyses, offered as examples that can be improved upon with more information and work.

The studies have been prepared under several limitations, including time and not having access to the full range of analytical resources. Consequently, there may be errors in some details. The basic events are considered to be correct but could be refined with access to all relevant data.

The fire studies are presented in terms of factual events with some interpretation. They demonstrate the potential and need for comprehensive post-fire analysis.

Opportunities and Key Recommendations for improvement are summarised below.

Preparation and planning

A Risk-based Approach to Bushfires

Strengthen systems for a risk-based approach to bushfire suppression, to improve decisions and limit the scale and consequences of fires.

Recommendations for a Risk-based Approach to Bushfires

- Apply a rigorous, risk-based decision framework to all bushfire suppression activities, based on the Australian Institute for Disaster Resilience guidelines.
- Ensure that long-term threats such as remote fires are assessed alongside more immediate risks and that response priorities and resource deployment are more balanced.
- Undertake and document risk assessment of all suppression options before acting, as rigorously as time allows.
- Ensure environmental risks are fully considered in bushfire suppression risk assessments.

Aspects of Bushland Management

Ensure that governments and agencies promote factual information to the public and develop evidence-based and multi-tenure mitigation programs for bushfire risk. Recognise environmental needs and balance them against fire management aimed at protecting human communities. Increase research into the best ways to reduce fire impacts.

Recommendations on Aspects of Bushland Management

- Encourage and resource agencies to educate communities and firefighters about land management and fire management that is based on evidence, risk and objectives.
- Ensure conservation objectives of land management are not compromised unless there are proven and substantial benefits to community protection from fire, especially in the core of large bushland areas.
- Avoid reducing moist vegetation types in the landscape through repeated fire.
- Elevate NSW NPWS Reserve Fire Management Strategies so they are supported, recognised and followed during fire suppression activities. Fully resource the regular revision of these strategies.
- Focus programs aimed at protecting communities from fire on the bushland edge.
- Undertake comprehensive analysis and research into the suppression benefits of prescribed burns during the 2019-2020 fires and cross-analyse these with the actual suppression strategies deployed by Incident Management Teams.
- Ensure prescribed burning and other fire mitigation strategies are risk-based and evidence-based.
- Integrate and resource fire mitigation planning and program implementation across all tenures on the bushland edge.
- Recognise the limitations and complexity of burning for hazard reduction on the bushland edge.
- Maximise methods other than burning to reduce risk to communities.
- Ensure fire mitigation programs are tailored to the specific needs and situation of each community.
- Expand research into the best mix of methods to reduce the impacts of fire on communities.

Community Fire Planning

Accelerate the rollout of Community Protection Plans based on the recent RFS guideline, through a committed and prioritised program supported by policy, targets, funding and resources.

Recommendations for Community Fire Planning

- Expand the Community Protection Plan program to cover all at-risk rural villages and suburbs by 2030.
- Establish Community Fire Units in all receptive at-risk communities.
- Review how well existing Community Protection Plans worked for communities affected by the 2019-2020 fires as a way of refining and improving the CPP program.

Critical Fire Incident Management Skills

Increase cross-agency investment to develop greater numbers of expert Fire Strategists, Aircraft Specialists and Divisional Commanders (DCs), so that fire suppression can be much more successful.

Recommendations for Critical Fire Management Skills

- Recognise landscape-based Fire Strategist as an essential role in the IMT planning team.
- Review fire training and competency requirements in light of new and evolving suppression strategies.
- Accept the need for more experts in critical fire roles and that Fire Strategists, many Aviation Specialists and Divisional Commanders need to be paid professionals.
- Develop a cross-agency program to produce more Fire Strategists, Aviation Specialists and Divisional Commanders with expert abilities.
- Re-assess the competency and currency requirements for some Aviation Specialist roles.
- Review public fire warning systems and ensure inter-state consistency in their application.
- Investigate the use of new technology for mapping and observing fires when reconnaissance by aircraft is impeded.

Research

Increase investment in targeted bushfire research and expand the independence and scope of research to support more evidence-based and better bushfire management.

Recommendations for Research

(see specific research-related recommendations in other sections)

- Fund research into the barriers that have inhibited evidence-based fire management in Australia.
- Open up fire research by funding and encouraging a wider diversity of researchers.
- Mount a major research program based on the 2019-2020 fires, with an emphasis on bushfire mitigation and suppression.

Response to bushfires

Initial Attack for Remote Area Fires

Improve detection technology, place higher priority on putting out remote ignitions, train strategists and invest in enough people with the right skills and the right aircraft so that more fires can be put out when small.

Recommendations on Initial Attack for Remote Fires

- Invest as a priority in a dedicated Australian satellite platform for real-time fire detection and monitoring.
- Make aerial reconnaissance to follow electrical storms mandatory in the bushfire season.
- Assign a high priority to remote fire threats in high risk conditions. Retain standby RAF teams and aircraft for rapid deployment when electrical storms are predicted, even if other fires are going and causing damage.
- Resolve the issues that are preventing regular night shift or first light operations on remote fires.
- Greatly expand RAFT resources in the form of trained and fit personnel and aircraft, especially for forecast high risk seasons. Establish a seasonal and substantial RAFT capacity based in vulnerable regions in eastern NSW. For practicality and effectiveness these should be integrated with existing NPWS operations.
- Research the best mix of aircraft to support rapid suppression of remote fires.
- Train more expert strategists for fires in remote bushland.

Fire Behaviour Modelling

Critically review the effectiveness of current fire modelling, expand research and develop improved modelling that accounts for all variables, to help make fire suppression and management more successful with less impact on people and environment.

Recommendations for Fire Behaviour Modelling

- Fund research into the barriers that have inhibited evidence-based fire management in Australia.
- Open up fire behaviour research by funding a wider diversity of researchers.
- Invest in the development of fire behaviour models that can generate more accurate predictions across all fire landscapes, incorporating all generic and localised factors.
- Require that fire behaviour models meet the standards of peer review before they are utilised.
- Formally review and document the inadequacy of current fire behaviour models and the imposition that this places on FBANs and fire decision-makers.

Suppression Strategies for Large Fires

Reduce bushfire costs and impacts by using different strategies for some remote and large fires. Minimise fire size and impacts through selection of optimal strategies, by applying more rigorous procedures for backburning and expanding research into the effectiveness of fire suppression methods. Upgrade the State Bush Fire Plan to include objectives and methods for bush fire suppression.

Recommendations for Suppression Strategies for Large Fires

- Commission an independent review of the overall strategic approach to the 2019-2020 bushfires in NSW.

- Upgrade the NSW Bush Fire Plan to include objectives and methods for a strategic approach to suppressing bushfires, with public involvement to build community understanding.
- Produce a manual on options for suppression of large fires.
- Train and mentor more landscape-based fire strategists in regions of high fire risk.
- Add a system of record keeping for all large fire operations to ensure simple records are kept of fire control actions and outcomes.
- Urgently undertake substantially more research into bushfire suppression, including analysis of large fires from the 2019-20 season.
- Develop scalable (for all levels of the operation) decision tools to make decisions on backburns more rigorous and defensible.
- Expand the scope and scale of training for fire analysts and strategists and ensure experience is accumulated and recognised.
- Develop a detailed manual on backburning and roll out training across fire agencies.
- Require training and certification for leaders of large and difficult backburns.
- Ensure that the risks of backburn escape are factored into incident planning, with appropriate public warnings.

Fire Incident Management Arrangements

Increase training and mentoring to produce a larger pool of very competent people for key IMT and fireground roles. Decentralise command, standardise IMT shift arrangements, improve continuity in IMT roles, ensure the best use of local knowledge in key roles and improve the management of heavy plant operations.

Recommendations for Fire Incident Management Arrangements

- Evaluate the performance of the AIMS and revise as necessary.
- Incident command should be decentralised whenever possible. Avoid the tendency to cluster fires if resources permit.
- Greater emphasis should be placed on continuity of people in key IMT positions.
- Aim for consistency in shift patterns across all agencies.
- Officers appointed to Divisional Commander positions must be trained and competent.
- Command points for Divisional Commanders need to be appropriately resourced and equipped, including support from an Intelligence Officer, a Resources Officer and a Communications Officer. At times access to a dedicated helicopter could be an advantage.
- Ensure plant management is undertaken to increase operational efficiency and protect environmental and community values. Track the location of plant and fire ground vehicles using GPS systems.

Recovery

Post Fire Review of Operations

Re-build post-fire review processes from the ground up to be structured, compulsory, thorough, independent, honest, unflinching and blame-free. Remove obstacles that have inhibited this in the past. Undertake a major research program into suppression strategies. Make a culture of analysis and learning an integral part of fire management with commitment and funding from agencies. Consider enshrining review principles and processes in legislation. Energetically communicate and audit review outcomes through fire agencies to ensure that lessons learnt are understood and adopted.

Recommendations for Post Fire Review of Operations

- Re-build post-fire review processes from the ground up to be structured, compulsory, thorough, independent, honest, unflinching and blame-free.
- Remove obstacles that have inhibited such review processes in the past.
- Make a culture of learning from past operations an integral part of fire management with commitment and funding from agencies.
- Consider enshrining review principles and processes in legislation.
- Energetically communicate and audit review outcomes through fire agencies to ensure that lessons learnt are understood and adopted.
- Undertake a major research program into suppression strategies.

Environmental Recovery

Reduce the size of fires to minimise all impacts including on the environment and ecosystems. Greatly expand research on bushfire impacts, ecological baselines and fire recovery. Increase investment in ecological recovery programs.

Recommendations for Environmental Recovery

- Implement measures to reduce the size and intensity of wildfires.
- Upgrade and enforce mechanisms as outlined in other sections, to minimise impacts during fires.
- Prepare a statewide strategy for environmental recovery from the 2019-2020 fires.
- Increase research into the ecological impacts of bushfire, and especially the 2019-2020 fires.
- Properly fund within overall fire costs, the repair and recovery of bushfire impacts, especially those resulting from suppression operations.
- Identify and undertake critical post-fire, weed and feral animal control programs.
- Support community-led recovery programs by increasing resources and training for NGOs, NPWS, Local Land Services, the Department of Agriculture and Local Government-supported Bushcare and Landcare groups.
- Increase protection for unburnt areas of bushland.
- Ensure that the conservation of ecological values is afforded significant priority when determining prescribed burning programs and objectives in areas left unburnt by the 2019-2020 fires and in core areas of conservation reserves.
- Develop and roll out an education program for communities and fire agencies on the ecological issues around bushfire and fire suppression.

Community Education

Significantly expand community fire education in rural and regional NSW while the impacts of the 2020 fires are fresh in the community's mind. This can build both community resilience to fire and informed support for fire management.

Recommendations for Community Education

- Include education as a formal component of community fire planning
- Further develop training resources which focus on particular issues where community understanding during the could be improved. These include:
    - A package which considers the key elements of fire behaviour
    - The difference between ember attack and cold burnt leaves and ash
    - The difference between spot fires and fire fronts
    - The role of hazard reduction in reducing risk
    - The nature of fuels
    - Property preparation
    - Leaving and defending
    - Understanding risk.
    - Media education
- Establish a system of Community Champions who are given responsibilities for disseminating information during emergencies.

Introduction

The scale of these bushfires is unprecedented anywhere in the world… There has never been a more important time to draw on that scientific evidence base to help guide Australia's short- and long-term responses to the devastating bushfires ravaging our nation and that are causing uncertainty about our future… We must improve our understanding of fire behaviour and other adverse weather events, and we must continually develop new technologies, practices and behaviours to assist our nation to respond and adapt to, manage, and mitigate against such extreme events.

Australian Academy of Science
"Statement regarding Australian bushfires",
10 January 2020

A note of thanks

Catastrophic disaster: Is what is beyond our current arrangements, thinking, experience and imagination (i.e. that has overwhelmed our technical, non-technical and social systems and resources, and has degraded or disabled governance structures and strategic and operational decision-making functions).

Australian Government, Department of Home Affairs

An incident doesn't become a catastrophe because the emergency services are overwhelmed; rather they are overwhelmed because they are facing a catastrophic event.

Holloway, summarising research by Eburn & Dovers

The 2019-20 bushfire season was a catastrophe by any measure. But it could have been much worse. Drought and weather conditions were such that with no intervention most bushfires would have burnt to their natural limits – either the sea or the edge of communities. Some fires did burn to those limits. Others were stopped by the massive firefighting effort. Many houses and lives were saved because so many people went to extraordinary lengths, doing their utmost in extremely challenging situations. We recognise and thank them all.

About the authors

We are 12 bushfire practitioners, fire managers, land managers, fire researchers and ecologists who have informally collaborated to develop this report. Together we have over 400 years of practical, professional experience in bushfires, land management and fire ecology across a range of fire landscapes in NSW, Victoria, Tasmania and WA. Our experience covers every aspect of bushfire, from lighting planned fires to putting out wildfires, from working with rake-hoes and hoses to Incident Controller on Section 44 fires, from measuring fuel moisture to analysing and modelling fire behaviour, from planning village fire protection to community fire education, from mapping fires to assessing their ecological impacts. Most of all, we come at fire from an operational, on-ground perspective.

Most of us have worked for various government agencies but we are now all independent and able to speak freely on bushfire matters. This ability to speak from real experience is important. Many of us have been in work situations, dealing with bushfires and fire issues, where we have not been able to comment publicly due to constraints on public officials. This is the case for the vast majority of active, professional bushfire practitioners today. In NSW they work for agencies like the Rural Fire Service (RFS), NSW National Parks and Wildlife Service (NPWS), Fire and Rescue NSW (FRNSW) and Forestry Corporation (ForestCorp) and are not permitted to comment 'out of school'. When we were in that situation there was much we would have liked to say, just as many current employees would also like to comment.

We are not on the outside looking in. We are part of the great coalition of community, volunteers and professionals who work together on bushfires. We have experienced and understand the difficult decisions that have to be made, the challenges and heartbreaks inherent in firefighting.

About this report

This report focuses on bushfire management in NSW, what occurred during the 2019-2020 fire season and how it can be improved upon. Many of the recommendations focus on operations and have broader application across other states and jurisdictions aside from those referenced.

All 12 authors *(Appendix A)* have worked as volunteers on this report, putting in many hundreds of hours. Inevitably there have been limitations to what could be achieved in this way, and without access to the full range of information. This report comes from the breadth and depth of our combined experience, and from applying our expertise to close observation and analysis of the recent NSW bushfires. In this we have benefitted from the anonymous input of many people who were involved in those fires. Some of us were also actively involved, at various levels. All of us were directly affected.

Over the years we have witnessed ongoing and commendable progress in many aspects of bushfire management. We have been involved with some of those changes. We have also observed important and longstanding issues that need to be addressed more vigorously. This report analyses some of those issues and suggests ways that they can be improved.

Each issue includes a statement of the issue and the opportunities for improvement, followed by a summary of the issue, recommendations and a detailed analysis. References for each issue appear at the end of each these sections.

A very important part of this report comprises fire studies from the recent season. These fire studies are detailed with maps of the events, other data and analysis. The studies both provide the basis for, and illustrate many of, the issues discussed in the body of this report.

The challenge

All aspects of fire management are complex and challenging. Bushfire suppression is particularly challenging. When controlling fires many decisions about fast-moving situations have to be made quickly and within many constraints. Perfection is impossible. There are always logistical, resource and communication problems. When it's over, every firefighter and fire manager wrestles with the 'what ifs' and 'if onlys'. The authors have done this too.

These doubts and concerns deserve to be channelled into proper analysis. There can be no criticism of hindsight; it is essential and invaluable. Likewise, difficulties should not be shrugged away as if they are immovable. Some may be just bad luck, but many others are a product of how fire suppression is thought about, organised and resourced. Ongoing analysis and re-assessment are vital.

Strategies and systems for fire management and suppression in Australia have evolved over time as new technologies, organisational thinking and resources have become available. Current practices have been tested during the extensive 2019-2020 fires and amongst many 'wins', have not always been successful.

New thinking is required to meet the challenge of climate change and a changed fire environment across Australia's bushland. Evidence-based opportunities are already available to improve fire management and suppression, and other ideas offer great potential if validated by more analysis and research. Some of these opportunities and their history are well known across the fire community, but their application has been limited.

Our aim is simple: to analyse and suggest improvements in how bushfires are managed, for the benefit of all.

We believe that improvements can only be made by thoroughly and objectively reviewing events, actions, systems and processes. There can be no shying away from this because the consequences of bushfires are so great. With climate change those consequences will increase. What has worked in the past may no longer work in the future. What has not worked so well in the past can be improved.

> *What is needed is a quantum shift in our thinking. Just doing the same thing or planning to do the same thing, but just more of it, is a simple solution that is neat and plausible. And wrong. …This is the time to consider seriously the hard questions and not continue with business as usual. This will require new thinking, new research, new investment and, importantly, new commitment.*
>
> Dr Richard Thornton, CEO Bushfire & Natural Hazards Cooperative Research Centre,
> "Doing more of the same on fires will not mitigate disaster impact"
> *The Australian*, 4 January 2020

Summary of key issues

The central point of this report is that changes to how bushfires are managed can reduce the size, impacts and costs of fires.

While there were many successes in controlling and limiting the 2019-2020 fires, some issues have contributed to larger fires with unintended and costly outcomes. Improvements could be implemented to better manage risk and thereby reduce impacts. There is also a need to strengthen preparation and recovery programs. The aim is to improve fire management practices to reduce the impact on people and wildlife, as well as the cost and risk of bushfires.

We want to draw attention to obstacles that sometimes stood in the way of the best outcomes. Some of these have history, but the extraordinary conditions and scale of the 2019-2020 fires strained the system to such an extent that other cracks appeared. This is not surprising and not the fault of any individual. Fires were burning in ways and in places that had never been seen before. Many people, including firefighters and fire managers, struggled to understand what was happening. They were faced with very challenging and traumatic decisions, week after week.

What has worked in the past often did not work this time and may not in the future. It is important to unflinchingly examine weaknesses in the system and how they can be strengthened.

The most important difficulties included:

- the underlying science of fire
- learnings from past fires
- overall strategic approach
- some resourcing issues
- initial attack and
- fire suppression strategies.

Other issues were:

- management arrangements
- critical skills
- environmental recovery and
- community understanding and engagement.

All these issues are connected because each one affects the others. Effective review of all major fire operations as an ongoing routine is critical, especially the fires of 2019-2020. It is only through careful examination of what happened that we can do ‘more of the good’ and improve what might have been better, thereby reducing the impact and trauma of future fires, for everyone.

Part 1 – Causes and Contributing Factors

1.1 Summary of Fire Studies

Eleven analyses of fires and fire events from the 2019-2020 season in NSW are presented in *Part 5 – Detailed Fire Studies*. These studies, combined with other information gathered about the fires, have informed our discussion of the issues covered in this report. These issues are cross-referenced to the fire studies in *Figure 1*.

The studies have been prepared under several limitations, including time and not having access to the full range of analytical resources. Consequently, there may be errors in some details. The basic events are considered to be correct but could be refined with access to all relevant information. The studies are 'first cut' analyses, offered as examples that can be improved with more information and work.

These studies demonstrate the potential for comprehensive post-fire analysis. Such work can identify successful and unsuccessful strategies, and the factors that made the difference. Conclusions can then inform future operations and improved suppression practices. A clear understanding of events is fundamental to analytical review and a lessons learned culture. Every major fire should be analysed in this way. By spending a tiny fraction of suppression costs on post-fire analysis, the impacts, trauma and costs of future fires could be reduced.

The fires are presented in terms of factual events with some interpretation. The reasons for various decisions made on the fires, and the influences on those decisions, are mostly unknown. Speculation on these aspects is avoided.

The studies are introduced with an overview of the climate and weather in eastern NSW before and during the fires. The studies then examine a range of events focusing on strategies employed to control the fires. The objective was to consider why some strategies worked and others did not.

The conclusions drawn from these fire case studies could be applied across all the bushfires:

- The importance of rapid and effective initial attack within 2-6 hours after detection and working overnight when fuel moisture and wind speeds can be favourable for safe ground crew operation.
- Applying effective fire containment strategies using a variety of options instead of over-reliance on backburning (in other words indirect attack).
- The risk of backburn failures due to unfavourable drought fuel conditions, dead fine fuel moisture content and local wind conditions. The need to withdraw from operations when the proposed backburn is outside guidelines.

We especially highlight the need for integrated knowledge of fire landscapes, fuel types, ambient drought conditions and fire weather patterns, both historical and during the suppression of a bushfire. Much of the detailed knowledge and experience has been lost in the fire agencies as a result of organisational restructures in the last 20 years.

NB: It is recognised that these studies do not consider unknown factors that may have applied in some situations. Operations during the extraordinary 2019-2020 fire season were sometimes hampered by issues that constrained suppression options. These factors included smoke affecting aerial operations, inadequate fireground information and the limited supply of critical firefighting resources such as aircraft and RAF teams. Because it has not been possible to take these constraints into account, these studies should be taken as identifying potential alternative strategies and outcomes. Nevertheless, analysis such as in these fire studies is always valuable.

Fire Study No.	Bushfire	Risk-based Approach	Bushland Management	Critical Skills	Initial Attack	Fire Modelling	Suppression Strategies
1	Green Wattle Ck overview	✓		✓	✓		✓
2	Green Wattle Ck Seabrook Road escape	✓	✓				✓
3	Gospers Mountain- South-west section	✓					✓
4	Gospers Mountain Newnes Plateau	✓		✓			✓
5	Gospers Mountain Mount Wilson escape	✓		✓			✓
6	Mount Wilson Road (Grose)	✓	✓	✓			✓
7	Currowan-Tianjara Complex – early stages	✓			✓		✓
8	Currowan-Tianjara Complex – Milton-Conjola	✓					✓
9	Currowan-Tianjara complex – Clyde Mountain	✓					✓
10	Half Penny Hill	✓		✓	✓		✓
11	Bees Nest	✓				✓	✓

Figure 1: Main issues from this report addressed in Part 5 – Detailed Fire Studies

Part 2 – Preparation and Planning

2.1 A Risk-based Approach to Bushfires

Issue

It is not evident that risk-based approaches were always applied to bushfire suppression decisions during the 2019-2020 season. This may have been a factor in missed opportunities to control some fires and unsuccessful strategies at other times. Environmental risks are not always given appropriate weight.

Opportunity

Strengthen systems for a risk-based approach to bushfire suppression, to improve decisions and limit the scale and consequences of fires.

Issue Summary

All bushfire management is about managing risk. Risk management is fundamental to most of the issues examined in this report, especially preparedness and response. It is particularly important during bushfire suppression which is the focus here *(see also Section 3.3 - Suppression Strategies for Large Fires)*.

The magnitude of risk is expressed as a combination of two dimensions: consequence and likelihood. In bushfire suppression the risk can relate to impact on the many components of people and communities, firefighters, infrastructure, environment and economy. Both the going fire and proposed control actions can be assessed using the two components of risk.

Risk assessment is critical to strategic operational decisions on fires, such as where to prioritise effort and resources. With multiple fires a triage risk approach may be needed to rank fires against the capacity to respond. Actions to control fires can also pose risks, sometimes of a consequence comparable to the actual wildfire. The risk of proposed control actions can be compared to the risk of the actual fire and of alternative control options.

Rigorous risk-based methodology should be applied at all stages of fire suppression. Experience from events of the 2019-2020 season suggests that this was not always the case. This applies to some high-risk suppression actions, consideration of environmental risks and also how initial attack on some remote fires was not adequately resourced. Risk-based approaches can improve effectiveness, efficiency and accountability. They can help to ensure environmental impacts are minimised.

In the often fast-changing environment of bushfire, time constraints will sometimes limit how much effort can go into risk assessment. Risk-based approaches cannot always deliver the 'best' decision. This makes it more imperative that risk-based approaches are systematic, routine and 'second nature'. With training and experience, rapid assessment with some level of effectiveness becomes possible. Risk-based management of future fires can be greatly informed by analysing past situations.

Minimised risk delivers smaller, less intense fires for reduced life/property/ecological loss, lower cost and less impact on firefighters' lives and communities.

Recommendations for a Risk-based Approach to Bushfires

- Apply a rigorous, risk-based decision framework to all bushfire suppression activities, based on the Australian Institute for Disaster Resilience guidelines.
- Ensure that long-term threats such as remote fires are assessed alongside more immediate risks and that response priorities and resource deployment are more balanced.
- Undertake and document risk assessment of all suppression options before acting, as rigorously as time allows.
- Ensure environmental risks are fully considered in bushfire suppression risk assessments.

Issue Analysis

Risk management

There is a vast body of literature on risk management and how it is applied to emergencies. In the Australian context, important documents have been issued by the Australian Institute for Disaster Resilience. They are based on Australian risk management standard AS ISO 31000:2018 Risk Management - Guidelines *(Standards Australia 2010)*. Although these documents can be quite technical and theoretical, they can be translated into very pragmatic systems for bushfire suppression.

The Australian Emergency Management Arrangements Handbook *(AIDR 2019)* specifies this principle for risk-based emergency management:

> *"Emergency managers use sound risk management principles and processes in prioritising, allocating and monitoring resources to manage the risks from hazards. Risk-based planning will anticipate the effect of efforts, the changing hazard landscape and the changing consequences of the emergency."*
> *(AIDR 2020, p2)*

The handbook also advises how to form an appreciation of the risk, which is applicable to fire suppression:

> *"The first step in risk analysis is to determine what is known about the risk to support an understanding of consequence and likelihood. This can include:*
> - *historical data of previous events and the likelihood of their occurrence*
> - *modelling of events*
> - *assessments of likely consequence resulting from events.*
>
> *Expert opinion can also be used in addition to data, information and modelling to interpret the evidence in the context of the risk being considered."*
> *(AIDR 2020, p25)*

In the bushfire context, expert opinion will generally come from the IMT and State Operations. Any opinion may vary in quality, especially if not supported by the other listed components of risk assessment.

The National Emergency Risk Assessment Guidelines *(AIDR 2020)* provide a detailed framework for emergency managers to implement the above processes. The guidelines use the following criteria for risk assessment, and note that the criteria should *"reflect community viewpoints and common values, and give consideration to social, environmental and humanitarian factors"*:

- *consequence level (from insignificant to catastrophic)*
- *likelihood level (extremely rare to almost certain)*
- *risk level (very low to extreme)*
- *confidence level (lowest to highest). (AIFDR 2020, p20)*

Risk assessment can be quantitative (eg number of houses exposed, area in hectares that might burn) but is more usually qualitative. The matrix in *Figure 2* can be used to rank likelihood and consequence in qualitative assessment. A detailed risk analysis, as shown in *Figure 3*, is used in this assessment.

	CONSEQUENCE LEVEL				
LIKELIHOOD	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC
ALMOST CERTAIN	Medium	Medium	High	Extreme	Extreme
LIKELY	Low	Medium	High	Extreme	Extreme
UNLIKELY	Low	Low	Medium	High	Extreme
RARE	Very low	Low	Medium	High	High
VERY RARE	Very low	Very low	Low	Medium	High
EXTREMELY RARE	Very low	Very low	Low	Medium	High

Figure 2: Qualitative risk matrix
Source: AIDR 2020

In bushfire suppression, fire control actions would constitute 'risk treatment'. These processes can be adapted and simplified for practical use during bushfire suppression. Risk assessment can be applied to every fire operation, from deciding where to send LATs to which fires are most threatening, whether a high-risk strategy is the best one, and how crews are deployed for property protection.

Risk-based approach for initial attack

A number of the 2019-2020 fires that began as lightning strikes in remote bushland were either not attacked or attacked inadequately and went on to become very large fires with serious impacts. It may have been possible to extinguish them early, but they later required large resource commitments over long periods *(see Section 3.1 - Initial Attack for Remote Fires)*. Risk assessment may have been one reason for these outcomes.

It can be difficult to assess competing risks when multiple fires are going. There is a natural tendency to focus on immediate risks against longer-term threats. When houses are burning down in one place, is it appropriate to divert resources to put out a lightning strike that is only small and a long way from anywhere? Given the outcome (consequence) of some of those ignitions in 2019-2020 (eg Currowan fire, Green Wattle Creek fire) such a choice might be justified. Attacking a small fire that has the potential to become a major threat, albeit down the track, saves resources at a later time and can reduce the risk of subsequent loss of life and property. 'A stich in time', as they say.

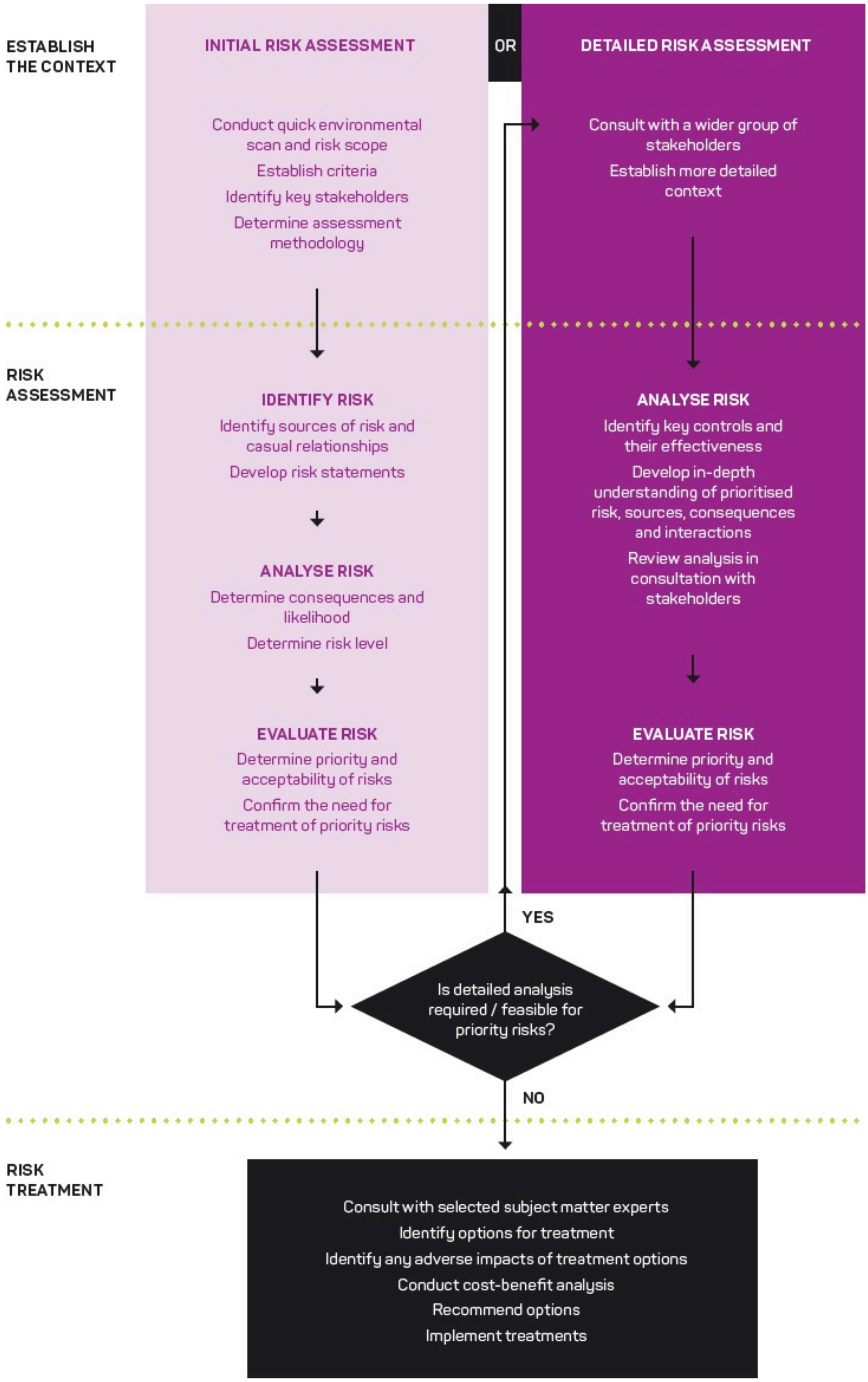

Figure 3: Initial and detailed risk analysis.
Source: AIDR 2020

The logic can be that such fires can be left till later while immediate issues are dealt with. There is always the hope that it will rain before neglected fires grow big and reach settlement. Given that the official forecasts for the 2019-2020 summer were for an extended dry period with little prospect of rain, any such hope was not well founded. The amount of the resources required to attend to a remote fire would not always make a significant difference to a large property protection operation.

A need to prioritise remote fires was recognised in the leadup to 31 December 2019. A day of extreme fire weather was forecast, along with thunderstorms and lightning. The RFS Commissioner said in the media that planes and crews would be reserved to attack any new fires. Such a risk-based approach is commendable.

Risk-based approach for strategy comparison

A risk-based approach is also very helpful for assessing options for controlling a fire *(see Section 3.3 - Suppression Strategies for Large Fires)*. All strategies have risks. They range from simply not working (failing to stop the fire) and danger to firefighters to the risk of the strategy causing more damage. Damage can include backburn escapes that expand the fire or that impact assets and environmental impact from a larger burnt area or earthworks.

Assessing the likelihood and consequences of different suppression options is very challenging, but essential. Should firefighters be put in harm's way or pulled out in preference to aerial attack? Is it too dangerous to put RAF teams in? When it comes to backburning for instance, what are the potential consequences if the backburn escapes? How likely is it to escape? What happens if we don't backburn? Is it a critical action at this time? What factors contribute to the risk and how uncertain are they? Similar questions can and need to be asked of any proposed strategy. Will the natural control line of a rainforest creek hold? What happens if it doesn't? Are there fallback options? How much bush or property is exposed?

Such considerations would be second nature to many fire suppression planners and managers but may not always move beyond being considered and discussed. Risk assessment should be formalised and documented whenever possible to support the best decisions and ensure rigour and accountability.

Large backburns were a major focus of suppression efforts in the 2019-2020 season. Many succeeded while others were problematic. Some led to serious consequences. Inadequate assessment of risks against threat and consequence may have been a factor in some adverse events, such as at Mt Wilson and Balmoral. In some instances, the threat level from the actual fire was low at the time.

An overarching aim of limiting the spread and intensity of fire is key to reducing risks all round.

Environmental risks

The environmental risks of bushfires can receive little attention during crises, compared to the outpouring of community grief that often follows. This was evidenced in the 2019-2020 fires by the extensive post-fire media coverage of the impacts on wildlife. Three main causes of environmental impacts are:

- the size and intensity of fires
- damaging but often necessary practices such as earthworks for containment lines and
- use of retardant chemicals.

The recent fires led to many instances of environmental impacts that might have been avoided. The World Heritage listed Jenolan Caves reserve was devastated by a high-intensity disputed backburn and the floods that followed. Some containment lines were 'overdone' in the South East Forests. A number of fires grew large to burn more World Heritage listed forest in the Blue Mountains and northern Gondwanan rainforests *(The Guardian 2020).*

Figure 4 is a matrix of criteria for environmental risks at the 'major' to 'catastrophic' level. It is considered that a number of impacts during the 2019-2020 fire season reached 'major' level and some possibly 'catastrophic' but are yet to be fully assessed.

LEVEL	CRITERIA	STATE OR NATIONAL RISK DESCRIPTION	REGIONAL RISK DESCRIPTION	LOCAL RISK DESCRIPTION
CATASTROPHIC	Loss of species and/or landscapes	Permanent destruction of an ecosystem or species recognised at the national level	Permanent destruction of an ecosystem or species recognised at the national or state level, and/or Severe damage to or loss of an ecosystem or species recognised at the national level	Permanent destruction of an ecosystem or species recognised at the local, regional, state or national level, and/or Severe damage to or loss of an ecosystem or species recognised at the national or state level, and/or Significant loss or impairment of an ecosystem or species recognised at the national level
	Loss of environmental value	Permanent destruction of environmental values of interest	Permanent destruction of environmental values of interest	Permanent destruction of environmental values of interest
MAJOR	Loss of species and/or landscapes	Severe damage to or loss of an ecosystem or species recognised at the national level, and/or Permanent destruction of an ecosystem or species recognised at the state level	Permanent destruction of an ecosystem or species recognised at the local/regional level, and/or Severe damage to or loss of an ecosystem or species recognised at the state level, and/or Significant loss or impairment of an ecosystem or species recognised at the national level	Minor damage to ecosystems or species recognised at the national level, and/or Significant loss or impairment of an ecosystem or species recognised at the state level, and/or Severe damage to or loss of an ecosystem or species recognised at the local or regional level
	Loss of environmental value	Severe damage to environmental values of interest	Severe damage to environmental values of interest	Severe damage to environmental values of interest

Figure 4: Environmental consequences and criteria
Source: AIDR 2020

There were also environmental successes, such as efforts to protect Yarrangobilly Caves (Kosciuszko National Park) and the Wollemi Pine (Wollemi National Park). These operations came about through recognition of the threat to these assets *(Australian Alps national parks 2020, SMH 2020).* It is not known if operations were preceded by formal risk assessments.

Environmental risks need to be properly assessed as part of a broader risk-based approach to suppression strategies. Overall, keeping fires small and managing their energy output is a prime objective to reduce environmental impacts. Suppression and/or remedial earthworks, if required, should be well-managed. Assessing the risks before such works are undertaken will help to ensure such impacts are minimised.

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2.2 Aspects of Bushland Management

(NB - This is not a comprehensive treatment of this topic but focuses on just a few aspects of bushland management that are within the authors' expertise.)

Issue

Public discussion about the fire risk posed by bushland areas is hampered by a flawed view that fire mitigation and nature conservation must be in conflict. Ideological agendas, misinformation, selective use of evidence and simplistic solutions are widespread.

Opportunity

Ensure that governments and agencies promote factual information to the public and develop evidence-based and multi-tenure mitigation programs for bushfire risk. Recognise environmental needs and balance them against fire management aimed at protecting human communities. Increase research into the best ways to reduce fire impacts.

Issue Summary

Bushfire mitigation means all the activities undertaken to reduce the impact of fire on people and their assets. For land managers, such as NPWS and ForestCorp, fire mitigation is a major aspect of looking after our bushland but is far from the only consideration. Fire-specific agencies, such as RFS and FRNSW, have a narrower focus. These different objectives are enshrined in legislation for each agency.

The environmental values of conservation areas are vital to the community and our future. These values include conservation of species, ecosystems, geodiversity, landscapes, air quality, water catchment, recreation, tourism, physical and mental health, aesthetics, cultural connections, economy, art and many more*.* The global systems that support human existence and quality of life are under ever more pressure. Conservation reserves and other remnants of nature are more valuable than they have ever been.

The 'problem' of bushfire mainly exists at the bushland edge, where fires impact on human lives and assets. Reducing the risk of fire to human lives and assets should focus on managing this interface. The interface has two sides: in one direction is the fire coming out of bushland and on the other is the community facing that fire. 'Both sides of the fence' need to be addressed in a balanced and integrated way to reduce risk. Both 'toolsets' need to be used. Bushland can carry some of the burden but not the whole burden. Attempts to force more mitigation back into the bushland will result in less risk reduction. The better alternative is an integrated program on all types of private and public lands on the edge. Currently it is easier to carry out works on some lands than on others. Fire and fire mitigation are complex; simple solutions are wrong and will not help *(Bradstock 2009)*.

Bushfires can also damage natural values, especially under human-induced climate change. Fire has played a part in Australian ecosystems for many millions of years. It is a key driver of where different vegetation communities occur. Changes in the pattern of fire over time can change vegetation and damage wildlife populations. Too frequent fire is recognised under NSW law as a process that threatens the survival of some species *(NSW TSSC 2000)*. Increasing frequency and intensity of fire is forecast to occur in south-east Australia as climate change progresses *(Climate Council 2019)* Many scientists assess that this is already happening.

In the core of large bushland areas, prescribed burning is best focused on ecological outcomes. On the bushland fringe it is best focused on protecting human communities. This is a risk-based approach that is also pragmatic and realistic, based on logic and evidence. It is given effect inside conservation reserves through fire management zoning.

Even on the bushland edge, prescribed burning can only be part of an effective fire mitigation program. Burning faces many difficulties and limitations close to assets and is not always possible, so other strategies are needed. These include all the ways communities can be made more fire resilient, such as planning controls, building standards, property management, mechanical vegetation management, clearing, water supplies, sprinkler systems, irrigation, firefighting resources, access roads and more.

Areas set aside for conservation have complex management needs. Within their broader conservation objectives, national parks, world heritage areas, council reserves and similar areas need to manage the increasing bushfire risk to both humans and nature. These aims do not necessarily conflict, as long as bushland is not expected to carry the whole fire mitigation burden. NPWS Reserve Fire Management Strategies are key legal instruments in managing bush fires and need to be better supported and used.

Beyond the bushland edge in areas remote from settlement, fire management should be more focused on ecological outcomes. The key to working out the best mix of strategies is to use the evidence already available. In this way fire risk can be reduced while ecosystems are conserved. Ongoing research is also essential to refine how these outcomes can be achieved. The 2019-2020 fires can be researched to increase knowledge in many areas, especially how prescribed burns and other practices performed to assist fire suppression.

Recommendations on Aspects of Bushland Management

- Encourage and resource agencies to educate communities and firefighters about land management and fire management that is based on evidence, risk and objectives.
- Ensure conservation objectives of land management are not compromised unless there are proven and substantial benefits to community protection from fire, especially in the core of large bushland areas.
- Avoid reducing moist vegetation types in the landscape through repeated fire.
- Elevate NSW NPWS Reserve Fire Management Strategies so they are supported, recognised and followed during fire suppression activities. Fully resource the regular revision of these strategies.
- Focus programs aimed at protecting communities from fire on the bushland edge.
- Undertake comprehensive analysis and research into the suppression benefits of prescribed burns during the 2019-2020 fires and cross-analyse these with the actual suppression strategies deployed by Incident Management Teams.
- Ensure prescribed burning and other fire mitigation strategies are risk-based and evidence-based.
- Integrate and resource fire mitigation planning and program implementation across all tenures on the bushland edge.
- Recognise the limitations and complexity of burning for hazard reduction on the bushland edge.
- Maximise methods other than burning to reduce risk to communities.
- Ensure fire mitigation programs are tailored to the specific needs and situation of each community.
- Expand research into the best mix of methods to reduce the impacts of fire on communities.

Issue Analysis

Management of conservation areas

The management of areas set aside for conservation and recreation in NSW is driven by objectives in legislation, including the National Parks and Wildlife Act. NSW NPWS manages more than 9% of the state including most large bushland reserves. Similar laws apply to Crown, local council and forestry flora reserves. How these objectives will be met in particular reserves is detailed in plans of management, also required by law. Such plans balance a range of objectives with the resources available to undertake management programs. They are prepared with public consultation.

Fire is an important part of reserve management, especially for large bushland areas. This aspect of reserve management is mandated by legislation and presented in more detail in fire management documents. The NSW NPWS framework document is a statewide bushfire strategy *(NPWS nd, reprinted 2013)*. It includes principles for fire management in NPWS reserves *(Figure 5)* with this over-arching purpose:

> *"…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."*

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.

Figure 5: Principles for fire management in NPWS reserves
Source: NSW NPWS nd, reprinted 2013

NPWS also prepares Reserve Fire Management Strategies (RFMS) for all bushfire prone national parks and reserves. Through detailed analysis of many factors they balance objectives for conservation and fire mitigation.

RFMSs are recognised as ‘relevant plans’ for ‘managed land’ under the NSW Rural Fires Act 1997. The Act requires the RFS Commissioner to ‘take into consideration’ such plans *(section 44(3))*, and fire control officers to comply with such plans *(section 38 (4))* when carrying out their functions. However, these strategies are not always followed during fire suppression, and not always because of life-and-death necessities. This is shown by many events during the 2019-20 fires.

Examples of RFMSs for large national parks include those for Wollemi National Park *(NSW NPWS 2008)* and Kosciuszko National Park *(NSW NPWS 2005).* Many are overdue for revision, especially in the light of climate change and new formats. More recent plans have shifted to a map-based format which is easier to use, especially during wildfires. An example is the strategy for Warrumbungle National Park *(NSW NPWS 2016)*. This strategy was prepared after the disastrous 2013 bushfire that affected much of the park and surrounds.

While concise, map-based strategies contain detailed information on fire mitigation, fire suppression and ecosystem management. The Warrumbungle strategy includes:

- vegetation management guidelines
- suppression strategies
- operational guidelines;
- broad vegetation communities
- bushfire risk management strategies
- vegetation suitability for prescribed burn
- status of biodiversity thresholds.

Several mechanisms are used to balance fire management objectives. One is to identify the suitability of different vegetation areas for prescribed burning *(Figure 6).* Another is to zone the reserve for different fire management treatments *(Figure 7)*. The three zones are Asset Protection, Strategic Fire Advantage and Land Management. Through this sequence the emphasis of prescribed burning shifts from asset protection to ecological management.

Reserve Fire Management Strategies are the ‘tip of the iceberg’ for a lot of research, analysis, experience, consulting and planning which has been done ‘behind the scenes’ over many years. Strategies go through consultation with and review by, the public and other agencies. RFMSs are well-considered and important documents that express how fire mitigation and conservation can both be achieved. They deserve to be supported, recognised and followed. Bushfire planning within NPWS needs to be fully resourced in support of improved fire management practices in large bushland areas.

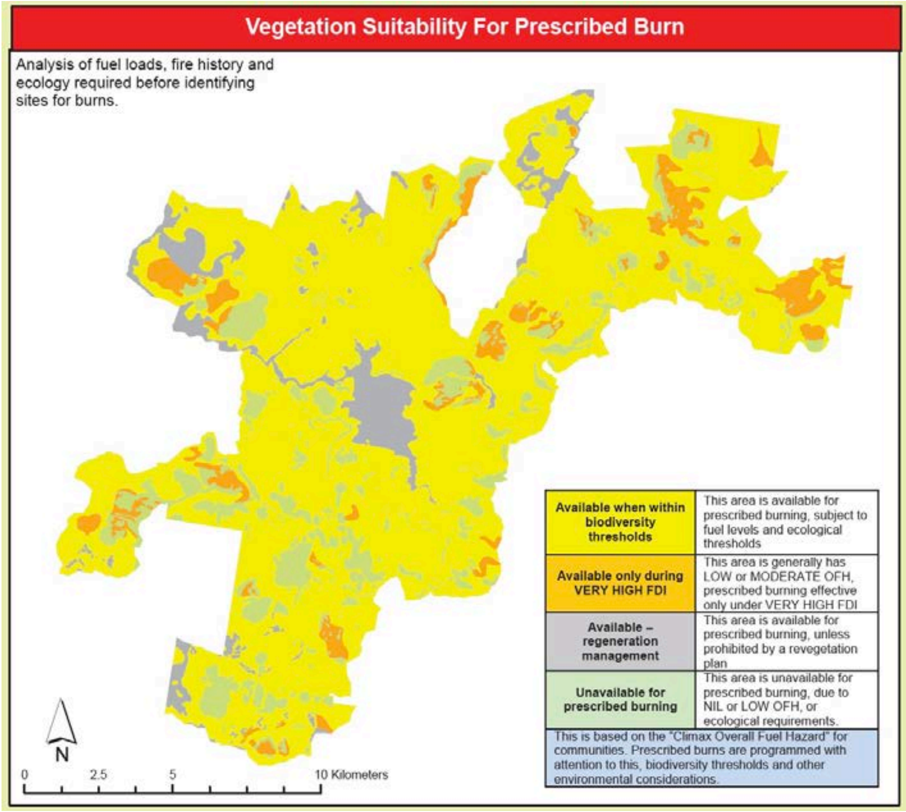

Figure 6: Map of vegetation suitability for prescribed burning, Warrumbungle National Park
Source: NSW NPWS 2016

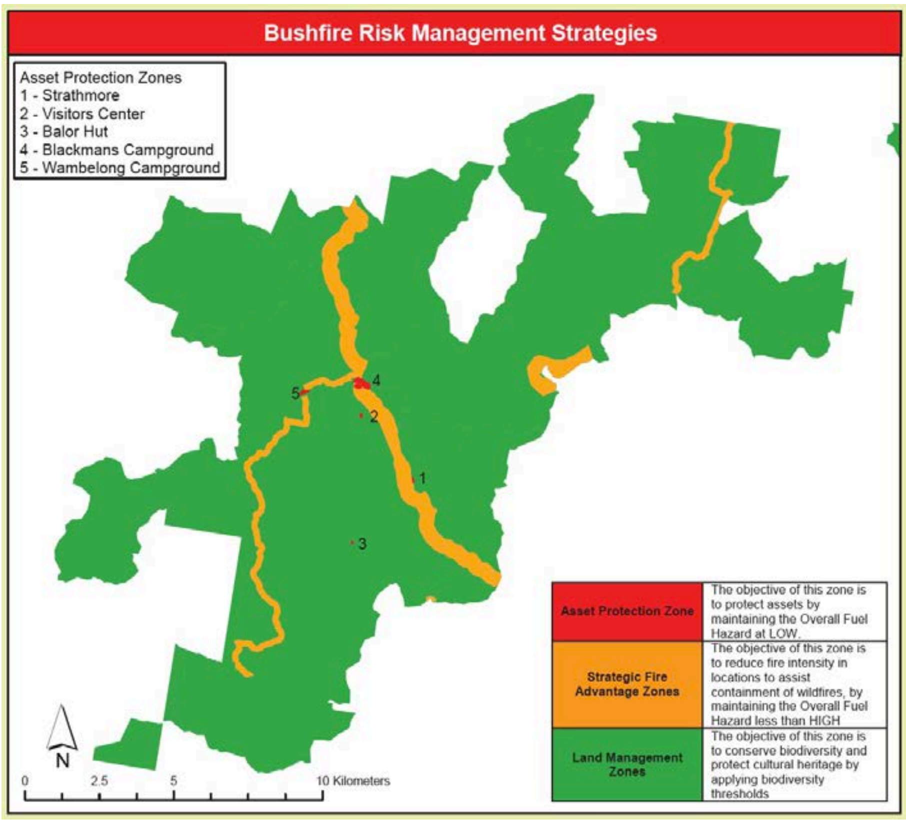

Figure 7: Fire management zones and objectives for Warrumbungle National Park
Source: NSW NPWS 2016

Prescribed burning

Prescribed burning is undertaken for different purposes. The term 'hazard reduction' is often applied to prescribed burns done to protect human communities. This is also called fuel reduction burning or fuel mitigation burning. The objective is to reduce fuel close to assets in the off-season to slow or stop a summer wildfire. This can assist control efforts or reduce the intensity of impact. Burns can be quite small, just a few hectares, or hundreds of hectares in size.

Strategic prescribed burning is done deeper into bushland and further from assets. Burns can be quite large (hundreds or thousands of hectares). The objective is to provide a strategic 'barrier' to help stop or slow a large wildfire and to create a mix of fire-age classes in the vegetation.

Ecological burning can be carried out in any bushland but is most appropriate in remote areas. The objective is to manage the vegetation to retain biodiversity. Such burns may also produce strategic fire advantage, but this is not their main purpose.

Prescribed burning for any purpose is a topic of ongoing controversy in the community. Some people oppose any such burning, while others think there should be a lot more of it. To many people, 'no fuel means no fire' and it's the best or the only way of reducing risk.

Much of the public debate is poorly informed on the scientific evidence. Even scientists debate the pros and cons of fuel mitigation burning. The issues are canvassed in a large body of scientific and popular literature and will not be fully reviewed here. An extensive set of data is available on how prescribed burns performed during the 2019-2020 fires. This data can be researched to add greatly to the understanding of how burns of different ages in a variety of vegetation communities performed under a range of fire and weather conditions.

Without going deeper into this complex subject of prescribed burning and the myriad of widely available arguments, a few less well-known challenges in hazard reduction burning are addressed below.

More burning faces practical problems

To increase the number of hazard reduction burns and the area covered, a number of obstacles would have to be overcome. The RFS Commissioner has said that the main constraints are smoke pollution and narrowing 'burn windows' of suitable weather conditions *(ABC 2020)*. The latter is due to climate change *(Earth Systems and Climate Change Hub 2019)*. Other major constraints are the difficulty of getting enough RFS volunteers to assist with burns on weekdays and obtaining all the private permissions to burn private land.

The weekday constraint further limits the number of suitable weather days when burning can be done. This adds to the plan-prepare-cancel cycle that so many burns go through before they are achieved. Many patches of bush identified for burning overlap multiple land parcels and tenures, so private permissions are required. RFS has powers under the Rural Fires Act to over-ride this need for permission but is not known to have used them. Some landowners will never give permission.

Burning near properties is difficult

The most important areas of bush to fuel reduce are those right next to assets. These are often small areas complicated by roads, tracks, electricity lines, other services, fences, complex tenure, convoluted bush boundaries, dams, buildings and other assets. Burning is tricky without endangering some of these assets.

Operations need large numbers of people and trucks and very careful lighting patterns *(NSW Fire Brigades 2009)*. For these reasons some areas are not feasible to burn. Burns way out in the bush, although providing little benefit to private assets, are much easier to plan and execute.

Burning needs to be in the right place at the right time

Burning some distance from assets may help overall control of a wildfire, if it's in the right place when a fire comes. But it will not reduce fire intensity at the property interface. It is only this part of the fire that impacts on assets, so this is where hazard reduction burning for property protection can be most effective.

Probability also comes into play. Research has shown that the benefit of fuel reduction burning falls rapidly over time. After only two to three years, past fire will have little effect on the speed and intensity of a forest wildfire burning under severe to catastrophic conditions *(Climate Council 2020).* The main drivers of fire in those conditions are wind and fuel dryness, not the amount of fuel. So, unless hazard reduction burning is very widespread and recent, the chances are small of a burn being in the right place to stop or slow a fire at any particular place. Despite pressure from landowners, burning on other land to protect their property will not always help, and then only for a short time.

Burning can inhibit wildfire suppression

Prescribed burning for asset protection needs to be carefully positioned in the landscape. These same areas are often where backburning can be undertaken during a wildfire. It may not be possible to backburn bushland which has already burnt in recent times, but a wind-driven wildfire coming the other way can still burn through it. This is because the conditions under which a backburn can be safely done are different (milder) to when a wildfire is advancing.

Some bush can't be burnt for hazard reduction

Some forest types will only burn under very dry conditions, and then they burn at high intensity. These conditions mostly occur in summer, when any fire in these forests may be uncontrollable. Tall eucalypt forests with a mesic (moist) understory are prime examples. Rainforests almost never burn and should not be deliberately burnt because of their special biodiversity values. Climate change may cause more rainforest to burn when extreme to catastrophic conditions occur.

Work undertaken for this report *(Gellie in preparation)* analysed and mapped the burning 'treatability' of natural vegetation in eastern NSW into three categories *(Figure 8)*:

- Treatable - low to medium tall forests or woodlands exposed to the sun and with sufficient surface fuel loads in excess of 12-15 tonne/ha with a grassy or xerophyllous shrubby understorey.
- Somewhat treatable - medium-tall forests partially sheltered from the sun with a mixture of xerophyllous or mesophyllous shrubby understorey; surface fuels 15-22 t/ha.
- Not treatable - tall forests with a mesophyllous understory, rainforests, or Acacia shrublands in sheltered parts of a forest landscape remaining moist for most of the year. Also includes shrublands and woodlands on rocky outcrops or woodlands with naturally low fuels.

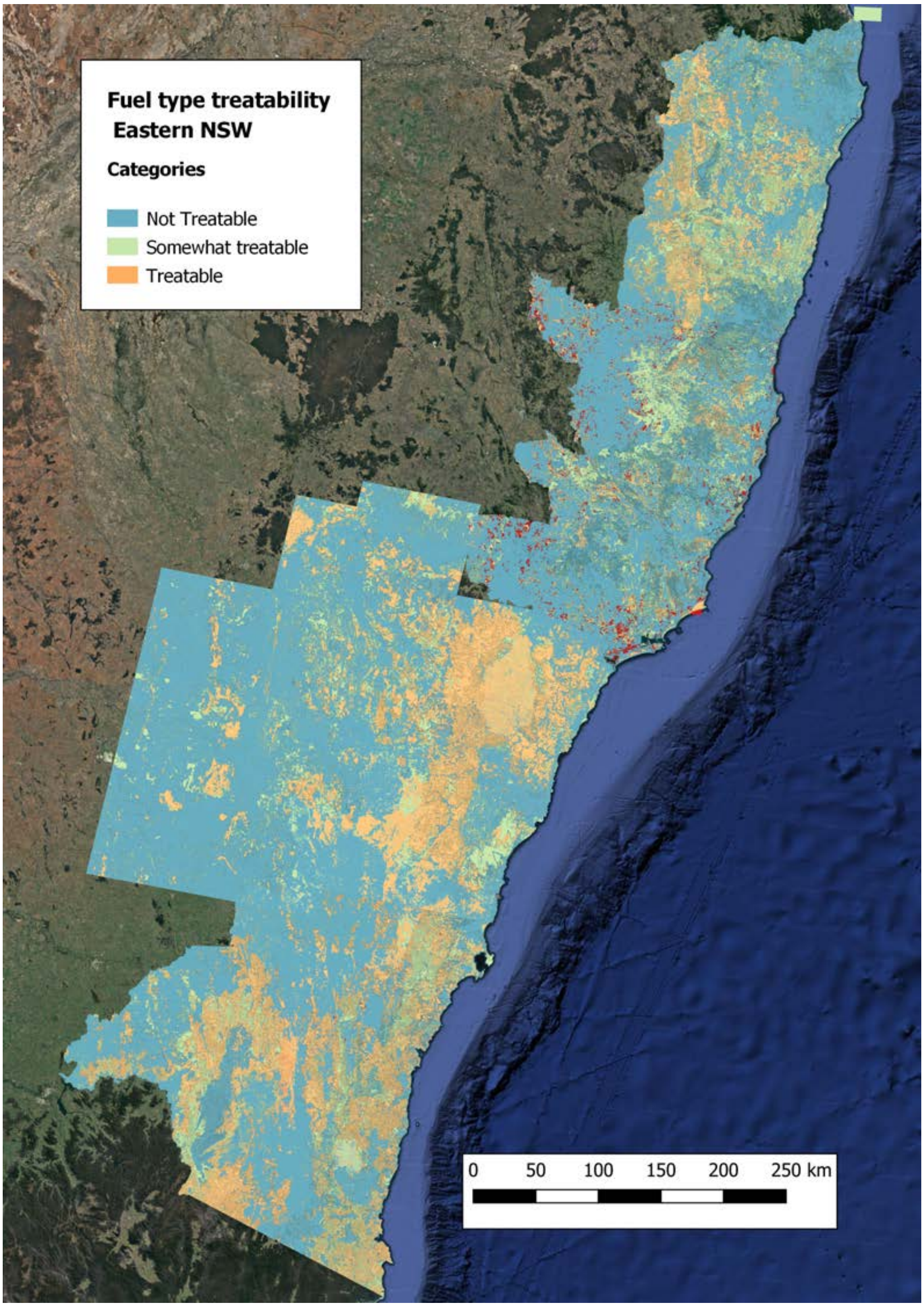

Figure 8: Fuel type 'treatability' map for eastern NSW.
Source: Gellie in preparation

The classification draws on flammability differences in eucalypt forests and woodlands which are based on three main leaf morphologies. The varying proportions of the three leaf types can be used to classify vegetation. This methodology has been used to assess fuel type treatability and landscape susceptibility to large landscape fires *(Gellie 2009)*. It is one approach in considering how much bushland can be effectively managed with prescribed fire. The analysis shows that large areas of NSW forests do not readily lend themselves to prescribed burning because they are too moist. Prescribed burning is limited by the inherent qualities of different vegetation types.

Burning more bush may increase the fire risk

Fire is a major factor determining vegetation types in Australia. A change in fire patterns can alter the structure and species composition of vegetation communities. These processes are well understood *(eg Specht and Specht 1999)*. Repeated burning of wet eucalypt forest can eliminate the fire-sensitive plants and convert the forest to a drier type. In the high country of the Australian Alps, grasslands can become shrubbier *(Camac et al 2017)*. In every case examined so far, the vegetation becomes more flammable with increased burning *(Zylstra 2018)*.

Repeated fires burning in drier vegetation can also gradually push back the edges of moist, low flammability vegetation. This is a particular concern, given the impact of last season's fires on Gondwanan rainforests *(Kooyman et al 2020).*

Both in small areas and across whole landscapes, frequent burning can be counterproductive by leading to increased fire risk. This creates a greater need for even more burning to protect fire-exposed human assets. So, hazard reduction can, in some situations, lead to more fire hazard. This perverse outcome needs to be carefully assessed and avoided in any prescribed burning program.

Hectare-based targets are not helpful

The Royal Commission into the 2009 bushfires in Victoria recommended that the state should aim to burn a 'rolling target' of at least 5% of public land each year *(Victorian Bushfires Royal Commission 2010, Recommendation 56)*. Many scientific advisers to the Commission recommended against this simplistic approach, but it was adopted by the government. When the target could not be reached, a review recommended a shift away from a hectare-based fuel reduction target to a risk-reduction target *(Inspector General for Emergency Management 2015)*. This was also the view of the Bushfire Royal Commission Implementation Monitor; their report found that the target was unachievable, inappropriate and not based on risk. Victoria then abandoned the 'hectare target' and adopted a more risk-based approach.

A media story on the Tathra fire of March 2018 reported comments by Professor Ross Bradstock of the Centre for Environmental Risk Management of Bushfires:

> *"multiple studies - particularly since the devastating Black Saturday bushfires in Victoria in 2009 - had shown broadscale planned burns were less effective in suppressing fire activity than work much closer to homes and other buildings. Creating a so-called 'defensible space', extending about 40 metres from residences, was critical, he said. Depending on the area, further work out to a couple of kilometres would also help." (SMH 2018)*

In recent years in NSW, many of the total hectares of prescribed burn have come from large burns well inside national parks. Some of these were for strategic advantage purposes, some of which proved to be helpful in containing the 2019-2020 fires. Examples were a May 2019 burn in Nattai National Park and a burn in the Grose Valley of Blue Mountains National Park. These burns appear to have helped successful suppression strategies on the Green Wattle Creek and Grose fires respectively.

NSW RFS measures prescribed burning according to 'number of properties covered', as well as total property value *(NSW RFS 2019)*. To reduce risk, this approach is both more meaningful and more effective than a hectare-based measure. However, the assumptions remain simplistic. They do not account for the diminishing effects of burns over time or the risk of causing increased flammability over time.

Building community resilience to fire

Burning in remote bushland does little to protect communities. Burning close to assets is problematic and can only ever be a part of a community protection program. An effective program must take a broad approach and use every available strategy, not just burning. Programs must also be specific to the situation of each community. Generalisations are unhelpful. Even the best program cannot remove all the risk from where the bush meets the town, farm, property or plantation *(Bradstock 2009)*.

Strategies may include burning, planning controls, building standards, property management, mechanical vegetation control, clearing, water supplies, sprinkler systems, RFS and Fire and Rescue street-based fire units, irrigation, access roads and more. The best mix and which methods are possible, will vary from community to community and from place to place within communities *(see Section 2.3 - Community Fire Planning)*.

Every fire-exposed community should have a fire protection plan that is resourced and active. The current situation is that many such communities don't. Instead they have an uncoordinated collection of actions by various landholders, public and private. Some take risk seriously and do good work, others do nothing, and many lie in between. Some communities might be hit by a wildfire once in a lifetime or longer. This happened to many villages in the 2019-2020 fires. For these communities getting a whole-of-community fire plan together will always be difficult.

Land tenure is complex on the edge of settlement, but fire does not respect lines on maps. Fire protection has to be coordinated across all tenures, on both sides of the bushland/community 'fence'. This does not mean 'tenure-blind', because the purpose of each land parcel needs to be respected. It would be inappropriate to burn a vineyard or an orchard, or to clearfell a nature reserve. The 'fence' can be very convoluted and complicated. Some places are simply very hard to protect. There is a huge legacy of housing and other assets in hard-to-protect situations. In many rural areas, houses are still being built in places that will be very difficult, if not impossible, to protect on high risk fire days.

Many authorities have pointed out that for house blocks and other small properties, the best protection happens in immediate surrounds. Professor Ross Bradstock has said that research 'overwhelmingly' demonstrates that creating a 40 to 50 metre fuel break around a house can give it a much greater chance of surviving fires, and *"that vegetation clearance is one of the most effective things to do to mitigate risk"*. *(The Guardian, 2019)*

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2.3 Community Fire Planning

Issue
Protection for fire-exposed communities is best planned at the community level, but many at-risk communities have not prepared local plans. Many impacted communities were poorly prepared for the 2019-2020 bushfires.

Opportunity
Accelerate the rollout of Community Protection Plans based on the recent RFS guideline, through a committed and prioritised program supported by policy, targets, funding and resources.

Issue Summary
Planning for fire at state and district level cannot produce the detail needed to mitigate fire impacts on specific communities. Detailed local planning, preparation and community commitment are required. Many communities affected by the 2019-2020 fires were not adequately prepared. Community fire planning can ensure that at-risk villages and suburbs are in a much better position to build resilience and defend themselves. This is frontline work that supports and supplements the efforts of firefighting agencies.

Associated issues that can be addressed through community fire planning include community understanding of fire, unmanaged or poorly managed land and establishment of firefighting resources such as Community Fire Units.

NSW RFS have been producing Community Protection Plans (CPPs) for several years and have recently formalised the process with comprehensive guidelines (*RFS 2019b*). To date there seems to be no formalised program or specific resourcing. This is the important next step to building community fire resilience.

Recommendations for Community Fire Planning
- Expand the Community Protection Plan program to cover all at-risk rural villages and suburbs by 2030.
- Establish Community Fire Units in all receptive at-risk communities.
- Review how well existing Community Protection Plans worked for communities affected by the 2019-2020 fires as a way of refining and improving the CPP program.

Issue Analysis
What is community fire planning?
It can be argued that 'all fire protection is local'. Planning at state and district level cannot produce the detail required to mitigate the fire risk for specific communities. Detailed local planning and preparation are required. With the increasing severity and scale of fires, agency firefighters cannot help everyone. For some years the NSW RFS has been warning the public that they cannot rely on a fire truck being there every time they need one. Communities need to be more self-sufficient.

Many communities impacted by the 2019-2020 fires were not adequately prepared. Community fire planning will not 'save' communities from fire but can help to ensure that they are much better prepared to defend themselves than they would be otherwise.

The purpose of community fire planning is not just a process, but outcomes. The process itself is worthwhile as it helps to educate the community and to encourage individual understanding and action. Planning develops a common appreciation of the specific risks to a community and what needs to be done to reduce them. The process involves landholders, fire agencies and other organisations.

Outcomes can be many, including:

- a record of how fires have impacted in the past
- learnings from past fires
- the identification of fire risks and advantages
- important values to be protected
- a program of mitigation works
- a case for funding to support works
- actions to be undertaken before each fire season and when a fire threatens
- identification of fire refuges
- assistance with recovery after fires.

Community fire planning contributes to overall community engagement on fire on all fronts, through participation, information sharing, consultation, collaboration and empowerment. The phases of engagement are shown in *Figure 9*.

Figure 9: Community engagement model
Source: AIDR 2013

This sort of planning for fire at the community level has been undertaken in NSW since the 1980s, but mostly in an ad hoc way. Some of the first such plans were prepared in the Blue Mountains when NSW NPWS worked with the NSW RFS and outlying communities such as Bilpin. Examples of data collected for Bilpin as part of an early 1990s community fire plan are shown in *Figure 10 and Figure 11.*

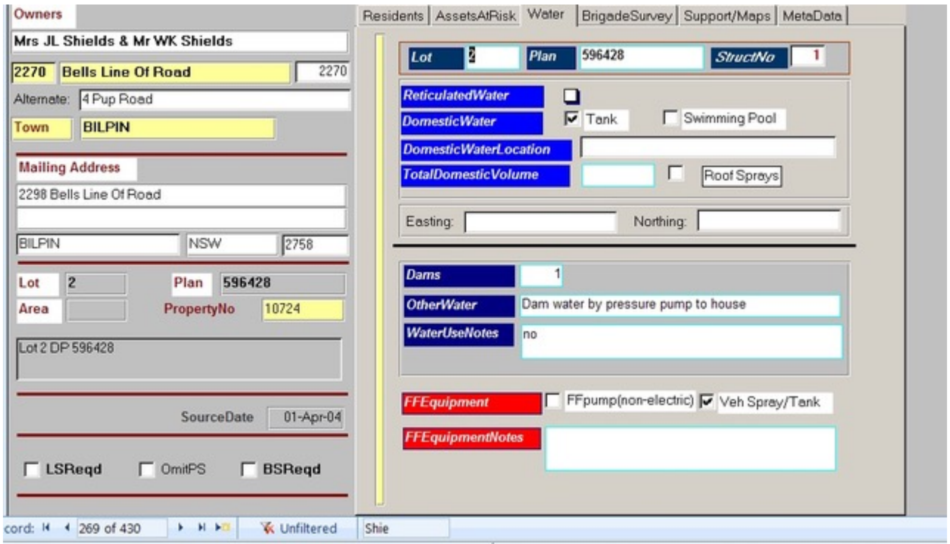

Figure 10: Screen 4 from Bilpin (Blue Mountains) Community Fire Plan database on Access software, detailing Assets at Risk for specific properties. This was to be filled in by the owner. All the information had values behind the screen from which the asset is given a risk rating. If the risk rating was a high, then a brigade survey would be done.

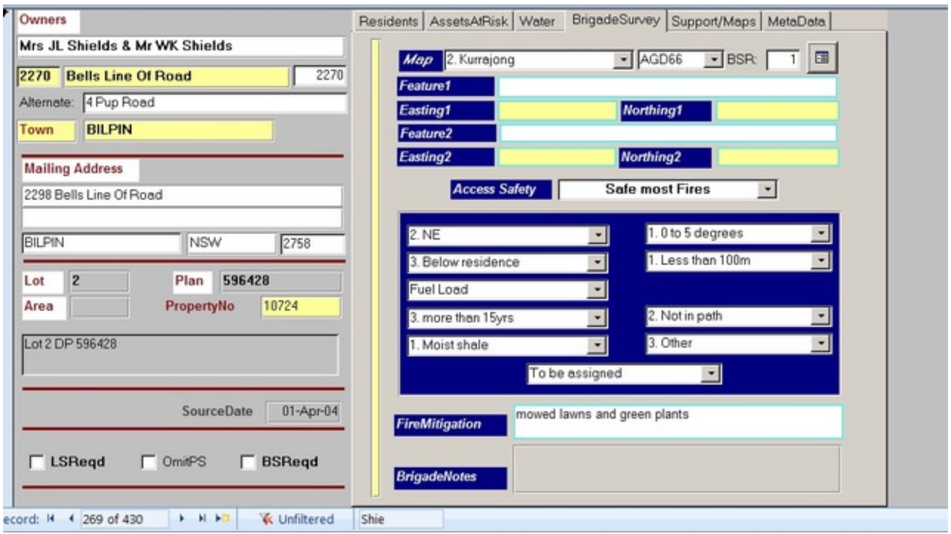

Figure 11: Screen 5 from Bilpin (Blue Mountains) Community Fire Plan database on Access software, detailing Water and Fire Fighting Equipment for a specific property.

Community fire units

Community Fire Units (CFUs) are loosely connected to community fire planning. CFUs are teams of "*local residents living in urban areas close to bushland who are supported by Fire and Rescue NSW to enhance their safety and resilience to bushfires*" (*FRNSW 2019, page 58*). A CFU program was established by FRNSW after the 1994 bushfires. A similar program for rural communities was later taken up by NSW RFS (*RFS 2011*). The status of the program is not covered in the RFS Annual Report (*RFS 2019a*).

As of June 2019, the FRNSW program included 519 CFUs in metropolitan and regional NSW with 4,797 volunteers *(FRNSW 2019, page 58)*. FRNSW CFUs are supported on the basis of community risk and priority.

> "*The primary aim of the program is to empower local residents to protect their own properties and that of their immediate neighbours from the impact of bushfires*" *(G. Mullins, NSW Fire Brigade Commissioner, CRCS 2008)*.

In this way CFUs both augment and support agency resources from NSW RFS and FRNSW and encourage self-reliance and resilience. The presence of local resources is a consideration in community fire planning.

The NSW RFS program is smaller. In rural communities many landowners are already involved with their local RFS brigades and/or have their own fire units on trailers or trucks.

Unmanaged land

An important issue in community fire planning is land which is unmanaged or poorly managed for fire mitigation. This can include private land but also small patches of public land like road verges, easements, public utility land and 'no-man's-land'. These areas may be unkempt or high in fuel and close to assets, and hence a high risk during fires.

The most effective risk reduction is immediately adjacent to assets. This was highlighted by the extent of damage in some communities from the 2019-2020 fires, especially rural residential areas and small villages where assets are intermixed with bush or paddocks. Examples are Balmoral (Southern Highlands), Batlow (Snowy Mountains) and Wytaliba (Northern Tablelands) *(see Figure 12 and Figure 13)*.

On both public and private tenures there can be confusion over who is responsible and what is permissible for risk mitigation. A community fire plan can help to resolve these issues and identify both responsibilities and actions.

Figure 12: Aerial image of Batlow (Snowy Mountains) showing bush patches close to town

Figure 13: Aerial image of Wytaliba (Northern Tablelands) showing residences dispersed within bushland

Recent community fire planning

Community fire planning requires a high level of community engagement. For some villages and suburbs, fire is a rare event while other communities experience fires more often, perhaps every 10 or 20 years or so. There is a limit to how many communities will be capable of preparing a useful fire plan. Then they must be able to implement the plan, and update and maintain it. Official support needs to be prioritised according to both the fire risk (magnitude and probability) and community capability.

By the end of June 2019, the RFS program had produced 134 Community Protection Plans (CPPs), with 35 more in progress (*RFS 2019a*). Completed plans are available online (*RFS 2020*). Over the 2018-19 financial year the RFS spent $11 million on its Bush Fire Mitigation and Resilience Program. Most of this went to fire trails and prescribed burning, "*with $1.5 million allocated for resilience projects that increase the bushfire protection and readiness of NSW communities*" (*RFS 2019a*). This relatively low investment suggests that more could be spent on CPP implementation to achieve more widespread and better community preparation.

An example of a good plan from a fire-exposed and enthusiastic community comes from Mount Wilson-Mount Irvine in the Blue Mountains. A map from this plan is shown in *Figure 14 (RFS 2012)*. These two linked but small and isolated communities are surrounded by bushland, mostly national park. They have suffered many serious fires over many years and have a strong RFS brigade and an engaged community.

In late 2019 these communities spent several weeks preparing for the approach of the Gospers Mountain fire. Guided by their Community Protection Plan, they cleared trails, planned, gathered resources, and prepared properties. As it happened, the worst fire struck from an unexpected direction, but in the ensuing campaign the careful preparation kept losses to a minimum.

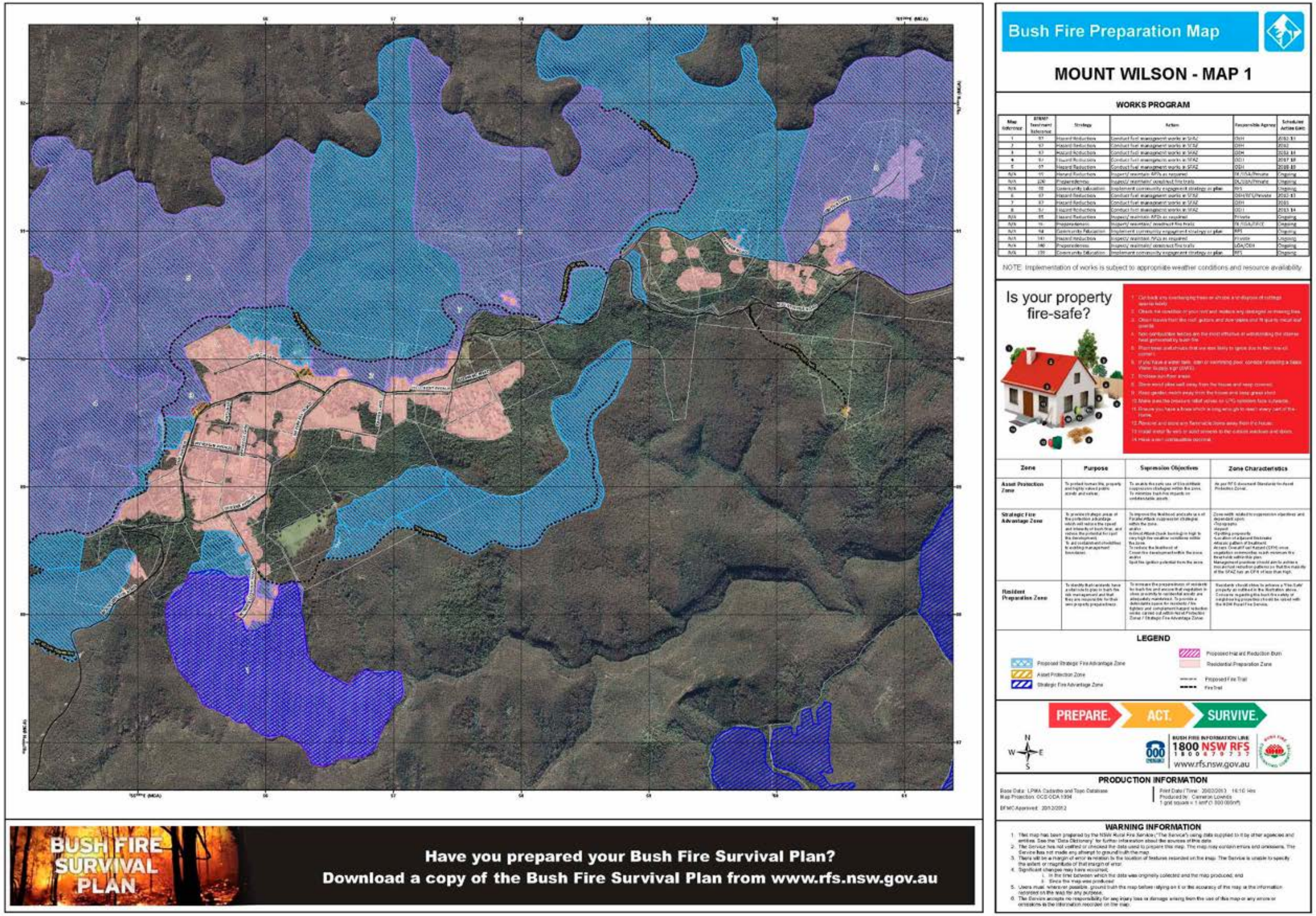

Figure 14: Bushfire Preparation Map for Mount Wilson, Blue Mountains
Source: Mount Wilson-Mount Irvine Community Fire Plan (RFS 2012)

The way forward

In 2019 the NSW RFS prepared a draft guideline for Community Protection Plans (CPPs) *(RFS 2019b)*. The guideline notes that: "*The NSW Government has committed to developing local planning strategies for communities at risk of bushfire*" *(RFS 2019b, page 8)*. This move was partly in response to recommendations that came out of the Royal Commission into the 2009 Victorian bushfires. It is understood the RFS draft has recently been approved by the NSW Bushfire Coordinating Committee (BFCC).

The Community Protection Planning Guideline is a comprehensive document that begins with a concise description of CPPs:

> *"CPPs provide the public, fire services and land management agencies with easy to understand information that is specific to a community. A CPP consists of three maps with supporting documentation. It presents an overview of the bushfire threat for the area, the protection options available to the community as well as the current and proposed risk treatment works. The CPP also captures any locally important information, including the location of Special Fire Protection Purpose (SFPP) assets, which can be used by local brigades and emergency services during pre-incident planning exercises and firefighting operations." (RFS 2019b, page 7).*

Under the guideline a CPP may be initiated by the local Bush Fire Management Committee through their Bush Fire Risk Management Plan, or directly by the RFS (*RFS 2019b*, page 8). It is implicit that a community can request a plan to be prepared. The guideline describes the role, function and format of CPPs, how to go about preparing one and how to promote and carry out the completed plan. Community consultation and involvement of government agencies are critical. Guidelines for a communication strategy are included (*RFS 2019b, Appendix 2).*

The model CPP is based around three maps *(RFS 2019b, page 11)*:

- Bush Fire Survival Map
- Bush Fire Preparation Map
- Operational Brigade Map.

As for implementation; *"A cooperative approach between land managers, fire services and the community is to be adopted in the implementation of required works and enhancing the bushfire protection for the area"* (*RFS 2019b*, page 37).

This guideline is an excellent resource, a major step forward and a strong basis for an expanded community fire planning program across NSW. It deserves to be rolled out with energy. Plan development and implementation need additional resourcing. While the enthusiasm and time of local RFS staff and communities is essential, it is unclear how well the CPP program is supported with policy, targets, priorities, funding and accountability (RFS 2020).

Some communities impacted by the 2019-2020 fires had CPPs in place. These include Batlow, Broulee, Bungonia, Cabramurra, Hilltop, Rosedale and Wonboyn (*RFS 2020*). A review of how the plans performed in action would provide valuable insights for assessing and refining the CPP program.

Case Study – Lakewood and High Country Estates, Snowy Mountains

An example of a fire-prepared community during the 2019-2020 season was Lakewood Estate and the neighbouring High Country Estate, rural residential estates near Jindabyne, with about 150 blocks. A Community Fire Unit was established by NSW RFS less than two years ago. On the worst fire days of the past season, CFU members roamed the Estates with trailer units and established standpipe water sources at strategic points. The members made regular visits to less able and concerned residents and assisted them to make informed choices as to whether to stay or leave. Although Jindabyne was not directly impacted by fire the potential was certainly there.

Because the CFU, which is part of the Jindabyne Rural Fire Brigade, had worked with the RFS district staff to develop a community fire protection plan, all known and available water sources such as tanks with storz fittings were known and mapped.

This level of advance preparation and the daily work of the CFU on extreme days took a huge load off the Jindabyne Brigade firefighters so they could focus their efforts more broadly across the brigade area and into adjoining brigade areas. (RFS 2018, Darlington pers comm 2020)

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2.4 Critical Fire Incident Management Skills

Issue

The scale and complexity of the 2019-2020 fires revealed shortages of skilled people in critical expert operational roles, notably strategy, aerial firefighting and divisional command.

Opportunity

Increase cross-agency investment to develop greater numbers of expert Fire Strategists, Aircraft Specialists and Divisional Commanders (DCs), so that fire suppression can be much more successful.

Issue Summary

Managing large and complex bushfires is a very challenging task involving many people. Expert specialist skills are needed in many operational areas and at multiple levels in the organisational structure. Any skill that is a weak link in the chain of planning and command can lead to poor outcomes, such as failure to control the fire.

The scale and complexity of the 2019-2020 fires strained all resources, with many vital skills in short supply. Events point to critical shortages of highly skilled people in three areas in particular: strategy, aerial firefighting and divisional command. These shortages have been longstanding but became critical during the recent very long and intense season. Current processes seem to be inadequate to produce enough people with these skills, and to then assess the ability of individuals to operate at an expert level of competence. Training is a complex task for fire agencies, especially with many thousands of volunteers, but targeted investment in critical skills can help to avoid on-ground problems during emergencies.

Many reports from the field show that some strategies and operations were simply not able to be undertaken because the right people were not available. In other cases, strategies failed due to inexperience or inadequate skills, such as with some backburns. Over the length of the summer crisis people were unavoidably thrust into roles for which they were not fully prepared.

There is no consistent method that Incident Management Teams (IMTs) use to decide on strategies to control fires. With little science or guidelines to support decisions it is a common experience that strategies are resolved by discussion amongst the most experienced or confident officers. Fire Strategist has only been a recognised role within IMTs in recent years, and their main task has been to plan longer term suppression and the recovery phase. There is a need for expert strategists that work on short-term, shift-to-shift suppression strategies. Fire Strategists will be more effective if they are experienced with fire in the local landscape.

Aircraft specialists are shown in *Figure 15*. There was a serious shortage of expert aviation roles available in Australia this past season, including Aircraft Officers, Airbase Managers, Air Attack Supervisors, Air Observers and Aerial Incendiary Operators. This led to ineffective use of aircraft and the failure of some strategies. These roles are time-consuming and expensive to train and to maintain currency. Air Attack Supervisor (AAS) and Aerial Incendiary (AI) roles are especially critical to the success of many fire suppression strategies.

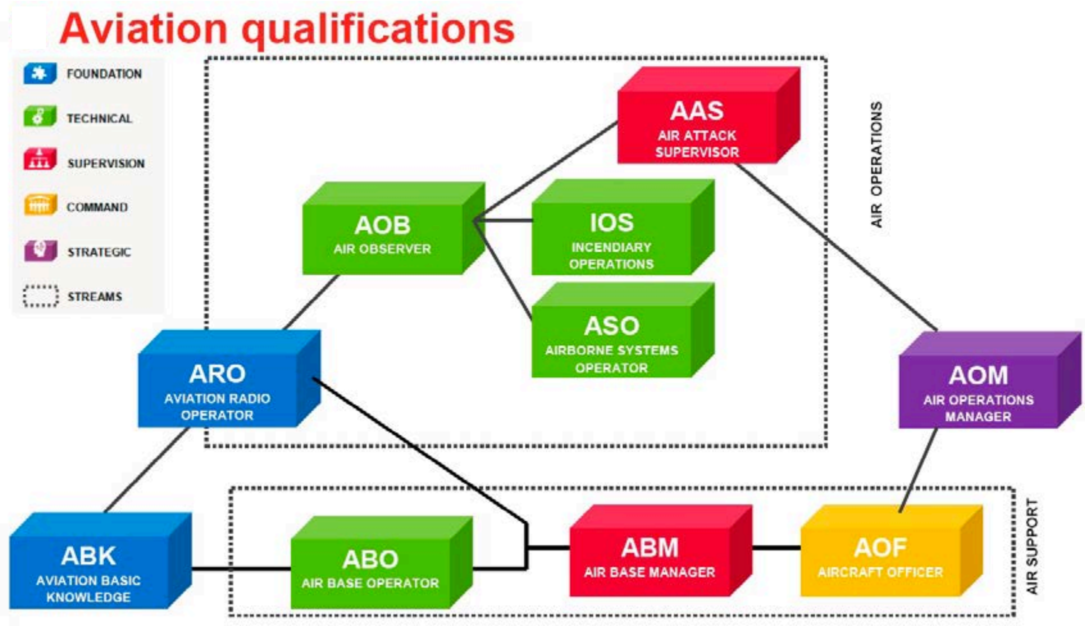

Figure 15: RFS pathways for aviation training
Source: RFS 2017

Divisional Commanders (DCs) are lynchpins in the execution of fire suppression. Their skills and leadership can make the difference between success and failure on a strategy. In the 2019-2020 fires, people who lacked the necessary competency had to step into DC roles. This had consequences such as poorly executed strategies. Good DCs need diverse skills and take time and a lot of continuous experience to develop. The role should be paid professional. Agencies need a strong commitment to nurturing and mentoring expert DCs.

Since 2004 both RFS and NPWS have had formalised firefighting training programs which offer nationally recognised qualifications under the Vocational Education and Training (VET) system *(RFS 2017, OEH nd)*. Training is aligned with units of competency from the national Public Safety Training Package PUA12 *(AIS, 2013)*. As Registered Training Organisations, both agencies offer Certificates II, III and IV from this package *(Figure 16)*.

There is a risk that when training becomes highly formalised, desired outcomes may be lost in the detail. The aim of developing highly competent operators is more than just generating numbers of people completing courses. Courses alone will not develop high competence. On-the-job experience, mentoring and assessment by experienced experts are critical. Few volunteers will be able to commit the time needed to become expert in advanced roles. More professional officers are needed in these positions.

The best people from all agencies need to be used during major incidents. Formal processes should be strengthened and resourced for training, mentoring and assessing people to expert level in critical but scarce skills.

Training people to an expert level in any specialist role is difficult and expensive. The alternative is using people who are not sufficiently competent in critical roles with potentially serious consequences, such as strategy failure. More experts are needed to avoid this situation. Most of these people will need to come from the professional ranks of fire agencies.

Divisional Commanders and Group Captains need more training in the capabilities of various aircraft and in the use of radio repeaters. The use of drones for fire edge mapping and direct observation needs thorough investigation. The fire warning and *Fires Near Me* app systems need to be consistent across the country and accurate.

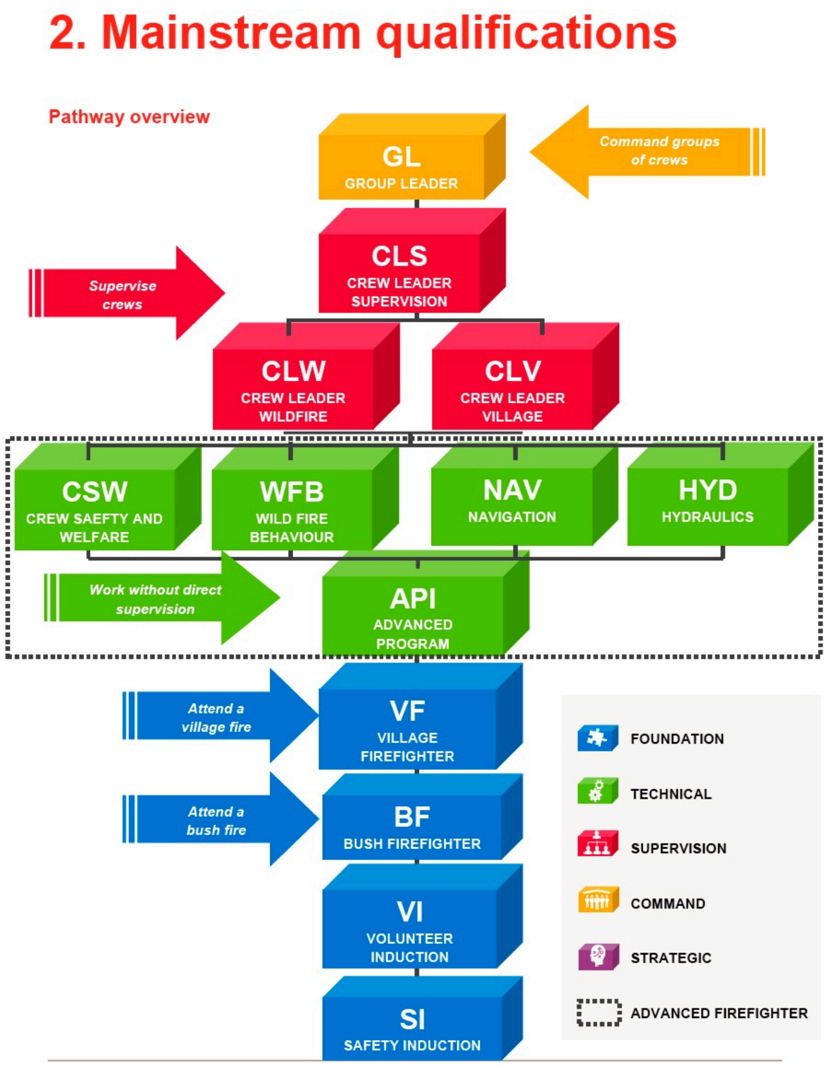

Figure 16: RFS training pathway for 'mainstream' firefighting
Source: RFS 2017

Recommendations for Critical Fire Management Skills

- Recognise landscape-based Fire Strategist as an essential role in the IMT planning team.
- Review fire training and competency requirements in light of new and evolving suppression strategies.
- Accept the need for more experts in critical fire roles and that Fire Strategists, many Aviation Specialists and Divisional Commanders need to be paid professionals.
- Develop a cross-agency program to produce more Fire Strategists, Aviation Specialists and Divisional Commanders with expert abilities.
- Re-assess the competency and currency requirements for some Aviation Specialist roles.
- Review public fire warning systems and ensure inter-state consistency in their application.
- Investigate the use of new technology for mapping and observing fires when reconnaissance by aircraft is impeded.

Issue Analysis

Fire Strategists

There is no consistent method that IMTs use to decide on strategies to control fires. Nominally, the Planning Officer leads the planning team to develop, assess and recommend strategy options in consultation with the Operations Team. Many inputs are used such as weather forecasts, predictions for fire behaviour and rates of spread, timing, terrain, access, potential containment lines and available resources. Options, or just one preferred plan, are then put to the core IMT. The final strategy is approved by the Incident Controller, documented in the Incident Action Plan (IAP) and carried out on the ground.

In the real world, strategies are often hotly debated inside and outside the IMT. With little science or guidelines to support decisions it is a common experience that strategies are resolved by discussion amongst the most experienced or confident officers. Ideally this is based on a wealth of experience and past success, but dominant individuals can prevail over objective analysis. Strategies are sometimes directed from above, from State Operations.

Planning Officers are usually trained and qualified for their vital role, but that training is mainly about performing the processes of planning. Training in strategy to put out fires is limited and spread across a range of training programs or is assumed to be developed through experience. Both methods produce unreliable results.

The other key player is the Fire Behaviour Analyst (FBAN), who sits within the Planning Team when available. Their main expertise is predicting what the fire will do. There are problems with the tools used, as outlined in *Section 3.2 - Fire Behaviour Modelling*. In the RFS system FBAN training extends to developing suppression options for a level 2 wildfire *(RFS 2017)*. FBANs are few in number with variable skill levels.

The ideal Fire Strategist would be an experienced fire analyst with extensive on-ground experience, detailed knowledge of fire in the local landscape, high-level scientific, Geographic Information System (GIS) and fire behaviour modelling skills. They will understand the nuances of how fires behave in the local terrain and vegetation; how to use natural fire advantages; how to manage the energy output of the fire; where it will run; how fires have behaved in the past; the limitations and risks of various strategies, and local fire weather conditions.

Such experts are in high demand but very few in number. Some are in RFS, usually in the ranks of very experienced volunteers or local professional staff. Others are in NPWS, because NPWS constantly works with fire in the landscapes of the large bushland areas they manage, and this is where the big fires also occur.

However, there is no recognised role within the IMT structure for short-term Fire Strategists. There is also no formal training program. This is one reason ineffective or counter-productive fire control strategies are sometimes attempted. It has been assumed the Planning Team takes care of this function, but if they do it, it tends to be by fortuitously having the right people available at the right time. The Planning Officer and team may have little expertise or local knowledge and in major fires, often come from outside the area. Any fire strategy, with or without a dedicated Fire Strategist, is best done as a team effort using the best local knowledge.

Professional staff of RFS and NPWS tend to move around from job to job, but the ideal Fire Strategist will have been in one area for some years to develop extensive understanding of fire in a particular landscape. That landscape could be quite big, such as the Snowy Mountains. Other NSW landscapes that deserve dedicated strategists are the South Coast, Central Coast, North Coast, Greater Blue Mountains and the escarpments areas of the south and north.

Aerial firefighting

Aerial firefighting uses aircraft to deliver fire-retarding and fire-suppressing liquids onto the fire, or in front of it. Liquids include water, gel, foam and retardant. A range of aircraft are used, including small, medium and large helicopters and fixed-wing aircraft from small agricultural planes to Large Air Tankers (LATs) and Very Large Air Tankers (VLATs). All aircraft have different capabilities and usefulness in different situations. Costs per aircraft range from about $1800 per hour for a small helicopter to about $35,000 per hour for a VLAT, plus applicable crew and retardant costs.

Feedback has suggested that there was a serious shortage of expert aviation roles available in Australia this past season, including Aircraft Officers, Airbase Managers, Air Attack Supervisors, Air Observers and Aerial Incendiary Operators. This led to ineffective use of aircraft and the failure of some strategies. RFS and NPWS both have formal training pathways for aviation roles *(Figure 17)*. Qualified people are mostly from these agencies, but they vary in experience and capability.

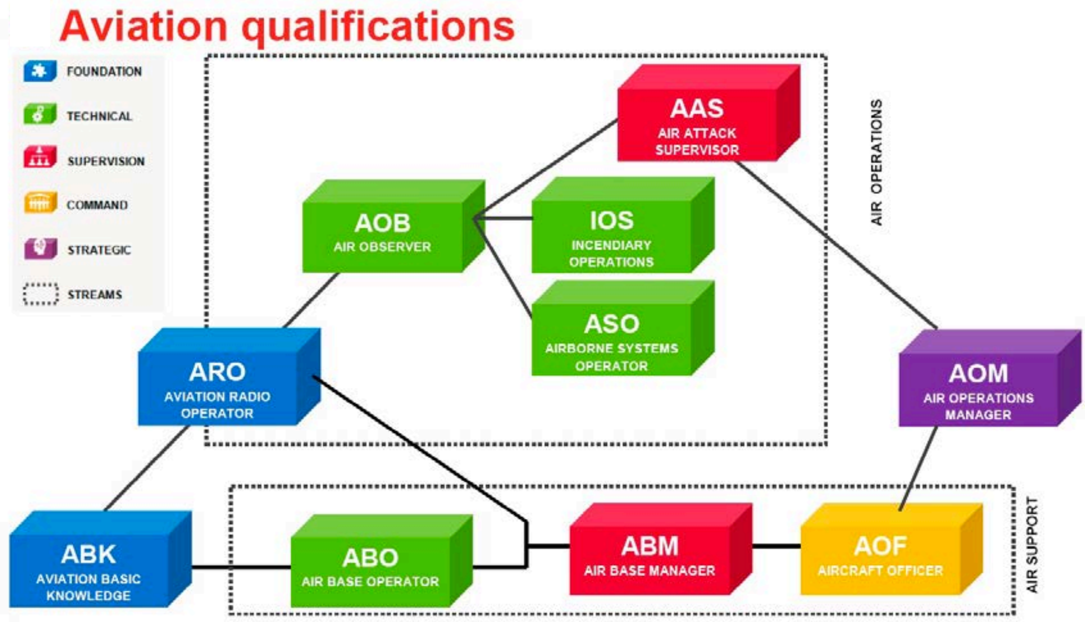

Figure 17: RFS pathways for aviation training
Source: RFS 2017

Aerial Incendiary (AI) work is a critical tactic in many fires. It involves dropping incendiaries from the air to burn the bush. This is commonly done to deepen backburns after the containment line and backburn edge have been established on the ground. It can also be done to burn out areas in front of the main fire during mild conditions, such as overnight, to reduce later fire intensity or fast runs of the fire. Little science exists to guide aerial incendiary operations. They can be risky and require a high level of expertise, experience and judgment.

Aircraft costs are the major expense in large fires. It is the job of the Air Attack Supervisor (AAS) to use these resources to maximum effect; a complex task. It is easy to commit many plane hours and money on a fire without having much benefit. Again, there is little science or analysis of past operations to support these decisions. Effectiveness is very dependent on the skill of the AAS and pilots. The critical role of the AAS is to fly around and observe the fire in a small plane or helicopter and direct the attacking aircraft on what to do. The AAS also consults with DCs on the ground and reports 'up the line'.

Many firefighting tasks can be done by air-dropping liquids. Helicopters can water-bucket the active fire to slow it down or damp it down enough so that ground crews can try to put it out more safely. Small planes can do the same. Both can also help protect houses and other assets. Larger planes, LATs and VLATs, are mostly used to drop pink retardant lines in front of the fire to slow the fire front down when it burns into the retardant. Water and retardant can save property, but they do not put fires out in the bush. Only people on the ground can do that. Large helicopters, LATs and VLATs cannot drop liquids near firefighters on the ground because of the danger.

Aircraft operational procedures vary from state to state. Sensible consistency needs to be incorporated. At the moment delays occur when one state assists another. A good example is that in NSW a RAF crew working on a fire can talk direct to the helicopter pilot that is dropping water from buckets on the fire. In Victoria crews cannot talk direct to pilots with all communications going through an AAS. Adoption of best practice at a national level is required, to overcome operational inconsistencies and constraints. The same occurs with data sharing constraints. NSW does not have access to Victorian data layers such as vegetation and this is a significant constraint to the production of fire maps in border areas by Air Observers.

More training is also needed in understanding the capabilities of various aircraft particularly for Divisional Commanders and Group Captains. With very large helicopters and LATs being used, few understand their different uses and capabilities or when to use retardant, gel, etc. Training in use of radio repeaters is also a high priority.

Divisional Commanders

When IAPs are handed down twice a day from the IMT, the DCs on the ground are responsible for carrying out the approved strategies. The detailed tactics are usually up to them, using the firefighting teams and resources they have been given. In large fires, DCs manage one geographical division of the fire, perhaps with many teams of people, vehicles and other machines. It is a vital role that can mean the difference between success and failure for a strategy. For example, if a backburn is started at a bad time, or lit up the wrong way or too quickly, or if it is not mopped up thoroughly, it can escape and ruin the strategy. On the other hand, an excellent DC with a good team can pull off a high-risk strategy and 'save the day'.

DCs must be good people managers and communicators. They need to be consultative but assertive when necessary. They need high-level firefighting skills and excellent understanding of fire behaviour, weather and their role in the wider operation. They must direct their 'troops' via Sector Commanders (SCs) and adapt to fast-changing circumstances while reporting to the Operations Officer (OO) in the IMT. As with other key firefighting roles, this is a complex set of skills. Not many people can combine these skills with aptitude. Reports from the field show that in the 2019-2020 fires, people who lacked the necessary competency had to step into DC roles *(see Section 3.4 - Fire Incident Management Arrangements)*. This had consequences such as poorly executed strategies.

Crew Leader (CL) is the minimum qualification being rolled out as a prerequisite for RFS Brigade Captains *(RFS 2020 pers comm).* This is one step below Sector Commander and two steps below Divisional Commander (designated as Crew Leader Supervision and Group Leader respectively in the RFS training system). Many RFS Brigade Captains filled DC roles in the recent fires.

In NPWS the basic training level for all firefighters is Crew Member, but most are trained to Crew Leader. The latter requires working under supervision for 60 hours before a candidate CL can perform the role unsupervised *(OEH 2004)*. To become a Divisional Commander, a qualified Crew Leader must complete courses in fire weather and leadership, display an aptitude for the role and then do a three-day program followed by another 60 hours of working under supervision *(see Figure 18)*. Good DCs take time and a lot of continuous experience to develop. The role should be paid professional. Agencies need a strong commitment to nurturing and mentoring expert DCs.

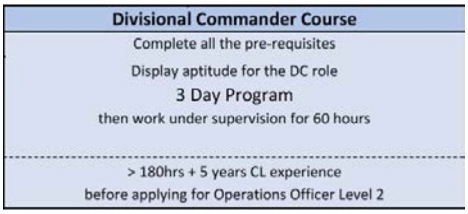

Figure 18: NPWS training for Divisional Commander
Source: OEH nd

Training systems

Training is not competency, but just the first step. In all fields where high-level skills are required, competency only develops over time, and after formal training. Aptitude and extensive experience are necessary. In the medical field, a medical degree is just the basic qualification. To become a functioning specialist takes more study, on-the-job training, mentoring, assessment and extensive experience. A similar training regime should apply to the expertise needed for many specialist roles in fire suppression. Rigorous training and mentoring systems are needed for Fire Strategists, Air Attack Supervisors, Aerial Incendiary Operators and Divisional Commanders.

The NPWS training system has some of these elements. It recognises the necessity of aptitude as a prerequisite and details experience-based training pathways for specific roles.

> *"Different levels of training will be offered to staff depending upon their capability to perform the role for which they are being trained. For example: Not every fire-fighter will become a Divisional Commander, so Divisional Commander training will only be offered to those who will ultimately be able to fulfil the role, having demonstrated both attitude and aptitude for that role…Training pathways for individual staff will be determined by operational need, individual experience, attitude and aptitude for that role." (OEH nd)*

An example is aviation specialists, such as AAS. To be trained in these roles, NPWS applicants must pass a selection process that applies rigorous criteria for personal skills and aptitudes. Applicants also must make a 10-year commitment to the role *(OEH nd)*. The RFS system apparently does not apply similar requirements of personal capability and experience.

At the moment most AI work is done by the AAS, but it may be more efficient if the Air Observers was to do this task? The problem is that to become an AAS you must first be a DC and this constrains the number of qualified people. Similarly, for Aircraft Officers. Due to the shortage of trained Aircraft Officers this season, unqualified people often performed this role. In order to become a DC there are certain fireground currency requirements which may or may not be essential or available to personnel who are capable of undertaking these aviation roles. Also Air Base Managers have a minimum requirement of Crew Leader but again, this could be seen as inappropriate for this role.

Training people to an expert level in any specialist role is difficult and expensive. The alternative is using people who are not sufficiently competent in critical roles with potentially serious consequences, such as strategy failure. More experts are needed to avoid this situation (acknowledging that it may not be possible to train enough people for major disasters). Most of these experts will need to come from the professional ranks of fire agencies.

Warning systems and new technology

The fire warning and *Fires Near Me* app systems need to be consistent across the country, to assist the community in interpreting their meaning, especially in border areas. Concerns about currency of the information was raised on mainstream and social media. Refer to *Section 4.3 - Community Education*.

The use of drones for fire edge mapping and real-time fire observation needs thorough investigation. This year there were many occasions when the location of fire edges was not known. Helicopters could not fly due to smoke. Drones may have been able to do this work without compromising safety. The Federal Government should lead this review. It may be something the ADF could advise on.

References

AIS (Australian Industry Standards) (2013) PUA12 – Public Safety Training Package, release 2.1, 2 May 2013, Department of Employment, Skills, Small and Family Business (training.gov.au)

OEH (Office of Environment & Heritage) (nd) NPWS Fire, Incident and Aviation Training Strategy 2017-2022

RFS (Rural Fire Service) (2017) NSW RFS Training: Training Information Booklet, version 3.1, the Service, Granville

2.5 Research

Issue

There are serious gaps in the scientific knowledge base to support bushfire management and particularly fire suppression. Not all fire management is evidence-based. Much research is funded by fire agencies and undertaken by a limited pool of researchers connected to a few institutions.

Opportunity

After the 2019-2020 fires and with the threat of escalating fire danger under climate change, there is an opportunity to increase investment in targeted bushfire research. Also, the independence and scope of research can be expanded. Together, these initiatives can support more evidence-based and better bushfire management.

Issue Summary

Australia has undertaken a lot of bushfire research. This has led to detailed understanding of many aspects, such as fire ecology, prescribed burning and fire weather. Other areas have not been so well researched. These include pragmatic and operational topics such as fire modelling and fire suppression.

Much of the current fire research is funded by fire agencies through particular institutions and associated researchers. The main institutions have been, at the national level, the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) in Melbourne and, at the NSW level, the Centre for Environmental Risk Management of Bushfires (CERMB) at Wollongong University. The latter is now part of the larger Bushfire Risk Management Research Hub. This model has many advantages and is achieving much useful research but gives limited attention to operational issues.

This model has some other drawbacks. As a human activity, science can be affected by personal biases, mindsets and influence from funding bodies. Fire agencies have specific ideas on questions that should be researched, or not. Other bushfire stakeholders may see different priorities. Groups of scientists may form views and resist alternative understandings. Research structures where individuals hold power over research priorities will tend to produce findings influenced by that leader. The history of science is full of colourful examples of ideas embraced and then abandoned, and disputes between different schools of thought. Peer review and diverse debate over theories and findings are fundamental to the scientific method and should be encouraged.

The authors are aware of fire researchers who have missed out on funding or who have been marginalised, possibly because their ideas challenged prevailing orthodoxy. Prescribed burning is one example of a fraught topic because it has powerful ideological dimensions. Both scientists and non-scientists have interests in supporting particular views about prescribed burning. Some scientists have expressed reluctance about trying to research certain topics because it may jeopardise official funding. Whatever the merit of those topics or alternative ideas, these obstacles do not make for healthy and robust scientific endeavour.

A case in point is research into bushfire suppression. Very little such work has been done despite the critical need to know what methods work and under what conditions. This is despite a wealth of events and records that can be analysed. The RFS lists such research as a priority *(see Section 3.3 - Suppression Strategies for Large Fires)* but there is little evidence that it has been supported through funding.

Science is stronger when diversified voices are heard and are supported to pursue a broad range of research questions.

The 2019-2020 fires present an enormous research opportunity. With so many fires spread over such a large area and variety of fire landscapes under different conditions, there is a wealth of data to be analysed and interpreted. Key issues needing more evidence include the role of prescribed burns in fire suppression and the effectiveness of backburning strategies and aerial attack.

Climate change will bring greater fire danger and longer fire seasons. More research is needed to meet the challenge of protecting communities, the environment and firefighters.

Recommendations for Research

(also see specific research-related recommendations in other sections)

- Fund research into the barriers that have inhibited evidence-based fire management in Australia.
- Open up fire research by funding and encouraging a wider diversity of researchers.
- Mount a major research program based on the 2019-2020 fires, with an emphasis on bushfire mitigation and suppression.

Issue Analysis

There are serious gaps in the scientific knowledge base to support bushfire management and particularly fire suppression. These gaps are highlighted by the program priorities of the main research institutions. The BNHCRC research themes are summarised as (*BNHCRC 2017*):

Policy and economics of hazards

- Governance and institutional knowledge
- Economics and strategic decisions
- Scenarios and loss analysis

Resilience to hazards

- Communications and warnings
- Emergency management capability
- Sustainable volunteering
- Understanding and enhancing resilience

Understanding and mitigating hazards

- Flood and coastal management
- Prescribed burning and catchment management
- Bushfire predictive services
- Built environment
- Severe and high impact weather

A recent BNHCRC report on *National research priorities for natural hazards emergency management* (*BNHCRC 2019a*) recommends these research priorities:

- Shared responsibility and community engagement
- Communicating risk and understanding the benefits of mitigation
- Impacts of climate change
- Predictive services, data and warnings

A supporting document (*BNHCRC 2019b*) emphasises several specific themes related to bushfires. The only theme related to pragmatic on-ground issues is fire modelling.

Research by the CERMB is currently focused on four major themes (*CERMB 2020)*:

- Bushfire risk and risk mitigation for fire-prone communities
- Carbon fuels and flammability
- Fire ecology and ecosystem risks
- Fire and climate change

In NSW, CERMB also leads the NSW Bushfire Risk Management Research Hub (*NSW BRMR Hub)* with funding from the NSW Department of Planning, Industry and Environment (DPIE). The current NSW BRMRH Hub programs *(BRMRH 2020)* are:

- Dynamic mapping and analysis of NSW fire regimes, past, present and future
- Fuel, flammability and carbon dynamics
- Greenhouse gases, particulate emissions and air quality
- Fire regime thresholds of potential concern for threatened biodiversity
- Health and social benefits of Aboriginal fire management programs
- Optimization of cost-effective fire management

Whilst all the research priorities of these major institutions are important and valuable, there is little focus on research to help firefighters and fire controllers on the ground.

References

BNHCRC (Bushfire and Natural Hazards Cooperative Research Centre) (2017) Research projects, achievements and outcomes

BNHCRC (Bushfire and Natural Hazards Cooperative Research Centre) (2019a) National research priorities for natural hazards emergency management: issues, priorities, directions, updated May 2019

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BRMRH (NSW Bushfire Risk Management Research Hub) (2020) at: https://www.uow.edu.au/science-medicine-health/research/cermb/nsw-bushfire-risk-management-research-hub/

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Part 3 – Response to Bushfires

3.1 Initial Attack for Remote Fires

Issue

Many large and damaging fires in the 2019-2020 season began as lightning strikes in remote bushland. They could have been extinguished when small but were not.

Opportunity

Improve detection technology, place higher priority on putting out remote ignitions, train strategists and invest in enough people with the right skills and the right aircraft. With these changes in place many recent NSW bushfires could have been eliminated.

> *"A vigorous initial response to a wildfire, a process referred to as 'initial attack', can greatly reduce the likelihood of the fire becoming larger and causing substantial damage. Successful initial attack depends on deploying the right number and kind of firefighting resources in a timely way." (Meznarich 2014)*

Issue Summary

The best time to control any bushfire is when it is small. Rapid and successful attack minimises the costs, risks and impacts of a fire. As fires grow bigger, they become harder to control and cost more to put out. More firefighters are then exposed to hazardous activities, the fire is more likely to damage towns, infrastructure and the environment, and more hazardous smoke is produced. Enlarged fires stretch firefighting resources, increasing the chances of property loss.

Rapid detection and vigorous initial attack are the first line of defence in fire suppression. This is especially important when there are multiple remote ignitions from lightning. This logic is basic and well understood but was not always applied during the 2019-2020 fires due a range of issues. Many remote lightning fires were put out, but others went on to become major disasters. Satellite technology is available for real-time fire detection and monitoring but is not yet specific to Australia's needs. Government investment is required.

At various times multiple lightning fires occurred at the same time and had to compete with larger going fires for limited resources. With many large fires running, smoke at times restricted aerial and RAFT attack. Axiomatically, most remote fires occur in national parks and similar large reserves. Remote fires are challenging because they are hard to reach with firefighting resources and can grow quickly.

Records show that most lightning fires in national parks and reserves are put out when small. This is partly due to the local knowledge, experience and skill of NPWS firefighters. Historically, two-thirds have been kept to under 10 ha in size, and almost 90% to under 500 ha. Changes can push this number towards 100%, including:

- higher priority to remote ignitions
- faster detection and attack
- stronger attack
- increase standby aircraft and highly competent RAF teams
- removal of obstacles to night shifts and early morning attack
- better training of more strategists.

Recommendations on Initial Attack for Remote Fires

- Invest as a priority in a dedicated Australian satellite platform for real-time fire detection and monitoring.
- Make aerial reconnaissance to follow electrical storms mandatory in the bushfire season.
- Assign a high priority to remote fire threats in high risk conditions. Retain standby RAF teams and aircraft for rapid deployment when electrical storms are predicted, even if other fires are going and causing damage.
- Resolve the issues that are preventing regular night shift or first light operations on remote fires.
- Greatly expand RAFT resources in the form of trained and fit personnel and aircraft, especially for forecast high risk seasons. Establish a seasonal and substantial RAFT capacity based in vulnerable regions in eastern NSW. For practicality and effectiveness these should be integrated with existing NPWS operations.
- Research the best mix of aircraft to support rapid suppression of remote fires.
- Train more expert strategists for fires in remote bushland.

Issue Analysis

Remote fires are challenging

Bushfires are ignited by lightning or by people. People can start a fire either accidentally or deliberately. Deliberately lit bushfires can be malicious (arson, which is a crime) or a planned fire which then escapes and burns more country than intended. The threat posed by any ignition depends on how fast the fire spreads, which in turn depends on the weather and fuel conditions. In summer, during conditions of high fire danger and dry fuel, a fire can spread very quickly and threaten property within minutes or grow uncontrollably in bushland. This is when rapid detection and sufficient response matter most.

Fires that start in urban, near urban and rural lands are often quickly reported by the public. Firefighters are often close at hand and can respond quickly with fire tankers and with force. On days of high fire danger, crews may be on standby, ready to go. In NSW the main response agencies to urban and rural fires are FRNSW or RFS respectively.

Remote fires are those which cannot be reached on the ground by firefighting vehicles. Fires in remote bushland are harder to detect and act on. The terrain can be rugged, with few public roads or fire trails. Most bushfires in remote areas are caused by lightning (*NPWS nd, reprinted 2013)*. They are usually spotted from a vantage point some distance away, or from a fire tower or aircraft. Remote cameras have also been used in the north of the state for fire detection. When electrical storms are forecast over large bushland areas during the fire season, agencies send up observer aircraft to spot lightning fires. These aerial patrols can continue for several days after the passage of storms, because strikes can be 'sleepers' that do not show up straight away, especially if dampened by rain.

Remote lightning fires were a major problem in the 2019-2020 season

Over the 16 years from 1995 to 2010, lightning was the known cause for 31% of a total 2886 fires on NSW conservation reserves, while 34% were caused by arson or suspected arson *(NPWS nd, reprinted 2013)*. In the Blue Mountains national park system, of 783 ignitions over ten years from 1997 to 2008, 53.5% were attributed to lightning *(NPWS unpublished data)*.

The role of lightning in starting large fires this past season was greater than the historical average. Lightning fires were widespread all along the eastern ranges, many in conservation reserves. Most or all of the large NSW bushfires were caused by lightning *(ABC News online, 2020)*, including Bees Nest (148,000 ha), Liberation Fire Trail (148,100), Gospers Mountain (512,000 ha), Green Wattle Creek (278,722 ha), Currowan (499,621 ha), Badja (315,512 ha) and Dunns Road (333,277 ha). All of these, except Dunns Road, started in remote bushland and were not put out early. Lightning also started large fires in Victoria, as well as many smaller blazes in NSW, some of which were overrun by other fires.

A higher than average count for lightning this past season is not surprising however this is not the reason why lightning fires dominated the total area burned. The main factor was the exceptionally dry forest fuels in an exceptionally hot and exceptionally dry year. In such dry conditions, storms were more likely to ignite forest fires and once started they were more likely to spread quickly. Going fires were also less constrained by corridors of normally moist vegetation *(Nolan et al 2020)*.

During the 2019-2020 season in NSW numerous remote fires were extinguished while small. Some however were not extinguished early and in the dry fuel conditions they spread over large areas. It was these fires that 'got away' that filled headlines and caused most of the impact. There is a need to examine why this happened.

Most remote fires are put out

Historically, a high proportion of remote lightning fires have been put out while small. The success rate of NPWS suppression of on-park fires is illustrated in *Figure 19* and *Figure 20 (NPWS nd, reprinted 2013)*. They show that 89% of nearly 3000 on-park ignitions were controlled on-park and that 79% of them were contained to less than 100 hectares in size. These counts were high, despite including many fires in remote and rugged terrain with difficult conditions for firefighters. Important factors are NPWS knowledge of the fire environments in parks and the skill and experience of their firefighters.

As for lightning fires, *Figure 21* shows that two-thirds of them between 1997 and 2007 in the Blue Mountains park system were kept to under 10 ha in size. Almost 90% were extinguished at less than 500 ha.

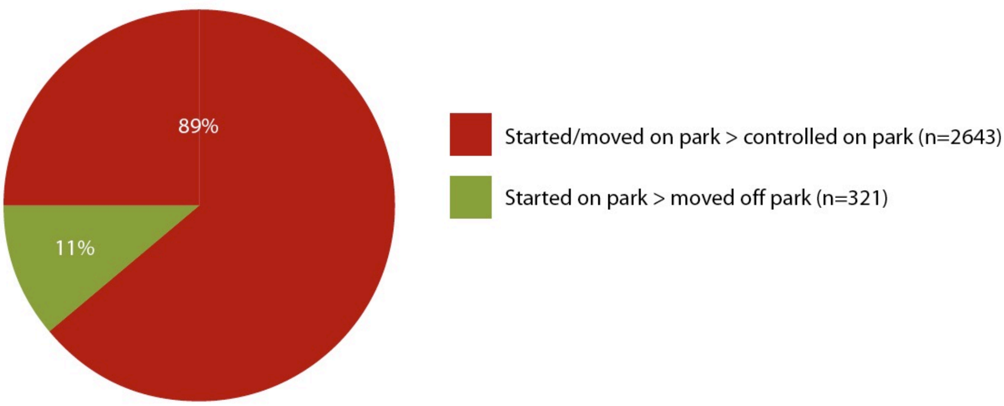

Figure 19: Origin of 2964 wildfire ignitions impacting NSW parks and reserves 2000-10
Source: NPWS nd, reprinted 2013

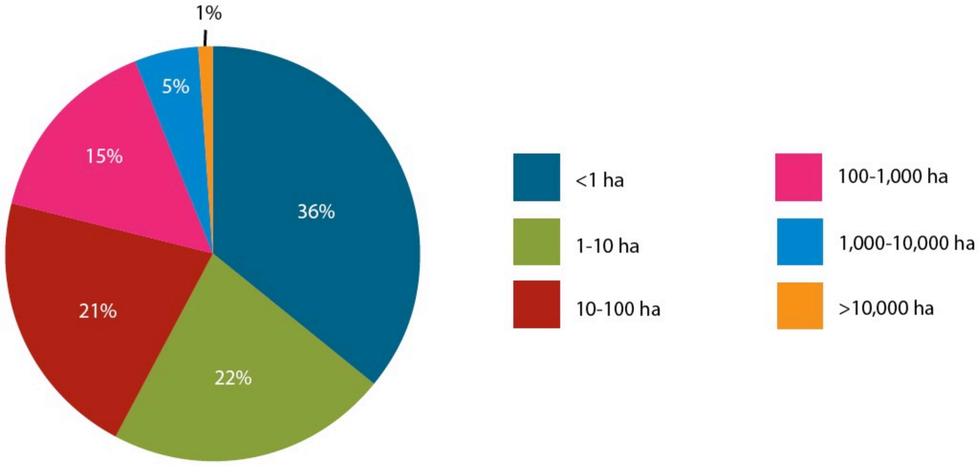

Figure 20: Size class distribution of 2964 NSW park bushfires 2000-10
Source: NPWS nd, reprinted 2013

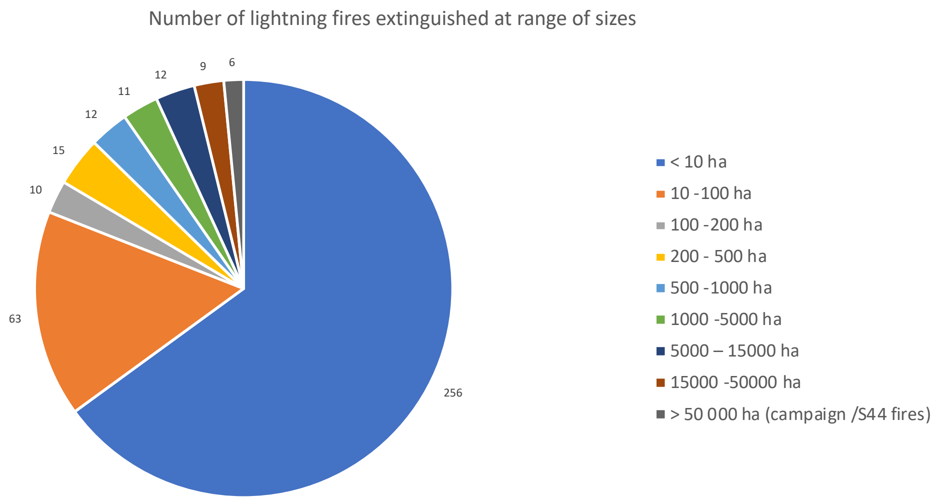

Figure 21: Size class distribution of 394 lightning fires in Blue Mountains parks 1997-2007
Source: NPWS unpublished data

During the 2019-2020 season many remote fires were extinguished while small. In the Blue Mountains national park system, 20 ignitions between August 2019 and January 2020 were extinguished at a size of less than 4 ha. At least 14 of these were from lightning. A number of other lightning fires were put out at larger sizes *(NPWS unpublished data)*. Examples include the Blackwater Creek fire in Wollemi National Park (later overrun by another fire) and the Linden Ridge fire in Blue Mountains National Park. The nearby escape of the Grose fire across the Wentworth Creek containment line was effectively a new remote fire and was put out by RAF teams.

Could all remote fires be extinguished?

As a fire grows, its length of active edge that needs to be suppressed grows exponentially. The rate of fire spread is largely determined by weather and fuel conditions. The faster and bigger the fire grows, the less likely it is that it can be contained. As a rule of thumb, the best window for response is about two hours after ignition but this timeframe can shrink to half an hour in adverse conditions. Speed of detection and attack are critical to success, as is the 'weight of attack' (the amount of resources - crews and aircraft) applied to the fire when it is small. If multiple ignitions occur at the same time, suppression is more complex. Multiple fires can be attacked in priority order according to the threat they pose.

The reasons for success or failure need to be examined. It is possible that some remote lightning ignitions are simply uncontainable when the prevailing conditions are too dangerous or quickly produce unmanageable fire behaviour. However, it is reasonable to consider whether all lightning fires could be contained if initial attack is both fast enough and large enough. To aspire to this aim, obstacles to success need to be removed.

Speed of detection

The fastest detection is from the air soon after ignition. Response to a remote fire reported from afar can be delayed because the location, size and rate of spread must first be confirmed from aircraft before ground attack. Systematic real time aerial patrol after lightning events will improve the speed of detection and action. There is great potential in real-time detection by satellite. This is already possible using existing technologies and should be evaluated for its cost and benefit. Remote cameras have also been used successfully in some areas.

There is great potential in real-time fire detection by satellite. This is already possible using existing technologies such as VIIRS (Visible Infrared Imaging Radiometer Suite), which can potentially detect fires at a size of 2 square metres at night and 18 square metres in the day *(Dr Marta Yebra pers comm 2020).* Australia-wide coverage could be achieved using a constellation of 10 CubeSats launched at the same time at a cost of about $15-20 million *(Yebra pers comm 2020)*. This would be an efficient national investment to reduce fire costs and impacts and should be further evaluated.

Speed of response

When storms are forecast over large bushland areas both detection systems and response aircraft and crews should be ‘stood up’. RAF resources must be available for immediate deployment after storms have passed through. In NSW this is often done by NPWS, who manage most of these areas. However, NPWS resources can currently handle only a small number of simultaneous ignitions. If there are multiple ignitions, then attack must be done consecutively which risks missing the best window to extinguish the ignition.

> *“Periodically, ignitions caused by multiple lightning strikes will occur in remote or rugged areas and can overwhelm suppression capability.”*
> *(NPWS nd, reprinted 2013)*

This statement illustrates the problem. NPWS has ready access to four light, single-engine helicopters which help suppress almost 80% of remote ignitions before they grow large. However, this resource is significantly below what is needed to move success closer to 100%.

If suitable crews, aircraft and support are not standing by waiting for the call, it can take some hours to put an operation together. The fire first needs to be assessed by a trained observer and strategies decided. Then helipad/s may need to be prepared, communications set up, crews called in and support teams organised back at base. Meanwhile, the fire keeps growing. Storms often occur in the afternoon, so a slow response can lead to the first attack being delayed until the following day. If several aircraft are available then assessment, insertion and water-bombing can occur together. With only one or two aircraft, these tasks must be done consecutively.

Timing and continuity of attack

If rapid attack is essential, so is efficiency in the ongoing operation. Night and early morning is when fires are at their quietest and easiest to control, especially for direct attack. There have been many issues with getting crews onto remote fires, or back onto them, early in the morning. These obstacles in organizing crew and aircraft need to be eliminated.

Night RAFT shifts and camping near the fireline were once routine but have now become rare. Without continuous effort to control a fire, success is much less likely. Issues include not enough RAFT personnel to run two shifts and safety concerns, both real and perceived. Observation planes, water-bombing aircraft and retardant LATs (large air tankers) cannot operate at night. However, they are less necessary because fires are less active. Night is often the best time for ground attack. These obstacles need to be addressed through operating procedures, safety training and night aviation support. If a safe remote night shift and/or fireground camping are not possible then the next best option is crew insertion and water bucketing at first light. This requires more helicopters and crews because of constraints on flying hours, which is one reason early starts are sometimes not possible.

Priority and weight of attack

Over-reaction is appropriate for a lightning strike that could grow into a large and damaging fire and is the best way to limit later risk. Energetic attack is essential, but often the opposite occurs, under-reaction. Insufficient weight of attack is caused by too few aircraft and dedicated crews or because resources have been sent to other fires perceived to pose a greater risk.

This was reportedly acknowledged by the IC for the giant Currowan fire. At a public meeting he was asked if the fire would not have got so big if more aerial resources were available at the start. He reportedly said that one helicopter had been tasked to bucket water on the fire in its early days, but *"…we are not the only fire in the state. There is only a finite number of aviation resources. All those resources are fully stretched, and they are prioritised in relation to properties directly under threat at the time. Did we have enough? Well, I didn't have enough fire trucks on every corner either". (Adcock 2020)*

Remote fires are often not given priority because their threat is perceived to be in the future rather than immediate. It is especially difficult for a Class 1 remote fire to attract resources away from a Section 44 fire elsewhere. It is understood that RFS policy in Section 44 fires is that only twin-engine helicopters are to be used for winching crews into remote fires. Such aircraft have been scarce in NSW (see below). However, NPWS has successfully suppressed hundreds of fires using single-engine helicopters, and it is understood twin engines are not necessarily safer if an engine fails while winching.

It is reported that a shortage of RAF teams was compounded by NPWS firefighters being deployed to property protection. This probably also occurred with RFS RAF personnel. These were all factors across the 2019-2020 fires.

Numerous ignitions were not attacked at all or were attacked inadequately. Many of these became disastrous fires some weeks later. The need to retain a rapid RAFT response, even when other fires are going, is critical to managing risks. At one stage during the fires, the RFS Commissioner said resources would be held back from going fires to deal with any new fires sparked by forecast lightning storms.

Mix of resources

If closer to 100% of remote lightning strikes are to be put out, then substantial investment is required. Given that some remote fires that got away this last season cost many millions of dollars each to suppress and caused widespread damage, investment is likely to be cost-effective with no downside.

More professional RAF personnel and aircraft are required. One possible model would see dedicated aerial strike teams set up in three strategic areas along the eastern ranges of NSW: northern ranges, Blue Mountains and southern ranges/Australian Alps. One estimate puts the cost at about $26 million per season. This would pay for 20 contracted medium helicopters plus a rotating professional RAF crew of about 8-12 people assigned to each aircraft for three months of the summer *(Public Service Association, pers comm)*. This commitment could be scaled up when a major fire season is forecast. Personnel can be employed on fire mitigation and other works in the off-season and during quiet periods of the fire season.

If a similar arrangement had been in place for 2019-2020, many fires that became large and damaging could have been put out when small. This would have had the flow-on effect of freeing resources to deal with other fires that were hitting towns and villages.

Aircraft

Additional aircraft for rapid attack water-bombing must also be explored. Suitable aircraft include small, medium and large helicopters, small fixed wing 'scoopers' and larger fixed-wing tankers (LATs and VLATs). A key point is that planes do not put out fires, only people on the ground can do that. However early attack from the air can 'knock down' a fire so that crews can be safely inserted on the ground. Later, water or retardant drops can reduce the spread and intensity of the fire so that ground forces can do their work. The Half Penny Hill fire in Kosciuszko National Park is recent example of successful aerial attack on a remote fire *(see Fire Study 10)*.

Large fixed-wing air tankers are not well suited to remote fires that have grown larger, or if smoke obscures flight paths and the ground. Crews must be withdrawn to safety before drops are made, and drops are not precise. Also, turnaround time can be lengthy from the large airfields that air tankers need. Even water drops from large helicopters require crews to be withdrawn some distance. At least once during the 2019-2020 fires the turbulence from a large air tanker blew the fire across a containment line.

A widespread view amongst firefighters experienced in aerial attack on remote fires is that medium to large helicopters offer the best 'bang for the buck' and can be used with more precision. Fixed-wing scoopers are also widely used in other countries and have been used in Australia for more than ten years. The typical Air Tractor 802 is contracted, carries 3,500 litres of water and needs about one kilometre of open water to re-fill. These aircraft have been effectively used from impoundments, lakes, rivers and estuaries.

The size of the fire and the rate at which water can be dropped on it are critical factors in slowing the fire. The drop rate depends on number of aircraft and turnaround time from water refills. Separation between aircraft is an absolute limit imposed for safety. Up to that limit, the shorter the time between aircraft drops the better, so the more aircraft the better. Overseas, fleets of scoopers are deployed in numbers to make water drops in rapid succession.

There has been little analysis of firefighting aircraft effectiveness in Australia. Research from the United States suggests that tankers and other aircraft can be very effective in stopping fires from 'getting away', especially in the very early stages of attack *(USDA 2019, Waters & Fuller 2020)*.

> *"The best opportunity to bring a bushfire under control is at or near the point of ignition, when the fire is small...Aircraft are an integral part of initial attack and together with ground crews, provide continuing support during an extended fire. Depending on where they are stationed, and their despatch protocols, aircraft can often get to a fire and start the initial attack before ground crews arrive." (Victorian Bushfires Royal Commission 2010)*

Strategies

The best strategies are fundamental for any fire but challenging to determine. With remote fires, intimate understanding of the landscape, vegetation, fire behaviour and natural fire barriers like rivers, rainforest and cliff lines is a big help. Trained strategists skilled in the local landscape are key to success on remote fires.

Recent advances

Recent and pending aircraft purchases by RFS may assist with rapid detection, aerial attack and RAF attack of remote fires in future. These include two Cessna Citation jets *(NSSN 2020)* and two Bell 412 helicopters *(RFS 2020)*.

The Citation jets are mounted with advanced scanning systems and can travel rapidly to a reported fire. The system can produce "multispectral high definition images that can be processed on board. The new jets also feature an automated fire detection system that can automatically map the fire edge" *(NSSN 2020)*. The jets can then act as the 'bird-dog' to guide aerial attack.

Being twin-engine, the Bell 412s meet the current requirements for winching in RAF teams to a Section 44 fire. It remains of some concern that there is no apparent peer-reviewed research to inform cost-effective aircraft options.

How are remote fires put out?

Remote Area Firefighting (RAF) was pioneered in NSW by NPWS in the 1970s. Helicopters fly Remote Area Firefighter Teams (RAFT) into remote bushland where they use 'dry' (waterless) firefighting methods to control fires. This includes directly attacking the fire and raking narrow cleared lines around the fire edge with hand-tools, implementing small backburns, using chainsaws to cut and remove logs on the fire perimeter, felling burning trees and rolling over logs. Natural fire boundaries like rainforest and gorges and aerial attack are also used.

Water-bucketing from helicopters has been the main form of aerial attack. In recent years large fixed-wing aircraft dropping fire retardant or gel have also been used with mixed results. Smaller fixed-wing water bombers are used more widely in Europe and USA.

In NSW, remote area firefighters get onto the ground by winching down from a helicopter, by exiting from a hover or by landing at a helipad. Helipads are either cut into the forest for the purpose or are naturally occurring sites (eg rock platforms, riverbeds). Often the first crew is winched down to cut a helipad which speeds up later crew insertions. NSW does not use rappelling or parachuting to exit helicopters, but other places do. More people can be inserted more quickly with these methods, but they do not allow rapid evacuation of crews should the fire escalate.

RAF methods can be very effective and are used to put out many remote fires across the NSW park system every year *(NPWS nd, reprinted 2013)*. For fires to be contained they need to be small in size, with low to moderate fire behaviour and not too much wind or smoke. Outside these conditions, RAF methods become too hazardous and firefighters must wait for conditions to improve or fall back to wider containment options.

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3.2. Fire Behaviour Modelling

Issue

Fire behaviour modelling is a fundamental tool to guide all firefighting and fire management. However, widely used models can be inaccurate and lead to decisions which are inappropriate, ineffective or even dangerous.

Opportunity

Critically review the effectiveness of current fire modelling, expand research and develop improved modelling that accounts for all variables. Better modelling can help make fire suppression and management more successful with less impact on people and environment.

Issue summary

Many activities in fire management depend on how fires are expected to behave. Fire managers use modelling software to predict fire behaviour (intensity and spread, across landscape and over time). Decisions depend on these models, from how to attack wildfires, to planning prescribed burns and how much to budget for aircraft.

Yet the most-used fire behaviour models are based on limited data and have major shortcomings. These models wrongly estimate fire severity and spread in many forest types. These problems are well known and require fire behaviour analysts to impose 'manual over-rides'. Getting fire behaviour wrong has major real-world consequences. Wildfires may be attacked in the wrong way or planned fires may burn in unintended ways. There is a need to review these models and explore alternatives.

Recommendations for Fire Behaviour Modelling

- Fund research into the barriers that have inhibited evidence-based fire management in Australia.
- Open up fire behaviour research by funding a wider diversity of researchers.
- Invest in the development of fire behaviour models that can generate more accurate predictions across all fire landscapes, incorporating all generic and localised factors.
- Require that fire behaviour models meet the standards of peer review before they are utilised.
- Formally review and document the inadequacy of current fire behaviour models and the imposition that this places on FBANs and fire decision-makers.

Issue Analysis

The importance of fire behaviour modelling

Fire behaviour in forests is very complex and dynamic because it depends on numerous variables. Factors include the amount of fuel on the ground, the density of shrubs and trees, the moisture levels of ground fuels and vegetation, the type of forest and its structure, the plant species in the forest, weather conditions like wind speed, temperature and humidity, the terrain, and angle and aspect of ground slope *(Zylstra et al 2016)*. These factors change in time, sometimes very rapidly, and across the landscape, sometimes in fine detail. All these factors must be taken into account to accurately predict the speed and intensity of a fire. This major scientific challenge is pursued through computer modelling, based on real-world measurements. The better the model, the more accurate the predictions and the more helpful they will be to fire managers. False predictions can cause problems.

During large NSW wildfires, the intensity and spread of fires is predicted with modelling software, but sometimes modified with local knowledge *(see Figure 22)*. This is done by trained Fire Behaviour Analysts (FBANs) or Planning Officers, either in the IMT or at RFS State Operations. The behaviour of proposed backburns may also be modelled. FBANS receive one week's training.

Decisions on what strategies to use to control fires are made on the basis of these predictions, usually with the input of experienced firefighters. Similar predictions are made when planning prescribed burns in the off-season. These predictions are a key driver of decisions about fires, with potentially serious consequences. They are also used to provide prediction maps and warnings to the public. During the 2019-2020 fires public advice on potential fire spread varied from reasonably accurate to severe under- and over-estimation. This has consequences for public anxiety and trust *(see Section 4.3 - Community Education)*.

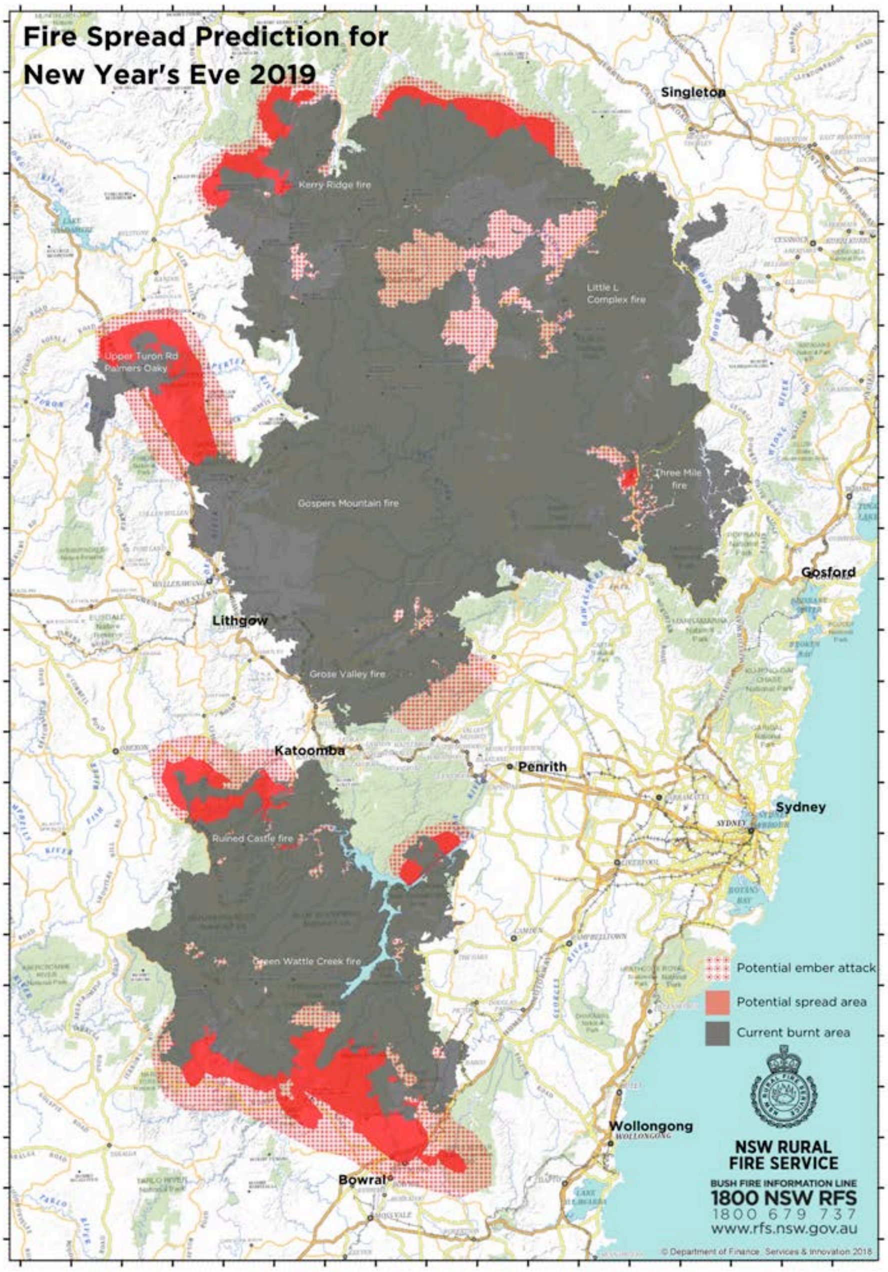

Figure 22: An example of the use of fire behaviour modelling to predict fire spread and areas of potential ember attack
Source: RFS 2019

Current fire behaviour models

Australian forest fire behaviour science is dominated by two empirical models *(Sullivan et al 2014)*; 'McArthur'*(McArthur 1967)* and 'Project Vesta' *(Cheney et al 2012)*. These have since been incorporated into software that applies the equations across landscapes to predict how fire will behave. The most-used software is 'Phoenix RapidFire' *(Tolhurst et al 2008)*, which is based on McArthur (1967). Phoenix RapidFire (Phoenix) is jointly owned by Australasian Fire Authorities Council (AFAC), the RFS, Department of Land, Water and Planning Victoria (DELWP) and the University of Melbourne, as a company limited by guarantee *(Maddocks Lawyers 2017)*.

All current fire behaviour models have problems

Problems with McArthur

The original model in use is derived from McArthur (1967), yet this was published only as a leaflet rather than as a transparent, evidence-based scientific contribution. The author took pains to make this clear, stating:

> *"...many of my observations and comments are tentative and may be proved wrong or subject to drastic change as more data becomes available."*

The central claim made in the leaflet is that fuel load is proportional to the rate of fire spread (often expressed as "double the fuel, double the fire"). But this claim has since been formally tested and proven to be wrong *(Burrows 1999a, 1999b)*. With no evidence to support it, this principle continues to underpin Australian fire management *(McCaw 2013)* and land management through its inclusion in Phoenix software.

In reality, the weight of leaf litter on a forest floor has very little influence on the way that fire spreads. Large flames occur when plants burn, so the critical question is whether plants will ignite or not. McArthur provides no way of answering this question and it seriously misrepresents the rate at which fire spreads through many forest types.

Problems with Phoenix software

McArthur and then Phoenix have led to a false understanding of the flammability of forests. A recent (and possibly the only) validation of Phoenix had a 100% fail rate in predicting areas of crown scorch *(Loschiavo et al 2017)*. Phoenix grossly over-estimates fire behaviour in many forests.

The manager of Planning and Predictive Services with the NSW RFS has said that *"Phoenix does not yet outperform people when predicting the spread and behaviour of a particular fire, but it is useful in deciding priorities between multiple fires. Nine times out of ten, manual analysts produce more accurate results than the model." (New York Times 2020)*

The practical reality during a wildfire is that FBANs are well aware of the inaccuracy of Phoenix. Even when burning very large areas across complex terrain, FBANs more often produce predictive maps calculated manually and drawn on paper by hand rather than depending on Phoenix software. They are trained to question the models and, where needed, override their predictions with their own estimates. The lack of sound, dependable science has placed FBANs in a position where life and death decisions depend, to varying extents, on their own experience and intuitions. Fire managers have learnt not to trust Phoenix predictions. This exposes everyone involved to undue stress, including concern about litigation.

Problems with Project Vesta

Although it has been peer-reviewed, Project Vesta (Vesta) software does little to improve this situation for eastern Australia because the model was developed for regrowth jarrah forest on gentle terrain in Western Australia. The data used to describe fuel are meaningful for jarrah forest but may not apply elsewhere. Project Vesta predicts every other forest type will burn in the same way as a jarrah forest.

This problem is exemplified by looking at how Vesta software predicts the spread of the 2009 Kilmore fire through old-growth mountain ash forest on Mt Disappointment, Victoria. Weather conditions and fuel inputs to Vesta have since been published for the location *(Cruz et al 2012)*.

When these are put into the model, they predict a rate of spread of 15.1 kilometres per hour across flat ground with 192 metre high flames[1]. However, the actual fire *"spread mostly as a high intensity surface fire with isolated torching trees" (Cruz et al 2012)*, despite the catastrophic conditions and very long-unburnt state of the forest. Cruz et al (2012) also state; *"This decrease in fire intensity resulted from the lower flammability of this forest type…"*

The purpose of a fire behaviour model is to quantify flammability and the way that it interacts with weather and terrain to produce behaviours such as flame heights and rates of spread. It may be that regrowth jarrah forest with such fuel factors would burn in the predicted way, if exposed to these conditions. However, such predictions have little relevance to decisions that must be made in the diverse range of forests across the steep terrain of eastern Australia.

FRaME as an alternative

To date, one peer-reviewed model exists for forests other than jarrah. FRaME (Fire Research and Modelling Environment) *(Zylstra et al 2016, Zylstra 2020)* incorporates a much larger suite of vegetation descriptors. It models fire behaviour using details of all component plant species including plant structure and leaf traits. Instead of using a single equation to calculate flame height for example, FRaME will use around half a million calculations to find out how all relevant factors interact. As a result, there is no input of a 'fuel load' instead, FRaME uses a description of the entire forest to calculate which plants will or won't ignite, and how they will burn.

By including physical measurements of plants and known drivers of fire behaviour such as leaf moisture *(Nolan et al 2016)*, FRaME may enable the better adoption of new remote sensing technologies. For example, LiDAR, a form of laser scanning conducted from the ground, drones, aircraft or satellites, is capable of measuring plant dimensions across large landscapes with centimetre accuracy, yet these measurements cannot yet be used as inputs to models that do not properly recognise the importance of plants as fuels. The moisture of plant foliage can also be measured from satellite and is known to be important to fire risk, yet FRaME is the only Australian model to utilise plant moisture as an input.

Although FRaME now has a user-friendly interface to enable modelling of both fire and fire effects on flora, fauna and soils *(Figure 23)*, the model has not yet been built into a spatial framework and requires sound knowledge of vegetation. Using new technology to collect this information will require investment. So at present, FRaME is mostly limited to use as a research tool.

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[1] Wind = 58 km.h.$^{-1}$, DFMC = 4.5%, surface score = 4, near-surface score = 4, near-surface height = 100cm, elevated height = 340cm.

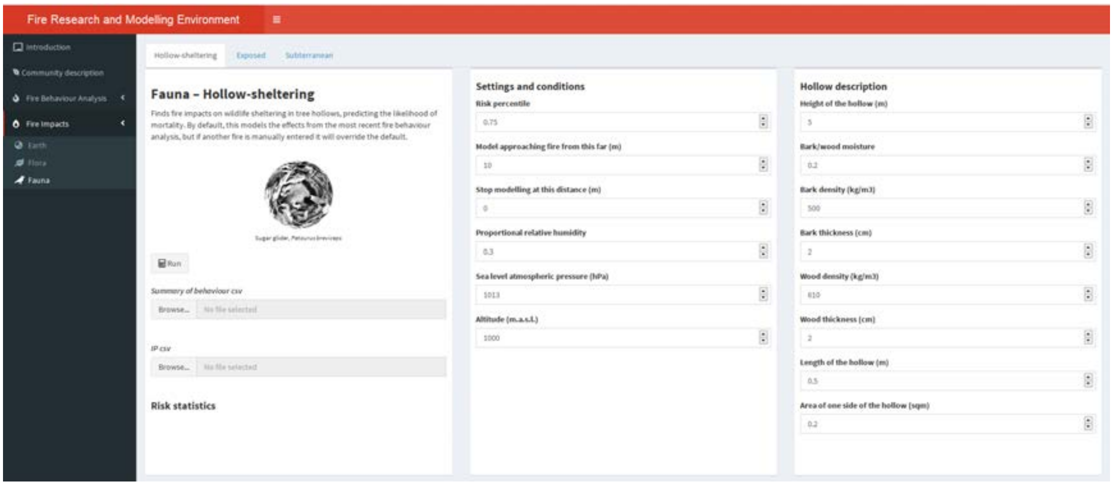

Figure 23: Part of the user-interface for FRaME
Source: Zylstra 2020

Benefits of better fire modelling

More accurate fire modelling that can capture a wider set of local variables can be the foundation of improved fire control and management. It goes to the heart of achieving smaller wildfires with less impact. Current models are generalised and perpetuate inaccuracies. They cannot be used for many purposes and thus are limiting advances in fire science at all levels. Effective fire modelling is a critical research tool.

If fire behaviour and spread can be predicted more accurately in a wider range of landscapes, then decisions on how to control wildfires can be more evidence-based and effective. Options can be more fully and objectively compared. More strategies will work out, with fewer failures. By avoiding actions likely to fail, resources can be deployed more efficiently to the best control actions. The safety of firefighters will be improved because they will get better advice on likely fire behaviour and will be carrying out fewer risky actions.

This improvement on multiple fronts will mean more fires can be contained to a smaller size. Smaller fires mean less burnt bushland, fewer houses lost and reduced trauma to communities and firefighters.

Planned burning can also be more effective with better modelling. This includes backburns used during wildfires as well as prescribed burning in the off-season to manage fuels and ecosystems. It should be possible to model with some accuracy how a burn will proceed across the landscape, what areas will burn, with what severity and with what speed. Backburns are high-risk and often escape due to the way they are lit or because fire behaviour is under-estimated. Better modelling can reduce both these risks and be used in virtual training.

Better modelling is a basic tool for long-term fire management in the landscape. This includes the planning of broad fuel management strategies and monitoring ecological changes due to fire. Substantial benefits could be achieved for protection of human assets, natural environments and wildlife.

The ways that improved modelling can produce better outcomes is illustrated by the tendency of long-unburnt forests to become less flammable *(see Fire Study 11 - Bees Nest Fire)*. This phenomenon has been observed over a 58-year study period in one of the largest analyses of fire history conducted in Australia *(Zylstra 2018)*. All forests examined in that study initially increased in flammability after a period of a couple of years, then remained flammable for a couple of decades. This observed reality contrasts with the theoretical one imposed by the current operational models. These do not account for the actual factors driving flammability, so they predict that long-unburnt forests will be the most flammable areas. This drives an operational reticence to aggressively attack fires in long-unburnt country, an inclination towards backburning, and a sense that failure to protect such forests from fire may actually be doing them good by reducing fuel loads.

This becomes more explicit when models such as Phoenix are used to plan fire management. Even irregular burning of remote, old-growth forests is modelled to provide some risk reduction benefit, when the reality is that it is likely to increase landscape flammability and destroy natural fire advantages.

Better fire modelling can therefore be used to identify natural fire advantages and guide more effective firefighting. If this is done, strategies can be applied out of season to utilise such advantages. These may include an increased focus on rapid attack and the training and resourcing of more RAF crews. Modelling can be used to determine the conditions under which different approaches are safe and effective.

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3.3 Suppression Strategies for Large Fires

Issue

Strategy is the most fundamental factor in effective bushfire suppression, especially for large fires, but receives little attention. Bushfire suppression has long emphasised backburn strategies and defensive property protection. Resourcing follows this emphasis. While often effective, this focus was not always successful in the 2019-2020 season, resulting in some fires having larger costs and impacts. What might have worked in the past is becoming more difficult as the climate changes. NSW does not have a document that spells out how bushfires are to be suppressed.

Opportunity

Bushfire costs and impacts can be reduced by using different strategies for some remote and large fires. More rigorous procedures for backburning and more research on the effectiveness of fire suppression methods can help to minimise fire size and impacts through selection of optimal strategies. Upgrade the State Bush Fire Plan to include objectives and methods for bush fire suppression.

Issue Summary

The usual objective for any bushfire is to keep it as small as possible and to extinguish it as soon as possible. This is the best approach to limit all impacts. Hence initial attack is crucial *(see Section 3.1 - Initial Attack for Remote Fires)*. If initial attack fails and the fire becomes large, a range of techniques can be used for control.

The aims must be to use the best strategies to put the fire where you want it, control its potential, put it out at the smallest possible size and limit impacts. These objectives need to be supported with the best fire analysis, risk assessment, evidence and decision tools.

Currently, strategy decisions are largely based on experience of what worked or didn't work in the past *(Simpson et al 2019)*. Unfortunately, these experiences are rarely analysed and documented. Little science or analysis of suppression strategy is available to help decision making (*SMH 2020b*). There are no known Australian manuals or courses on overall strategy choice for large fires. As the climate changes, bushfire suppression is becoming more difficult. What might have worked in the past may not work anymore.

Overall, the 2019-2020 fire operation was successful at limiting the impact to property and human lives but less successful at limiting the scale of the fires and their ecological impact. The ideal aim is to limit all impacts. How this might have been achieved deserves analysis. Despite the overall severity of the season, there were significant periods during the fires when conditions were suitable for closer containment and partial containment. It is likely that control opportunities were missed. Many operations were hampered by resource shortages, and important actions could not be carried out properly. At those times using the most effective strategies becomes even more important.

A range of suppression methods are available. They include direct attack, indirect attack, backburning, aerial attack, aerial ignition and defensive firefighting (property protection). All can be effective under different scenarios. All have their own advantages and risks depending on the situation. Strategic decision making is very difficult and based largely on experience and cultural biases.

Over-reliance on high-risk strategies like backburning can be counterproductive. Large backburns to contain threatening fires are difficult, precision operations requiring high skill levels. This was especially so in the very dry conditions of 2019-2020. When backburns escape they can have serious consequences. They can become new fires with destructive impacts and demanding many resources, which are then not available to other critical operations. Some alternative strategies offer lower risk and can reduce rather than increase the total energy and complexity of fire in the landscape.

Alternative strategies can be technically difficult and also require high-level skills. These include strategy expertise founded in the local landscape, aerial operations and remote area firefighting. These skills and resources are not as available as those used for truck-based firefighting. Resource imbalance leads to strategy imbalance. Decision making needs to be more evidence based, supported with rigorous assessment procedures and informed by extensive analysis and review of past operations. The objective is to reduce the size, impact and cost of fires. These objectives and the best way of achieving them can be added to the NSW Bush Fire Plan.

Recommendations for Suppression Strategies for Large Fires

- Commission an independent review of the overall strategic approach to the 2019-2020 bushfires in NSW.
- Upgrade the NSW Bush Fire Plan to include objectives and methods for a strategic approach to suppressing bushfires, with public involvement to build community understanding.
- Produce a manual on options for suppression of large fires.
- Train and mentor more landscape-based fire strategists in regions of high fire risk.
- Add a system of record keeping for all large fire operations to ensure simple records are kept of fire control actions and outcomes.
- Urgently undertake substantially more research into bushfire suppression, including analysis of large fires from the 2019-20 season.
- Develop scalable (for all levels of the operation) decision tools to make decisions on backburns more rigorous and defensible.
- Expand the scope and scale of training for fire analysts and strategists and ensure experience is accumulated and recognised.
- Develop a detailed manual on backburning and roll out training across fire agencies.
- Require training and certification for leaders of large and difficult backburns.
- Ensure that the risks of backburn escape are factored into incident planning, with appropriate public warnings.

Issue Analysis

Overview of bushfire suppression: a strategic approach

> *"…it has been an extraordinary, difficult, damaging, destructive, fatal and tragic fire season. And it is without precedent, and that's the reality."*
> *(RFS Commissioner, ABC 2020b)*

Tragically, 25 human lives and 2448 houses were lost in NSW in the 2019-2020 fires *(SMH 2020c)*. This traumatic toll could have been worse given the vast area of fire at 5.5 million hectares. The brutal statistics suggest that the total operation was successful at limiting the impact to property and human lives but less successful at limiting the scale of the fires and their ecological impact. It is likely that control opportunities were missed. Many operations were hampered by resource shortages, and important actions could not be carried out properly. At those times using the most effective strategies becomes even more important.

The ideal aim is to limit all impacts. Reducing the scale of fires could further reduce human and property impacts. This should be a key strategic aim. How smaller fire size might have been achieved is the subject of the following analysis.

A widespread view is that the fires were 'uncontrollable'. The NSW Premier stated that *"we won't contain these fires" (SMH 2019)*. A related view is that when strategies failed it was because of impossible conditions and nothing else could be done. It was an extraordinarily difficult season with stretched resources and many very challenging decisions to be made every day on multiple fires across the state. Even so, many strategies were successful.

The usual objective for any bushfire is to keep it as small as possible and to extinguish it as soon as possible. When initial attack fails and a fire becomes large, a range of techniques can be used for controlling it. Currently, strategy decisions are largely based on experience of what worked or didn't work in the past *(Simpson et al 2019)*. Unfortunately, these experiences are rarely analysed and documented. Little science or analysis of suppression strategy is available to help decision making *(SMH 2020b)*.

Suppression methods include direct attack, indirect attack, backburning, aerial attack, aerial ignition and defensive firefighting (property protection). All can work to control the fire under different scenarios. All have their own advantages and risks depending on the situation. A large fire may involve all of these options in different places and at different times. Large fires can be fast moving and complicated, especially in the very dry conditions of last summer.

Strategic decision-making is very difficult, but all options and considerations should be on the table. A strategic approach will try to optimise the use of always-limited resources across the various threats. This means applying the most effective and efficient mix of strategies to get the best outcomes. This may be easy in theory but is extremely challenging in practice.

The current NSW Bush Fire Plan *(NSW Government 2017)*, a sub-plan of the State Emergency Plan, states this as its Purpose:

> "*This plan describes the arrangements for the control and coordination by the New South Wales Rural Fire Service Commissioner for the response to Class 2 & 3 bush and grass fires, including those managed under the provisions of Section 44 of the Rural Fires Act 1997, and the provisions for emergency warnings at all classes of fires*." (*NSW Government 2017*)

and this as its Objective:

> *"The objective of bushfire management in New South Wales is to reduce the impact of bush and grass fires on human life, communities, essential and community infrastructure, industry, agricultural assets, the economy and the environment." (NSW Government 2017)*

The NSW Bush Fire Plan is about 'arrangements', not strategy. The Response section of the plan is mainly 'procedural' and does not address how bushfires are to be suppressed, or how the above Objective is to be achieved during suppression operations. There is an opportunity to update the NSW plan to include these features. Public involvement in this revision would help build community understanding of suppression rationale which is at present unstated.

Options for suppressing large fires

On days of extreme to catastrophic fire danger defensive firefighting was the only option. Other strategies were possible on the many days of more moderate conditions throughout

the season. This is evidenced by the number of backburns that were successful. However, it is helpful to consider the unsuccessful strategies and alternatives.
A dominant strategy for large fires has been to put a 'hard line' around the fire and some distance away from it. Containment lines can be existing (such as roads or paddock edges) or newly constructed (such as bulldozer lines). Typically, the bush between the containment line and the approaching fire front is then deliberately burnt out. This is backburning, a form of indirect attack, and an essential 'tool' in the toolbox of fire control. However large backburns can be over-emphasised compared to alternative strategies of closer containment which are not as widely understood.

The 'last resort' strategy with a dangerous fire is to abandon containment and 'fall back' to protect property and other assets. This defensive firefighting can be the only and best option when fires burn under extreme to catastrophic conditions. It is also the type of firefighting that dominates television news and public perceptions. Stopping fires from reaching this stage is better in every way but receives little media coverage or public exposure, and hence little community support.

Aerial operations are spectacular but alone cannot put fires out; only work on the ground can do that. Aerial work, such as water-bombing, retardant drops and burning with aerial incendiary drops, is used to slow fire behaviour and spread. This 'buys time' for on-ground firefighters to do their work and can reduce the severity of fire as it strikes assets.

Backburning

Backburning is an essential method in firefighting. It has been successful in containing numerous fires over decades. 'Fighting fire with fire' is a popular catchcry, along with 'damned if you do and damned if you don't'. A slogan heard less these days is 'don't add more fire to the landscape'. There are no black-and-white answers, and binary positions like all backburns are 'good' or all backburns are 'bad' are not helpful. Like any good tool, backburning needs to be applied wisely and properly.

When backburning works it securely and effectively 'seals off' the fire from advancing further. Backburning also has down sides. It adds more fire, increases the rate of energy release and produces more smoke. Backburning can also be difficult and high risk to do, especially in severe and deteriorating fire conditions. Some backburns 'break containment lines' and get away to cause new or expanded fires which impact on human assets and draw resources away from other operations. On large fires, backburns can extend over tens of kilometres with increasing risk of escape. Once started, backburns have to be either completed to the intended extent or abandoned.

Some backburns are done ad hoc in the field, or without detailed analysis and planning by the Incident Management Team. This leaves decision makers and firefighters exposed. More rigorous procedures have the potential to reduce backburn failures and protect firefighters and planners.

> *"Drip-torches should be kept under lock and key." (Anon, RFS Incident Controller 2007, pers comm)*

These difficulties were highlighted during the 2019-2020 fires with many successful backburns across NSW mixed with a number of backburn escapes. Several reasons for the backburn problems are possible (see below). Backburns were undertaken in risky conditions due to the pressure of threats, resource availability or other reasons. Fuel moisture was extremely low when some backburns were done. Many backburns were lit during the day instead of at night when conditions moderate.

Firefighters were very fatigued as particular operations and the season dragged on. People were performing roles above their ability due to shortages *(see Section 2.4 - Critical Fire Incident Management Skills and Section 3.4 - Fire Incident Management Arrangements)*.

Some escaped backburns had disastrous results, as at Mount Wilson (Gospers Mountain fire) and Balmoral (Green Wattle Creek fire). Both these backburns were lit during the day, in deteriorating weather and when there was no close threat from the approaching wildfire. A factor seems to have been under-estimation of the effects of extreme fuel dryness on backburn behaviour, coupled with inadequate risk and threat assessment and perhaps community discontent.

These problems continued almost throughout the fire season, although it is noted there was greater reluctance to backburn in the far south. The risk of backburn escapes can be minimised through improved planning, procedures and training. Also, other strategies can offer better outcomes in some situations compared to lighting large, high-risk backburns some distance from the fire.

How backburns can fail

There are several ways a backburn can either fail to stop the fire or can escape across the containment line:

- The backburn can burn directly across the containment line via flames, embers or falling trees, and crossovers cannot be extinguished due to terrain, conditions or insufficient resources.
- Embers from the active backburn may land (spot) so far back across the line that the spotover cannot be reached or extinguished before spreading. The likelihood of distance spotting increases with a hotter backburn, in windy conditions, with very low fuel moisture and when the backburn and other fire fronts merge.
- After the backburn has been completed, embers from smouldering vegetation or a burning tree can blow across the line, or a burning tree can fall across the line.
- There may not be enough fuel to carry the backburn, eg if the area has been recently burnt by prescribed fire or an earlier wildfire. In this case the approaching main fire may still burn through if it is wind-driven or in other more severe conditions.
- If the backburn is not deep enough, the approaching main fire can simply spot over the backburn and containment line before or as the two fires merge.

In the last two cases the backburn is not the cause of failure, ie the main fire would likely have burnt through the area anyway. The other situations can be put down to a risky or inadequate operation.

When a containment line is breached, the backburn is usually abandoned as it becomes dangerous for crews to continue. The alight section of the backburn is then free to cross the containment line on a broader front, possibly followed by the main fire. If such escapes are close to habitation, impact can happen quickly with little warning. This draws resources abruptly away from other operations, creating an opportunity cost and potentially leading to other significant risks. When a backburn is ineffective or escapes, effort has been wasted and unnecessary risks taken. This applies even if it was the best available option under the circumstances.

Backburning risks

Backburns pose certain risks, whether they work or not. Widespread smoke, much of it from backburning, was a serious health hazard to firefighters and the wider community this past season *(Arriagada et al 2020)*. Smoke also inhibited and prevented aerial operations such as helicopter water-bombing, LAT drops and fire mapping.

When fires converge, as when a backburn meets the main fire, the concentrated energy and convective power can drive up more embers and increase spotting. Adding backburns to the wildfire increases the total area of active fire and 'source fire area' has been identified as a key predictor of spotting *(Storey et al 2020)*. Convergence and convection can create a pyrocumulonimbus cloud or 'firestorm'. An unprecedented number of these events were seen in the 2019-2020 fires. This phenomenon produces spotting, intensifies winds and creates extreme and erratic fire behaviour. Such storms can also produce dry lightning, causing new fires. Climate change is likely to increase the risk of these backburning effects *(Dowdy et al 2018)*.

Risks of a backburn escaping increase in marginal or worsening conditions. Risks also arise if the burn is not lit up carefully or if resources are not enough to control the fire behaviour and 'jump' on spotovers quickly. The longer the backburn the more resources are needed to manage it. The potential for risks to multiply also increases.

The consequences of a backburn getting away can range from minor to disastrous. When fallback options are available, a minor consequence would be a slight increase in fire size or a slightly faster advance of the fire (plus wasted effort). A disastrous outcome could be a whole new and large fire that causes widespread damage and takes a lot of time and resources to combat. The full range of outcomes happened in the recent fires *(see Part 5 – Detailed Fire Studies)*. Full analysis is required, but information suggests that more backburns got away 'in the bush' (ie with bushland on both sides of the containment line) than on the edge of the bush (eg with paddocks on the other side of the line). Some backburns that escaped were unauthorised, and others were not carried out according to approved instructions.

The opportunity costs of a large backburn that either escapes or fails to stop the fire can be substantial, because they tie up resources that could be doing other critical tasks, like property protection. Resources were stretched very thinly throughout the season, with rarely enough to do what was required.

The risk of escape is often not factored into planning and community alerts. The public is not warned that a backburn could escape and what that could mean. Communities like Mt Wilson and Balmoral came under threat quickly after nearby backburn escapes *(Figure 24)*, with little time to prepare or move defensive resources into place. When a backburn escapes and produces a large new fire, this can absorb even more resources and loss to other operations. This occurred with the Erskine Range fire and Grose fire *(see Fire Studies 1 and 6)*. Knock-on effects can cause other failures in competing operations.

When planning strategies, the possible outcomes of failure (the risks) need to be carefully weighed against the threat being combatted and the risks of not acting. These are very difficult decisions. They need to be supported with rigorous assessment procedures and a stronger evidence base. Better fire modelling should be developed and used to assist backburning decisions.

Figure 24: Escaped Mt Wilson Road backburn, burning over Mt Tomah on 15 December 2019. Grose Valley in foreground (Blue Mountains National Park) was later burnt by this fire. Source: Ian Brown 2019

Decision-making for large strategic backburns

Some questions that can be considered:

- What specific fire threat is being confronted? What is the timing, probability, consequence and magnitude of the threat?
- What options are available to control the threat?
- What are the risks of the various options?
- What is the timing, probability, consequence and magnitude of each risk?
- What is the balance between threat and risk for each option?
- Is backburning the only or best option? Why?
- Are the risks of the backburn acceptable and/or manageable?
- If so, is there enough time for a backburn be completed, deepened and secured (mopped up) before the threat eventuates or the onset of dangerous conditions?
- If so, what quantity, type and skill level of resources are required to do this? Are they available and can they be organised and briefed in time?
- What is the best timing for the backburn?
- Is the range of forecast conditions and fire behaviour suitable for carrying out the backburn at this time?

The backburn process

Backburns are high risk, complex and difficult, especially large ones. They demand the utmost care. They must be rigorously planned, timed, prepared, carried out, patrolled and mopped up. All phases carry many opportunities for failure. The processes described below are optimal but not always followed. In the real world many issues can interfere with best practice.

Planning

Planning involves a careful assessment of the threat from the fire and consideration of control options. A detailed risk analysis of the options should follow. This includes assessing the critical issue of firefighter safety. If a backburn is decided, then it should be specified in terms of weather, timing, triggers for both beginning and cancelling the backburn, expected fire behaviour, resource needs, safety issues, leadership, lighting instructions and how risks will be managed. Possible escape of the fire must be planned for. If any of these things cannot be satisfactorily resolved, then the backburn is dubious.

Depending on the comparative risk of not doing a backburn, a decision to proceed may still be appropriate. With competing risks, judgment is needed and there can be no 'correct' decision. Using fire is dangerous. Prescribed burns in the off-season are only undertaken after a rigorous process of planning and assessment. Backburns to control wildfires involve equal or greater risks but are rarely planned to the same degree.

Preparation

The proposed containment line is assessed for risks, safety and practicality by skilled firefighters. Preparation may include grading or widening of the line, or removal of trees and other vegetation. Dead and rough-barked trees close to the line may be cleared around their base to prevent them catching fire and becoming problematic.

This summer saw instances where backburning was made unnecessarily harder and less successful due to poor trail preparation. The worst cases saw fresh windrows of felled and tangled trees pushed to the edge that was to be backburnt. Normal practice is to put windrows on the opposite side to the burn.

Timing

Timing is critical. The weather, atmospheric conditions, fuel dryness and vegetation type must be taken into account. The behaviour of the fire and spotting must be manageable. Backburns are often done at night in milder conditions for these reasons. Enough time is needed to complete the backburn, make it deep enough and 'black' out the edge before either the main fire front or severe weather arrive.

Implementation

Carrying out a backburn is a precision activity. Skilled leadership and firefighters are essential. Crews need to constantly monitor conditions and any risk of escape. The speed and pattern of light-up can control the fire behaviour or allow it to get out of hand and spread embers over the line. Crews must be able to attack and extinguish any spotover quickly.

Fire behaviour of the backburn needs to be managed. More intense fire will ignite more large items like tress, leave more smouldering material and make mopping up much harder. Enough resources (people and trucks) are needed to carefully watch these risks as the backburn is extended. Air support from helicopter bucketing may be useful, but to rely on them means the risk is high. Air support is not available at night. If crews are too far apart then blind spots will occur, especially as the length of the backburn increases.

Patrol and mop-up

This final and most difficult phase of a backburn is often not done rigorously. After ignition frequent patrol is necessary to find and extinguish any danger from burning material close to the line. Enough time needs to be available for thorough mopping-up of the backburn edge to 'black out' stage before more severe fire weather arrives. In very dry conditions, such as in the recent season, three days of mop-up to a depth of 100 metres is considered to be necessary for a high level of security. Many firefighters approach the task only with water from trucks. Yet in very dry conditions dry firefighting methods are the most effective; breaking up and turning over smouldering material like logs. This is hard manual work but essential, especially within about 20 metres of the line.

Inadequate mop-up is the cause of many backburn escapes. This comes down to both a lack of understanding and commitment, and resources being re-deployed too soon to perceived higher risks.

Backburning guidelines

There is no known training course specifically for backburning. Backburning is addressed by NSW RFS and NSW NPWS to some extent in routine bushfire training at the level of Bush Firefighter and Crew Leader Wildfire *(RFS 2019, OEH nd)*. *Figure 25* is an RFS standard operating procedure (SOP) for backburning. It includes some key points but has little detail. Omissions include the pattern of light-up and how to 'secure' the backburn. In practice, some of the listed points are not always followed, such as having the necessary 'time and resources' and avoiding risky conditions.

The fire management strategy for Warrumbungle National Park *(NPWS 2016)* includes this guideline for bushfire suppression:

> *"Any proposed backburning must be assessed on the required resources, their capacity and the time required to mop-up and secure proposed burn edges prior to the onset of Severe + conditions, and then hold." (NPWS 2016)*

This important principle was lacking at times in the 2019-2020 fires. Information from the field suggests this may often have been due to insufficient resources being available for sustained mopping-up.

The NSW Fire and Rescue manual on prescribed burning *(NSWFB 2009)* states that it does not apply to backburning. However, many of the principles are relevant to backburning and similar NSW manuals specific to backburning are not known to exist. The manual covers 'the role of the lighting crew and the lighting patterns in prescribed burning operations' in considerable detail. If the guidelines on 'controlling fire intensity' and 'stopping fire from escaping' were applied to backburning and backburn training, then this could help to minimise escapes.

S.O.P. #17
Backburning Activities

Scope

This SOP covers backburning - both strategic and tactical.

Procedure

- Backburning is used in indirect and parallel attacks and may be used to help defend a specific asset during defensive operations.
- Strategic backburning is used as the primary means to halt the main fire. It needs to be carefully co-ordinated, suitably resourced and must only be conducted under orders from the overall Incident Controller.
- Tactical backburning is used to protect a specific asset. It must not interfere with other firefighting operations and must only be conducted under orders from the officer in charge of the area which it will affect.
- All backburning must be strictly supervised. Officers in charge must ensure:
  - Weather and fuel conditions are suitable for a controllable backburn.
  - Adequate time and resources are available for the backburning operation (eg: tankers, firefighters, look-outs, communications, etc).
  - Backburning is commenced from suitable, safe "anchor" point/s.
  - Firefighters light-up on the correct side of the firebreak.
  - Spotovers can be quickly extinguished.
  - Firebreaks are sufficiently wide to be effective.
  - Wind direction and strength and relative humidity are monitored for change.
  - If firefighters can no longer see or communicate with one another, they are to cease lighting-up until they can.
- Backburning is not to be conducted when:
  - People or savable property is in the path of a backburn.
  - The fire is running in extreme conditions or the weather is forecast to create extreme conditions before the backburn is likely to be secured.
  - Long distance spotting is occurring.
  - The location of the fire edge is unknown.
  - There are no adequate control lines.
  - There is insufficient time or resources to conduct the backburn.

Definitions

Backburning: Igniting a fire so that it burns "back" towards the main fire along the inner edge of a control line to consume the fuel in the path of the main fire.

Figure 25: SOP for Backburning Activities
Source: NSW RFS 1999

Alternatives to backburning: landscape-based strategies

> *"When these big fires are burning in the mountain ranges, the only way we can stop them is by backburning unless it rains. Otherwise they sit and come out on the worst possible day, in multiple places." (RFS Deputy Commissioner commenting on Mt Wilson backburn escape, SMH 2020).*

As a generalisation the above comment contains some truth, but it does not apply to all fires at all times. Other expert commentators have expressed concern about the risks of backburning and the trauma for firefighters when they go wrong. Some have supported a re-think about it, especially in very dry conditions like the recent summer. These experts have included Craig Lapsley, former Victorian Commissioner for Emergency Management and Fire Services, prominent researcher Professor Ross Bradstock of the Centre for Environmental Risk Management of Bushfires and reportedly the RFS Commissioner (*ABC 2020a*).

> *"The conditions are so, so dry. That means there's no moisture in the soil, there's no moisture in the fuels, and the fire behaviour is different… which tells us that the tactics need to be seriously considered whether they are the right tactics to control fires and putting fire into the environment might be exactly the wrong way to do it, but it has been a tested technique for many years and it's been successful. But I think this year's different."*
> *(Lapsley on backburning, ABC 2020a).*

Backburning is rarely the only available strategy, but it can be attractive because of perceived simplicity and because it has the advantage of putting a secure 'hard edge' around the fire. Even if backburning is the 'only way', it then comes down to where, when and how to backburn. Not all backburns are appropriate or defensible. Backburning is an important tactic that needs to be used well.

Where a backburn will have serious consequences if it escapes, the 'do nothing' option may be better. This is not actually doing nothing, but rather falling back to concentrate resources into defensive firefighting (property protection). 'Falling forward' to use a 'close containment' strategy is another option. Close containment can be used to limit the fire to a smaller size, or to influence and reduce the energy, spread and behaviour of the fire. This can be a holding strategy to reduce the fire's impact over ensuing days. A mix of strategies can be flexibly applied at different times to the same fire or to different parts of a large fire.

Close containment is an alternative to large backburns from roads. This involves moving in closer to the active fire front to use methods such as small-scale backburns, direct attack and natural firebreaks. Direct attack is when firefighters attack the flames directly or create a containment line close to the fire front and put it out when it reaches the line. Natural firebreaks are features that can stop a fire in the right conditions such as rocky areas, cliff lines, gorges, rainforests, long unburnt tall forest and rivers. The occurrence of natural firebreaks varies in different landscapes. A mix of these methods can be used with aerial operations in support. Aerial incendiary work and water-bombing can be used to control and contain a fire against a natural firebreak.

Close containment is most applicable in mild to moderate conditions when danger to firefighters is acceptable. During the course of a long fire there can be many periods when such operations are viable. Large and complex fires may need to be managed progressively, section by section. This is called partial containment. For a fire where full containment is not feasible, techniques can be used to 'steer' a fire and manage fire behaviour. The aim is to reduce the rate of energy release and ensure that when days of severe conditions arrive the fire is constrained and cannot do its worst.

Fire control options during the 2019-2020 fires

Analysis of weather data from Richmond RAAF base done for this report (*Gellie pers comm April 2020)* has identified that the Forest Fire Danger Index (FFDI) was not in the severe to extreme range for much of the time between 25 November 2019 and 17 January 2020. There were ten 'spike' days when the FFDI exceeded 40 between 25 November and 4 January. These data provide background to fire control options in the Blue Mountains over this period.

On the 'spike' days firefighting options were limited, but there were significant periods when conditions were suitable for closer containment and partial containment. For the most part backburning was highly problematic during the day, but better at night because there was mostly good recovery of fuel moisture. Some tactical fall-forward strategies in key locations may also have been viable. It is likely that control opportunities were missed in the Blue Mountains fires as well as elsewhere in NSW.

The best strategies?

Both backburning and close containment have proven to be effective techniques for numerous fires. All types of strategies have a failure rate, but the chances of success can be increased with sound planning and assessment of options. The aims must be to use the best strategies to put the fire where you want it, control its potential, put it out at the smallest possible size and limit impacts. These objectives need to be supported with the best fire analysis, risk assessment, evidence and decision tools. There are no known Australian manuals or courses on overall strategy choice for large fires, and research is almost non-existent (see below).

Understanding of local landscape, vegetation, weather, fire history and fire behaviour is also vital to developing the best strategies. People with these landscape-based skills and depth of experience in fire suppression are in short supply *(see Section 2.4 – Critical Fire Incident Management Skills)*. Managing fires and deciding strategies from distant locations with an absence of intimate local landscape knowledge will always be less than ideal.

Landscape-based strategies can be complex and nuanced. They can require specialist resources to carry out, such as RAF teams and aerial incendiary experts. Shortages of specialist resources are one reason for fire management teams to favour relatively straightforward strategies like large backburns from major roads, using many fire trucks which are more readily available. However close containment strategies reduce overall risks and retain the option of falling back to roads if they fail.

Research

> *"...scientists have 'just about no research on the effectiveness' of the suppression of active fires despite such efforts drawing much of the resources in terms of water-bombing aircraft and other costly equipment, he said. 'There's also no research on the environmental effects of fire retardants in Australia,' Professor Bradstock said*." (*SMH 2020b*)

Currently, decisions on how to suppress fires are mainly based on experience. Very little research on the effectiveness of different strategies has been done in Australia or worldwide *(Simpson et al 2019)*. The research that has been done is basic, such as how long it takes to build containment lines *(Plucinski 2019)*. There is little support for evidence-based decision making. This unsatisfactory situation is one reason for sub-optimal decisions.

The lack of research arises from several factors. Researchers say suppression research is difficult because fire operations are complex, and records of actions and outcomes are poor. Post fire review processes do not tend to analyse successful versus unsuccessful strategies. *(see Section 4.1 - Post Fire Review of Operations)*. There has been resistance within agencies in acknowledging problems or adverse outcomes. Hence solutions have not been communicated across fire agencies and back to firefighters on the ground.

Some research questions could provide great benefits. A cogent example would be how many backburns and other strategies worked or didn't work, under what conditions, and what factors made the difference? The recent fire season produced a large number of suppression activities that beg for analysis.

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3.4 Fire Incident Management Arrangements

Issue

Although the Australasian Inter-Service Incident Management System (AIIMS) *(AFAC 2017)* is standardised across all fire agencies, the system comes under great stress when trained and experienced people are in short supply as occurred in the 2019-2020 fires. Other difficulties also became apparent. Incident management teams can produce excellent Incident Action Plans however these plans can be ineffective if an adequate number of trained, competent Divisional Commanders are not available and well-supported to implement the appropriate strategies and tactics.

Opportunity

After the 2019-2020 fires is the perfect time to review and revise some of the detailed aspects of AIIMS in the face of worsening fire seasons. Aspects that that should be addressed include more training and mentoring to produce a larger pool of very competent people for key IMT and fireground roles, standardisation of IMT shift arrangements, continuity in IMT roles, decentralisation of command, the best use of local knowledge in key roles and improving heavy plant operations.

Issue Summary

We have a tried and proven Incident Management System, but some aspects can be improved. The 2019-2020 season highlighted personnel and skill shortages in critical roles such as Incident Controllers, Operations Officers, Planning Officers and Divisional Commanders. These shortages affected the success of operations. With fire seasons becoming more intense and prolonged now is the time to ensure we have adequately trained and experienced personnel for the future.

Mentoring is often talked about but rarely used in a serious and formal manner to assist in skills development. It can take decades to produce capable and competent Incident Controllers, Operations Officers, Planning Officers and Divisional Commanders. Across Australia many who formerly held these roles have retired. There is a largely unused resource to utilise these retired officers as mentors to ensure the future IMT leadership positions are developed.

Local knowledge in key IMT and fireground roles is critical to successful fire suppression and such people need to be used to maximum benefit. Inconsistency in IMT shift arrangements was another issue highlighted in the 2019-2020 fires that needs to be addressed. Divisional Commanders are lynchpin fireground positions needing highly competent operators and adequate support in the field.

Plant work is commonly used to create or strengthen containment lines but can be high impact. Despite official guidelines on proper use there were instances of where bulldozer work was either counterproductive or caused unnecessary damage. Restoration is difficult and expensive, and not always covered under Section 44 fire costs.

Recommendations for Fire Incident Management Arrangements

- Evaluate the performance of the AIMS and revise as necessary.
- Incident command should be decentralised whenever possible. Avoid the tendency to cluster fires if resources permit.
- Greater emphasis should be placed on continuity of people in key IMT positions.
- Aim for consistency in shift patterns across all agencies.

- Officers appointed to Divisional Commander positions must be trained and competent.
- Command points for Divisional Commanders need to be appropriately resourced and equipped, including support from an Intelligence Officer, a Resources Officer and a Communications Officer. At times access to a dedicated helicopter could be an advantage.
- Ensure plant management is undertaken to increase operational efficiency and protect environmental and community values. Track the location of plant and fire ground vehicles using GPS systems.

Issue Analysis

The Incident Control System

All fire firefighting agencies in Australia now use the Australasian Inter-Service Incident Management System (AIIMS) *(AFAC 2017)* to manage bushfire response and coordination. It is a tried and proven system in Australia and in many other countries. In NSW it was first adopted by NSW NPWS in the early 1990's and by the mid 1990's was approved and adopted by NSW RFS. It is fortuitous that over the last few years all agencies have offered professional training in AIIMS to a greater number of their staff.

Incident Control System (ICS) structure and purpose

The ICS is based on a functional management structure with an Incident Controller over-sighting the functional areas; Operations, Planning, Logistics and Public Information *(Figure 26)*. Several other functional roles can be created if the complexity of the incident requires establishment of further roles. Each functional area has its own dedicated team leaders known as Operations Officer, Planning Officer, Logistics Officer and Public Information Officer. The people appointed to these roles are likely to come from a range of agencies and in the case of Section 44 fire incidents the key principle is that agency day-to-day roles are dropped, and everyone works as though they were in a single agency team.

For a very small incident that is quickly brought under control, the one person may in fact fulfil all functional area roles including that of Incident Controller. When a fire event is more complex and/or multiple fires occur in a locality, all functional areas will be established and within each functional area specialist officers will be appointed to manage specific tasks. In major prolonged incidents such as what was experienced during the 2019-2020 Australian bushfire season, the number of persons working in these functional areas in an incident control centre could easily total 50 or more for a day shift and a lesser number for a night shift.

All these people resources are known as the Incident Management Team or IMT. At the height of the 2019-2020 fire season there would have been 15 or more IMTs operating across the three states in eastern Australia at any one time; an exceptional logistical scale.

Prior to the completion of a shift (usually 12 to 14 hours) the IMT produces an Incident Action Plan. This plan lists the Incident Controller's intent, objectives and strategies matched to availability of resources for the next shift to implement. All IMT leaders receive a copy as do Divisional Commanders and other key field positions. Although this is usually a hard copy, increasingly QR codes are used to enable the ready uploading of this information to smart phones and tablets.

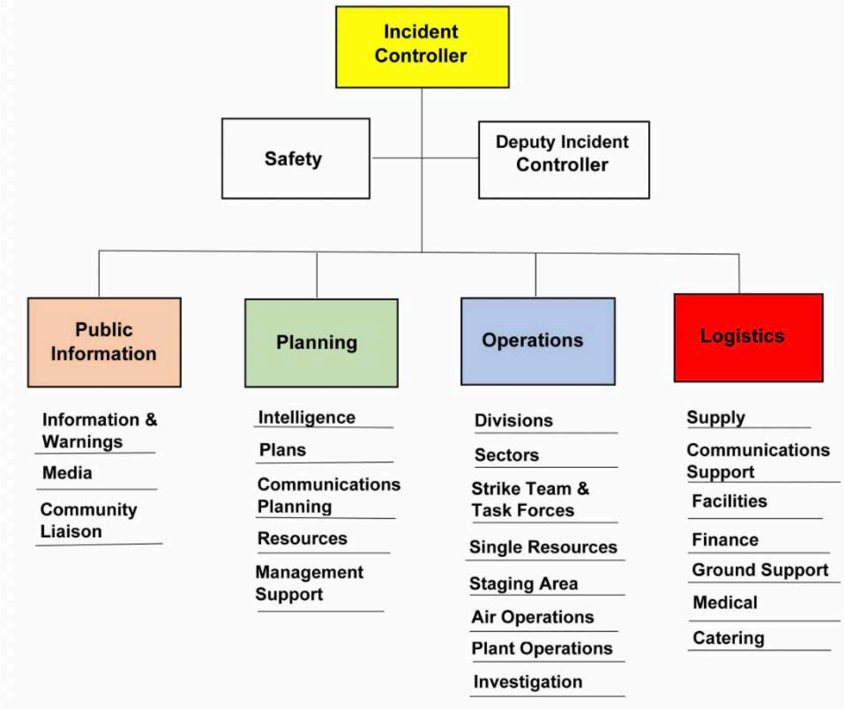

Figure 26: Incident Control System structure

IMTs do not put fires out. The critical work to contain and extinguish fires happens in the field and these locations could be 100 km or more from where the IMT is based.

There are a number of ways that IMTs can be set up. One model sees all the agencies coming together in the one building, usually called a fire control centre. Another model sees satellite or sub IMTs or forward controls established closer to where a fire is occurring. Either model has advantages and disadvantages but the total number of IMT resources should not change noticeably from one model to the other. As an example, the 2003 Snowy Mountains fires were managed from multiple locations. The main IMTs were established at Tumut and Jindabyne and forward controls were set up at Khancoban, Bombala and Cooma. Each forward control was headed by a Deputy Incident Controller and a Deputy Operations Officer. This model facilitated more local control via adoption of local knowledge, which is critical for a successful operation.

In a year like we have just experienced it is inevitable that many people will be asked to step up into positions well above their training and competency. Many performed well and should be given the opportunity to formally acquire the higher-level skills so they can be more effectively utilised in future fire campaigns. Others almost certainly feel they never want to be placed in a particular role again and may need support to get back into a role that is better matched to their personal comfort zone.

It is important to understand how resources are acquired to fill key IMT positions. The Incident Controller is often a local person, most likely a professional RFS manager, and is appointed for the duration of the incident. The Incident Controller will identify a number of key deputies such as overall Deputy Incident Controller or may ask the deputies to manage functional areas so the position of Deputy IC Operations or Deputy IC Planning may occur.

A trained and competent person will also be appointed to head up each of the functional teams being Operations, Planning, Logistics and Public Information. Ideally each of these team managers remains appointed and working in the IMT for the full duration of the incident except for rest days.

The reality brings another element to this. Due to resource shortages it is common for a specialist position such as a Planning Officer or Operations Officer to be appointed for a 5-day shift and possibly not to return to the incident in question. This creates a revolving door of people that may not have essential local knowledge. The consideration and application of local knowledge is one of the keys to successfully containing fires. In seasons like 2019-2020 it will never be possible to fill all key positions with people that possess local knowledge. However most Incident Controllers will try to ensure that as a minimum the Operations Officer or the Planning Officer have adequate local knowledge.

A key role in the planning team is the position of Fire Behaviour Analyst. This officer will be critically reviewing and predicting the fire behaviour, the spread of the fire and dangerous fire behaviour conditions. These considerations feed into the development of containment strategies. The application of local knowledge in fire analysis is very important.

Capacity to fill a number of IMT roles with experienced personnel this season was not possible, so untrained people stepped up into these roles. This highlights the need for ongoing training and mentoring of IMT staff. There may also be opportunities to establish a list of recently retired personnel who would be willing to be contracted in during major fire events

Inconsistent shift arrangements

To add to the complexity of the struggle to resource these key positions there is a lack of consistency with regards to duty periods across the professional ranks. For example, NSW NPWS non-fire line positions work five days, have a day off and work another five days then take two days off and repeat this cycle. ACT Parks staff work seven-day shifts. When international deployments were received the US and Canada staff worked 5-1-5 patterns.

Divisional Commanders

The critical field-based positions are the Divisional Commanders *(see Section 2.4 – Critical Incident Management Skills)* who report to the Operations Officer. Each Divisional Commander may have the operational area divided into several sectors, each led by a Sector Commander. Ideally these positions are filled with people with substantial firefighting and fire behaviour understanding and good communication and team management skills. The reality as shown this season, and in many others, is that Divisional Commanders have often not received specific training and have stepped up into the job without a full understanding of the role. For most incidents the Divisional Commander should have a competent assistant to provide communications support, record keeping and resource tracking.

The key roles of Divisional Commanders include the deployment of crews to appropriate tasks so that the broad strategy, developed by the IMT, can be safely and effectively implemented. The actual tactics that are used by crews should be communicated by the Divisional Commander.

For example, the IMT may develop a strategy (documented in the Incident Action Plan) to implement a backburn from point x to point y. The Operations Officer and the Divisional Commander should discuss this strategy via phone or radio or in person. The Divisional Commander should give the crews a tactical briefing, so they understand how the backburn is to be implemented, patrolled and mopped up. An example of a tactic may be to apply small manageable sections of discontinuous fire to achieve a more controllable backburn rather than a quickly ignited continuous line of fire that is likely to fail. During the backburn operation Crew Leaders or Sector Commanders will communicate fireline behaviour information to the Divisional Commander who will communicate relevant information to the Operations Officer. Requests for additional resources such as an Air Attack Supervisor, would be made by the Divisional Commander to the Operations Officer.

The theory isn't always applied. The reality often is that the Divisional Commander does not have the training and competency needed for this critical role. It is a tough role to perform. The 2019-2020 fire season saw many RFS Brigade Captains appointed to Divisional Commander positions and many worked in this role week after week with little rest. It would be fair to say that many of those in Divisional Commander roles did not have an adequate understanding of what the IMT was doing to support them. The effect of this is that essential communication of fire behaviour and other key field issues, which are often used by the Incident Controller to make decisions around warnings and alerts, may not get communicated to the Operations Officer and others in the IMT. This can result in a very unhealthy 'them and us' situation.

Of all the critical incident management positions, the Divisional Commander is the one to focus on to better manage future fires. More competent Divisional Commanders are needed from all firefighting agencies.

Assistance for the Divisional Commander

When fires are complex, run for protracted periods and involve lots of firefighters, plant and aircraft, the Divisional Commander needs to be properly supported. This is not a one-person role. Rather a Divisional Team is needed. This team could be made up of a competent and certified Divisional Commander and a Field Intelligence Officer who has the ability to be mobile. This will enable the assessment of fire behaviour, monitoring progress of implementation of fire containment strategies, solving minor problems before they become major ones and reporting fire behaviour and weather information back to the Divisional Commander and ultimately, the Operations Officer. The Divisional Commander also needs a capable Communications Officer to assist in the development and implementation of the Communications Plan.

The Divisional Team needs a good place to work from such as a dedicated bus or a proper room attached to, or near to, a brigade fire shed. There can be great strength in assembling a multi-agency Divisional Team as this can go a long way towards breaking down some of the barriers when field resources come from multiple agencies and professional and volunteer fire fighters work together.

When fires are complex just getting time to thoroughly read and understand the IAP can be a huge challenge for many Divisional Commanders. Training of Divisional Commanders and Divisional Teams is critical to assist them to appreciate that the IAP is actually prepared to enable them to better manage their tasks, keep everyone safe and eventually contain and extinguish the fire.

Heavy Plant Management

During major fires heavy plant resources (bulldozers, graders, excavators, feller bunchers etc) are widely used to construct or strengthen containment lines. This work is a critical component of fire suppression. There were many examples during the 2019-2020 fire season where over-zealous use of heavy plant has either been counterproductive from a fire suppression standpoint or led to unnecessary environmental damage and substantially increased rehabilitation costs. Rehabilitation costs are often not covered under Section 44 declarations.

Annex I of the current NSW policy on Management of Bush Fire Operations *(BFCC 2006)* is titled Minimal Impact Suppression and Rehabilitation Guidelines. Most of the 11 pages are about managing the impacts of plant use. However, experience in the 2019-2020 fires and many previous fires suggests that these guidelines are not always being followed.

Properly resourcing of the Plant Management function in IMTs is essential. Plant Management is a complex area and should not be under-resourced. The appropriate plant for the job must be procured in a way that meets audit requirements. Once on site the plant needs to be managed efficiently and stood down when no longer required. All plant needs to be tracked for efficiency and safety reasons. When plant is tasked to perform a job, such as brushing up or widening an existing fire trail, a capable Plant Supervisor, under the direction of a Resources Officer in the Divisional Team, needs to be attached to each heavy plant item. There were many instances during this season when the location of plant was not known. GPS tracking of vehicles is available and should be utilised by all heavy plant at fires.

References

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BFCC (NSW Bush Fire Coordinating Committee) (2006) POLICY NO. 2/2006 Management of Bush Fire Operations

Part 4 – Other Matters - Recovery

4.1 Post Fire Review of Operations

Issue

A continuous lesson learned culture is essential for ongoing improvement in bushfire suppression. Current review processes lack coherence, transparency and commitment. They do not result in analysis or full and frank assessment of fire suppression operations or adoption of lessons learned. This has allowed unsuccessful suppression practices to continue.

Opportunity

Re-build post-fire review processes from the ground up to be structured, compulsory, thorough, independent, honest, unflinching and blame-free. Remove obstacles that have inhibited this in the past. Undertake a major research program into suppression strategies. Make a culture of analysis and learning an integral part of fire management with commitment and funding from agencies. Consider enshrining review principles and processes in legislation. Energetically communicate and audit review outcomes through fire agencies to ensure that lessons learnt are understood and adopted.

Issue Summary

All large fires involve strategies that worked (ie effectively controlled the fire) and some that did not work (ie failed to control the fire or were counterproductive). Ineffective strategies can have serious consequences and, in some cases, have led to more damage than the fire itself. This applies to some escaped backburns. There are many reasons why strategies are more or less successful. It is important to analyse what worked and to critique what didn't work, and then to communicate and adopt lessons learned. Just as for strategies, the same goes for how resources are deployed, and the management structures used for major fires.

Bushfire suppression is a complex activity, especially for large fires. Suppression can involve many operations, decisions, strategies and tactics across time and a range of challenging situations, and under different management structures. By comparison, in other industries a narrow review might be enough to work out how and why an adverse event happened, such as an avoidable death in a hospital. The scale, complexity and consequence of bushfires can make them difficult to properly review, but these factors make it even more important to do so.

In NSW, bushfire debrief processes and outcomes lack rigour, transparency and outcome. Agency culture does not support critical analysis or encourage dealing with difficult issues. There is no public reporting, independent involvement, objective research or oversight from outside the operation. Incident Controllers report on fires they themselves have managed. Firefighters rarely find out what happens to their concerns. Documentation of fire event analysis and case studies is poor.

There is extensive global literature on how organisations can improve by reviewing actions, successes and failures. A culture of learning and improvement is widely considered as routine within industry and government. Structured review processes go under various terms including 'after action reviews' (AAR), 'post-mortems', 'lessons learned' and 'debriefs', but all have the same objective: to learn from past actions, incidents, successes and mistakes so that problems can be avoided and performance improved.

The evidence suggests that NSW bushfire agencies are not yet fully committed to formal, constructive and effective review processes for large fires. The processes that do exist lack coherence, transparency and commitment. This stands in contrast to the effective RFS investigation team that analyses the origins of wildfire.

There are many reasons for reviews to be ineffective, but they are mainly cultural. Incomplete review of fires can lead to a failure of wider learning, to ongoing safety issues and to inappropriate practices continuing (such as unsuccessful control strategies). Bushfire agencies can learn from other industries such as aviation and medicine and commit to revamping review processes from the ground up to create organisational resilience, defined as: *"the degree to which a system continuously prevents, detects, mitigates or ameliorates hazards or incidents" (Queensland Health, 2014)*.

The future lies in cultural change to support critical analysis of fire control operations. Change is hard and may need to be driven from outside the fire agencies.

Debriefs are just one part of the comprehensive and hierarchical system for lessons management that is needed. Sound theory and models of best practice are available to guide better operational review. Review processes must encourage the acknowledgement of errors as well as successes. Honest feedback must be strenuously encouraged to overcome the natural tendency to avoid criticism. Blame is to be avoided; rather the root cause of errors needs to be examined. When causes are identified they often come down to problems within the system in which people operate. Rigorous formal research into fire suppression should be promoted and funded to boost objective assessment, and effectively communicated. The objective is 'lessons learned', to promote constant improvement and better fire suppression, with real change to outcomes on the ground. This will benefit firefighters, bushfire agencies, governments and the wider community.

Recommendations for Post Fire Review of Operations

- Re-build post-fire review processes from the ground up to be structured, compulsory, thorough, independent, honest, unflinching and blame-free.
- Remove obstacles that have inhibited such review processes in the past.
- Make a culture of learning from past operations an integral part of fire management with commitment and funding from agencies.
- Consider enshrining review principles and processes in legislation.
- Energetically communicate and audit review outcomes through fire agencies to ensure that lessons learnt are understood and adopted.
- Undertake a major research program into suppression strategies.

Issue Analysis

Current review practices are inadequate

Bushfire reviews in Australia have historically been undertaken via two mechanisms, operational debriefs within and between agencies, and public inquiries. They can both work for some issues, but neither have been effective at reviewing fire control strategies. A third method, scientific evaluation of strategies, has been almost absent *(Simpson et al 2019)*.

Large fire debriefs

Debriefs are routinely undertaken for large emergency fires in NSW (Section 44 declarations under the Rural Fires Act). Section 44 debriefs are conducted by district Bush Fire Management Committees *(BFCC 2006)*, with all agencies represented. Usually agencies do their own internal debriefs and take issues to the Section 44 debrief. Along with the local fire combat agencies, other emergency and support agencies are represented such as local government, State Emergency Service, ambulance, police, transport, communications, electricity, health and welfare agencies.

Current policy *(BFCC, 2006)* requires that the minutes of the debrief are sent to the NSW Bush Fire Coordinating Committee. However, it is understood that the BFCC does not receive such minutes, and what happens to them is not apparent. It is a common complaint of participants that the process does not allow adequate airing of concerns and they do not know what happens to the issues that are raised. The authors have personally experienced many Section 44 debriefs that did not adequately discuss the most serious issues of the fire. The policy itself excludes the raising of some matters. The scope is limited to issues of 'coordinated arrangements', as stated under "Matters not relevant to the BFMC debrief":

> *"Only issues that are directly relevant to or which influence coordinated arrangements (for planning and/or suppression) are to be raised at the BFMC debrief." (BFCC, 2006)*

The scope of strategy review is also limited to matters impacting local bushfire planning:

> *"Strategies – those selected, and their effectiveness given the progress of the fire and weather conditions etc. Also briefly discuss potential strategies that were not adopted, and why. Not too detailed, but enough so that the BFMC gets some appreciation of whether its bush fire risk management plan and operations coordination plan helped or hindered the operation. Should also give an appreciation of the decisions that might need to be made for the next fire, and the need to amend the existing plans to assist." (BFCC, 2006)*

The policy does not include any process for review or assessment of the minutes or for adoption and promulgation of recommendations or lessons learned.

Less formal processes apply to non-Section 44 fires. NSW NPWS documents refer to incorporating 'lessons learned' from 'fire debriefs' *(NPWS nd, p28)* but there is no apparent framework for ensuring this happens. NPWS has a 'lessons learned' officer, but operational change, as a result of the role has, reportedly, been limited. RFS processes also lack transparency. RFS training materials include an After Action Review (AAR) debriefing format which is similar to many other AAR processes as originally developed by the US Army (*United States Army 2012*):

> *"In an After Action Review you ask the following key questions:*
> - *What did we set out to do – What was the mission and key tasks?*
> - *What actually happened? – Agree on what happened*
> - *Why did it happen? – Focus on what not who. Analyse in terms of cause and effect*
> - *What are we going to do next time? – Does it need to be fixed? Focus on what can be fixed. Outcomes are recorded as sustain or improve."*
>
> *(RFS nd)*

The RFS Annual Report for 2018-19 contains this reference to post-fire reviews:

> *"In 2018/19, pre-season briefings were again delivered through inter-agency cooperative events, such as regional face-to-face briefings, workshops, the state briefing and online delivery. Incident Controllers gave important insights into previous season's incidents, talking through the lessons learnt and helping implement operational changes to prepare for the coming season. This is an important component of the NSW RFS's commitment to conducting after-action reviews and debriefs." (RFS 2019)*

In welcoming the 2020 NSW Bushfire Inquiry, an NSW spokesperson said the RFS would also conduct their own internal investigations:

> *"After every season, we look to review what has happened, particularly because of the significant loss we have experienced. We owe it to the community and future generations to review what has happened and take lessons wherever possible to improve for the future." (RFS 2020)*

The RFS Commissioner has made a similar statement:

> *"We cannot go through a season like we've just gone through and not seek to take stock of what's happened and learn from what's happened. We owe a duty to those that have lost everything, and particularly those that have lost loved ones and those that have paid the ultimate price in trying to serve and protect their community, to make sure we have a look at what happened, how it happened, why it happened and what we can do better going into the future to ensure that we minimise the prospects of this ever happening again. Because that's what we've done for decades. And we need to continue to do that. We can't go through this season without doing so." (ABC 2020)*

If a formal framework exists for these debriefing and learning processes, then it is not apparent. No outcomes are readily available to the public. Many people in the RFS and other fire agencies report that they do not see outcomes. Errors leading to adverse events in the past have been repeated. An example from the Blue Mountains illustrates this. Serious fires have impacted the Grose Valley in 1994, 2006, 2013 and again in 2019. In three of these events the fire was partly or largely the result of deliberate backburns which escaped and entered the valley.

The bushfire community is widely disappointed in debriefs for large fires, because the most important problems are rarely discussed, and outcomes are not transparent. Reports coming out of debriefs for the 2019-2020 fires suggest this situation has not improved.

Debrief processes and outcomes lack rigour and transparency. Agency culture does not support critical analysis or encourage dealing with difficult issues. There is no public reporting, independent involvement, objective research or oversight from outside the operation. Incident Controllers report on fires they themselves have managed. Firefighters rarely find out what happens to their concerns. Debriefs deal with routine topics like communications and catering, but shy away from more complex issues like strategies, especially if they went wrong. Agreement on exactly what happened and where mistakes were made does not often occur. People are reluctant to comment on adverse events in front of 'outsiders'. A large open forum where many participants have no expert knowledge is not a suitable mechanism for reviewing strategies, which are technical.

The same concerns have been expressed widely in the firefighting community over many years but are rarely stated publicly. There is a history of dissatisfaction with debriefs from all levels of operations; from fireline crew to IMT members and across all NSW fire combat agencies *(SMH 2020, ABC 2015)*. This disillusionment is shared by the authors of this report.

Public inquiries

Between 1886 and 2017, 105 inquiries were conducted into Australian bushfires (BNHCRC nd). These included Royal Commissions, coronial inquiries, parliamentary inquiries and other types of inquiry.

From 2009 to 2017, 55 Australian inquiries and reviews into emergency management/natural hazards made a total of 1336 recommendations (*BNHCRC nd*). A rapid search of these recommendations discovered just four that were about post-incident review. Two of these were about bushfires.

The inquiry into the 2011 Margaret River, WA *(Keelty 2011)* fire recommended an independent review into the fire response, and that *"the Government consider enacting legislation to facilitate the review of all future major incidents…and the emergency response to them".*

A review into a 2016 'Extreme Weather Event' in South Australia *(Burns et al 2017)* recommended the establishment of a lessons management capability across the SA emergency management sector, and that processes be updated to *"provide more guidance regarding the types of debriefs, when they are required to be undertaken and at what level and guidance for undertaking and recording debriefs, and implementing lessons identified".*

All four recommendations are significant. Collectively they suggest that:

- major bushfire operations should be reviewed
- reviews should be formalised
- reviews should be independent
- reviews should be required by legislation
- lessons learned should be implemented
- lessons learned should be monitored.

These 55 inquiries apparently produced only one recommendation specifically about bushfire strategy, and even that was vague. The inquiry into the 2016 Tasmanian bushfires *(AFAC 2016)* recommended a review of fire suppression strategies and tactics, including *"a comparative analysis of fire suppression options whether aerial or ground-based"*.

It is notable that each of the three inquiries cited above were independent of both the emergency operation and government agencies.

Bushfire leaders often say that bushfire operations are one of the most heavily investigated of all government activities. However, the above analysis shows that past public inquiries have given little attention to fire suppression strategy and post-fire reviews. Despite a few useful recommendations coming from such inquiries, they seem to be a poor way to consider these issues. Mandatory and effective lessons management processes within government are a better option.

Research into emergency service response to major disasters

Research on bushfire inquiries is limited, but emergency law researchers M Eburn and S Dovers have published papers critiquing the adversarial approach and the damage it causes to firefighters *(Eburn and Dovers 2017)*. They have undertaken many years of research into how emergency service agencies deal with review and learning. They have tried to identify 'the value' (if any) of post event inquiries and of reducing the harm they cause, particularly to first responders *(Eburn 2020)*. Some of this research was summarised by The Hon. Paul Holloway in 2013 *(Eburn 2020)*, highlighting shortcomings and a need to shift away from blame to a 'lessons learned' culture. Key points

> *"Australian emergency management policy suffers from a lack of clear objectives or measures of success. This absence means that agencies, governments and citizens cannot identify whether or not policy objectives are being met and whether the emergency services are succeeding in their tasks or not...*
>
> *"Strategic Policy is being driven by the litigation blame game so agencies are focussing on 'what will we be blamed for?' and 'who will be blamed?' rather than how do we improve community safety… Post-event inquiries and processes should be rethought within the frame of lesson-learning rather than seeking fault.*
>
> *"A review should look to see what went well, so that policy can be developed to do more of the 'good', rather than less of the 'bad'. Processes need to be developed for emergency services such as those used in aviation and medicine, to facilitate open and honest disclosure of errors.*
>
> *The challenge is to enact laws to establish a 'lessons learned' centre or process that sufficiently balances the community's interests in ensuring that true lessons, including the lessons of error or neglect are identified, whilst also protecting members of the emergency services."*

Suppression research

Suppression is largely experience-based, and research is in its infancy *(Bradstock in SMH 2020a)*. For instance, there has been no specific assessment of aerial water-bombing or the effectiveness of large air tankers in Australia. The success rate of backburning has not been analysed. Suppression research is still coming to terms with basic issues like defining the tasks undertaken to control fires *(Simpson et al 2019)* and how long it takes to construct containment lines with machinery *(Plucinski 2019)*. These extracts from Simpson et al paint the picture:

> *"The suppression of large wildfires accounts for the vast majority of suppression costs. Despite these cost increases, we have a limited understanding of suppression efforts and their effectiveness on large wildfires.*
>
> *"In large fire management, objective measures of effectiveness are limited, or non-existent. Without such measures and without effective research-based fire-management tools, it is unsurprising that incident management team preferences can be as important as fire and environmental factors in explaining the number and type of resources that are used."*

Suppression research that looks at how well initial attack and various strategies work would be very helpful to fire decision-makers. But this type of research is said to be challenging because it is hard to find out exactly what was done on the fire, when it was done, what worked and what didn't. Actions listed in fire suppression plans are not always what ends up happening. This difficulty suggests that basic time-and-event recording during large fires needs to be improved to make later analysis easier.

Another obstacle to suppression research is a lack of support from fire agencies. They have not shown that that they see the importance of such research by funding it.

The RFS Corporate Plan 2014-2021 *(2018/19 update)* includes this objective:

> *"Effective performance and measurement of prevention, mitigation and bush firefighting strategies." (RFS 2018)*

However, the 2018-19 Annual Report *(RFS 2019)* includes no reporting on this objective, and it would seem that 'bush firefighting strategies' are not being measured or researched for effectiveness.

Other industries use formal review processes

A culture of learning and improvement is standard across many industries and governments. Structured review processes have been adopted by numerous and diverse organisations including the United States Army *(2012)*, NATO *(2016a, 2016b)*, Google *(Lunney and Leuder 2016)*, Atlassian *(2019)* and Queensland Health *(2014)*. Many of these processes go back over 20 years.

A review of many of these formal review processes reveals shared features that can be applied to large-scale fire operations. Effective reviews are:

- structured and multi-level
- focused on learning
- 'no-blame' - the question is not 'who' but 'what'
- inclusive, of all relevant personnel and views
- managed by an external facilitator and/or conducted independently
- based on establishing and agreeing on exactly what happened as a critical first step
- strong on analysis
- directed towards identifying and sharing lessons learned
- fully integrated into the organisation's programs.

Operational review in emergency management internationally

Australian bushfire agencies have been slow to embrace the opportunities offered by the wealth of available models for operational reviews. In the international fire and emergency sector, organisations that have produced or follow formal review processes include the National Wildfire Coordinating Group in the United States *(2016, 2020)* and New Zealand's Ministry of Civil Defence & Emergency Management *(2006)*.

The Wildland Fire Lessons Learned Center (nd) in the US was set up in 2002 after a 1994 South Canyon Fire disaster that killed 14 firefighters. It operates *"as a national, interagency, federally-funded organization with interagency staffing. The LLC's primary goal continues to be striving to improve safe work performance and organizational learning for all wildland firefighters." (https://www.wildfirelessons.net/aboutus)*

In practice on the ground, US Divisional Commanders do daily AARs at the end of every shift at set times, involving all divisional participants. Recommendations are followed up. Important outcomes are often reported at the next morning's IMT briefing.

Best practice operational review in Australia

Emergency Management Victoria *(EMV 2015, 2017, nd)*, the Australian Institute for Disaster Resilience *(AIDR 2019)* and NSW Office of Emergency Management *(OEM 2018)* have produced best practice documents for Australia, outlining fully developed systems of 'lessons management'. However adoption by fire agencies is limited.

Australian Institute for Disaster Resilience (AIDR)

The AIDR has produced the Lessons Management Handbook (*AIDR 2019*):

> *"The purpose of this handbook is to provide a national reference, principles and guidance for the practice of managing lessons. The process of managing lessons is integral to the continuous improvement of organizational capability and individual learning." (AIDR 2019, p2)*

The Working Group behind the handbook included agencies from the Commonwealth and all states except Tasmania. Bushfire agencies from Queensland, Victoria, South Australia and Western Australia were represented, with the State Emergency Service and the Office of Emergency Management from NSW. The handbook is a detailed guide to 'lessons learned' theory and practice and an excellent resource for bushfire agencies. The model does not seem to have been adopted in NSW.

The handbook details all the concepts and components of an effective lessons management system. These include rationale, learning culture, change management, principles, processes, 'no-blame' and 'just' culture, communication, debriefing, monitoring, reviewing and legal issues. Some of these concepts are very important in the context of reviewing bushfire operations in NSW.

> *"Lessons management is an overarching term that refers to collecting, analysing, disseminating and applying learning experiences from events, exercises, programs and reviews. These learning experiences include those that should be sustained and those that need to improve. The goal of this activity is ongoing improvement by organisations and the people who work for them. Organisational growth and continuous improvement are particularly relevant where preservation of life is the primary goal… Organisations are seen to be learning when their structures, processes and culture are able to evolve based on learning acquired from experience." (AIDR 2019, p3)*

The cycle for managing lessons *Figure 27* consists of four steps:

1. *collection*
2. *analysis*
3. *implementation*
4. *monitoring and review (AIDR 2019, p3)*

Figure 27: Lessons Management Cycle
Source: AIDR 2019, p3

It is important to note that debriefs, AARs and the like come within the information collection phase. Debriefs are just the earliest phase of a full lessons management system, which must proceed to adoption and monitoring.

'No-blame' is a basic requirement for effective review, which has evolved into the more nuanced concept of 'just' culture.

> *"A non-judgemental 'just' culture encourages learning and maximises the potential for ongoing improvement. If stakeholders do not feel safe to speak up without fear of ridicule or blame, or if others declaring a contrary view challenge them, they can be discouraged from sharing their experiences. The best performing teams work in an atmosphere where they are encouraged to speak up if they see anything 'dumb, dangerous or different." (Dekker 2007, quoted in AIDR 2019, p11)*

> *"In a 'just' culture, personnel are not punished for actions, omissions or decisions taken by them which are commensurate with their experience and training, but gross negligence, wilful violations and destructive acts are not tolerated." (AIDR 2019, p12)*

The handbook also addresses barriers to a lessons management system. It rightly identifies concerns about potential legal processes like coronials, inquiries and litigation. However, the handbook counsels that legal issues should not stand in the way of lessons management.

> *"Those involved in the lessons process should, generally, not be concerned how the material may be used in legal proceedings… during the debrief or lesson identification process, one cannot know in advance if the material might be relevant to any subsequent proceedings. As a lessons' manager, your role is focused on identifying the lessons that can be learned for future application – you are not responsible for speculating or determining potential liability arising from a particular incident." (AIDR 2019, p37)*

NSW Office of Emergency Management

The NSW Office of Emergency Management (OEM) has produced its own document largely based on the 2013 version of the AIDR *Lessons Management Handbook*. *A Lessons*

Management Framework for NSW Emergency Management Sector (OEM 2018b) sets out a detailed basis on which individual agencies can develop their lessons management systems. The mission of the NSW lessons management framework is described as:

> *"To provide a framework that captures and analyses information to develop lessons that can be applied to strengthen EM capability across the sector." (OEM 2018b, p6)*

The target audience is:

> *"The LMF is aimed at LM practitioners and those with a responsibility for implementing and maintaining LM within their organisations." (OEM 2018b, p8)*

However there is no apparent strategy or program associated with this document to ensure that leaders of emergency response agencies adopt and develop their own comprehensive lessons management system. Under Policy Context: State Level, the EOM document defers to the NSW State Emergency Plan, and that plan's reference to:

> *"Improving response and recovery – lessons from response and recovery also provide important insights to enhance planning and prevention activities." (NSW OEM 2018, p24)*

There is no imperative for fire agencies to learn from operations as part of a structured lessons management system. That seems to have been left to the agencies to decide. On the evidence, such systems remain in their infancy.

Emergency Management Victoria (EMV)

In 2015 a lessons management framework was approved for Victoria's emergency sector. EM-LEARN (Emergency Management – Lessons, Evaluation and Review Network) is a progressive system that supports the development of a culture of continuous improvement *(EMV 2015)*. It incorporates the key concepts of the first 2013 edition of the AIDR Lessons Management Handbook *(see Figure 28)*.

> *"Lessons management can facilitate learning and improvement resulting in more efficient and effective practices, improving safety and capturing knowledge. It also provides a platform for knowledge sharing interstate and internationally." (EMV 2015, p4)*

The framework focuses on systems of work, rather than the performance of individuals. It encourages the sharing of lessons, to sustain positive actions and to identify areas for improvement. Learning activities include debriefing, monitoring and reviews, which occur before, during and after emergencies. When fully functional, EM-LEARN will be integrated, evidence-based, continuous, consistent, transparent and holistic. Lessons are not 'learned' until they are adopted into changed practice.

> *"Victoria is seeing a shift towards a learning and improvement culture. We are slowly moving away from recommendations and towards lessons, away from reports and towards case studies and away from action tracking and towards monitoring improvement." (EMV nd)*

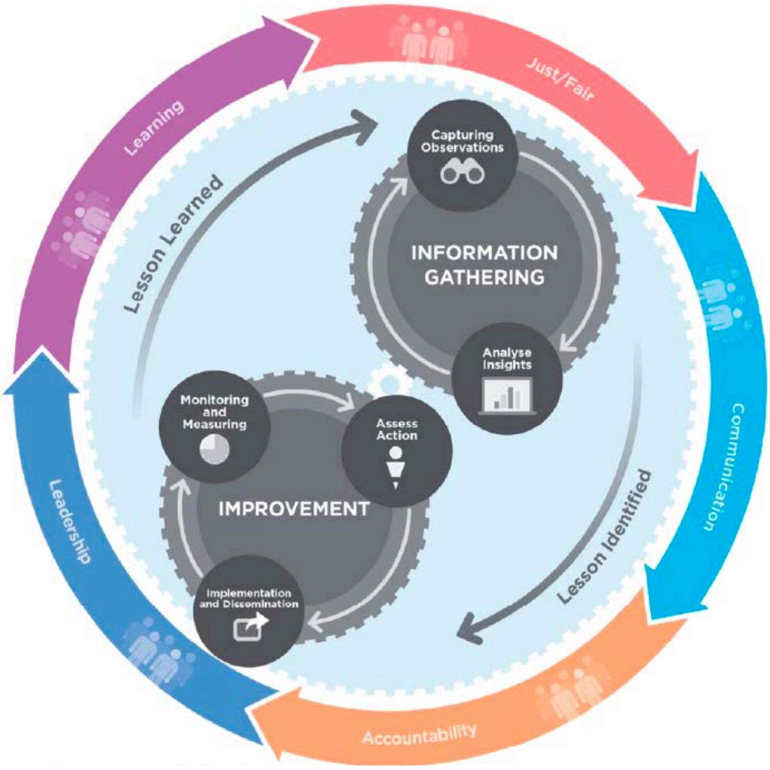

Figure 28: Lessons Management Life Cycle
Source: EMV 2015

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4.2 Environmental Recovery

Issue

The knowledge base, systems and resources for post-fire environmental recovery are very inadequate. Bushfire suppression operations can minimise environmental impacts but can also cause unnecessary damage.

Opportunity

Reduce the size of fires to minimise all impacts including on the environment and ecosystems. Greatly expand research on bushfire impacts, ecological baselines and fire recovery. Increase investment in ecological recovery programs.

Issue Summary

The scale of bushfire impacts on the natural environment of NSW caused by the 2019-2020 fires is significant with "most of the NSW Coast and Tablelands national parks and reserves burnt, much of them severely" *(GEEBAM IMAGES 2020, University of Sydney 2020b)*.

Just over half of the total area of 5.4 million hectares burnt in NSW was in national parks (2.7 million hectares), comprising 37% of the whole NSW park system *(NPWS 2020b)* with a much higher proportion of parks in the east of the state. Large areas of native State Forests were also burnt. Many affected areas in NSW had not previously been burnt in historical times, including sub-tropical and temperate rainforests from the Blue Mountains to the Queensland border.

Many iconic and treasured natural heritage sites and species were impacted, including Jenolan Caves, Koala and Brush-tailed Rock Wallaby populations, ancient Gondwanan rainforests, the Wollemi Pine and Blue Gum Forest in the Grose Valley. An independent analysis of the Greater Blue Mountains World Heritage Area (GBMWHA) found that 68% of the area was burnt, with a third of this at high to extreme severity (*Smith 2020).* Jenolan Caves and Blue Gum Forest have been devastated by the fire followed by severe and intense flooding.

Many areas have now been burnt more frequently and more extensively in one season than the ecosystem can sustain. This will probably cause major changes in habitat and ecosystem function. Estimates of the fauna killed by these fires *(University of Sydney 2020a, DPIE 2020)* indicate that large proportions of many animal species populations were lost. The estimated loss of endangered species of flora and fauna poses a major extinction threat to many of these populations.

Population recovery estimates for individual species need to be based on climate projections, not on the known responses over the last 80 years, when the climate was more stable. For many habitats, insufficient population density data is available to assist these predictions, since there have been few quantitative surveys, either before or after the fires.

The remaining unburnt areas in conservation reserves and on public and private lands are critical to the long- term recovery of biodiversity in the burnt national parks. Many have been reduced to islands in a sea of extensively burnt landscapes. The recovery operation needs to take place over a long time for the entire reserve system and adjoining land and not be limited to endangered species. Long term investment in NPWS personnel and budgets will be necessary for recovery to succeed *(NPWS 2020a)*.

The wider public, as well as the affected communities, are in shock at the magnitude of wildlife loss. Many people are buoyed by the media message of recovery represented by 'green shoots' with the thinking that all will be well. There needs to be an honest reporting of the actual prospects of recovery for ecosystems and their component species. To assist people to understand these impacts a public education campaign is needed.

Planning for environmental recovery during bushfires has been lacking. No statewide plan has yet emerged, many months after the fires. The role of IMTs, in both avoiding impacts and planning for recovery, is critical but under-performed. Once a fire is out, most IMTs disband before the recovery process has a chance to commence.

Recommendations for Environmental Recovery

- Implement measures to reduce the size and intensity of wildfires.
- Upgrade and enforce mechanisms as outlined in other sections, to minimise impacts during fires.
- Prepare a statewide strategy for environmental recovery from the 2019-2020 fires.
- Increase research into the ecological impacts of bushfire, and especially the 2019-2020 fires.
- Properly fund within overall fire costs, the repair and recovery of bushfire impacts, especially those resulting from suppression operations.
- Identify and undertake critical post-fire, weed and feral animal control programs.
- Support community-led recovery programs by increasing resources and training for NGOs, NPWS, Local Land Services, the Department of Agriculture and Local Government-supported Bushcare and Landcare groups.
- Increase protection for unburnt areas of bushland.
- Ensure that the conservation of ecological values is afforded significant priority when determining prescribed burning programs and objectives in areas left unburnt by the 2019-2020 fires and in core areas of conservation reserves.
- Develop and roll out an education program for communities and fire agencies on the ecological issues around bushfire and fire suppression.

Issue Analysis

Current status of ecological impacts

The scale and intensity of these fires has largely destroyed the pre-existing species assemblages. The pre-fire landscape mosaic of varied fire ages has been homogenized over large areas. In most cases it will not be recovered, except on a small and localised scale, and not for a very long time. Regeneration of flora and fauna populations to new biotic communities depends only partly on what existed before the fire, as much of the reproductive capacity has been lost. The remaining surviving habitat is patchy, essentially a series of biogeographic islands, subject to a new set of ecological thresholds determined by changed climate, soil degradation and loss of carbon and nutrients and threatened by an aggressive regime of competition, predation and invasion of weeds and feral animals.

It has not been possible for on ground assessments to be made due to NPWS restricting access on the basis of safety issues and distancing requirements for COVID19 protocols. This will lead to a dearth of good data for the months immediately after the fire. One rapid assessment was made recently of the National Icon of Blue Gum Forest *(Jones 2020)* in Blue Mountains National Park. This small example was still able to provide information for a research plan for the Grose Valley, which will seek substantial funding. Critical data from the proposed studies will assist managers to more scientifically manage the area, visitation and protection from fires.

Repopulation responses

There is no previous history of post fire recovery efforts to provide a model for the future. The recovery effort during these fires and immediately after, was mainly reactive and oriented to particular high-profile species *(NPWS 2020b)*. It was responding to a large emotive public audience fortified by media reporting. Some of the efforts are admirable eg koala rescue and recovery, though how effectively this will contribute to future viable regional populations is questionable with so much of that species' habitat being destroyed. A more detailed and longer-term recovery plan was proposed but has not yet appeared.

Long term studies of fauna responses after fire are uncommon. Comparative studies on fauna responses to fire started in Nadgee Nature Reserve after the 1972 wildfire and continued as the longest dataset of its kind *(Recher et al 2009)*. These were small mammal studies and documented mammal repopulation of the regenerating forest and heathlands in detail, over seasons and years. While the studied fauna will respond similarly in other areas after the recent fires, the scale of habitat destruction and mosaic disintegration, combined with climate change effects, will make the prediction of response more difficult. While this study was restricted to common resident mammals, other faunal species would show similar trends. For many less -common species and nomadic birds, responses will be even more difficult to predict.

If the burnt areas are left to self-regenerate, future climate, fire regimes and time will largely determine not only the spatial species arrays, but the integrity of the natural ecosystems. It is most likely that none of the reserved conservation areas will be stand-alone functioning ecosystems. Their effectiveness in the conservation role will increasingly depend on the surrounding landscape and its use.

The wider ecosystem picture is a challenge to all concerned as there is no past experience from which to learn. The following ecological issues need to be considered in any plan for future ecosystem management:

- Core areas, which are centres of high biodiversity and often of speciation, have been burnt hard, either by high frequency fires over many years, eg Blue Mountains *(University of Sydney 2020c)*, Kosciuszko and Morton-Budawang NPs, or high intensity fire following prolonged drought, such as occurred in the northern NSW rainforest reserves.
- Boundary buffer zones between large natural areas and forestry and agricultural land have been damaged extensively by fire, as well as by fire suppression operations.
- Major conservation areas have been dissected into numerous smaller 'islands' by fire and fire suppression operations, in particular by the use of earth moving machinery to clear containment lines and the lack of post fire revegetation and soil conservation programs. There is pressure to maintain these disturbed zones as permanent fire management assets.
- High quality breeding sites for many faunal species have been reduced severely in numbers and area, for example arboreal mammals and owls in the Kanangra-Boyd National Park and almost certainly in the South East Forests.
- Breeding sites will not recover to pre-fire conditions for many years if at all, due to alteration in vegetation structure and critical ecological factors such as food resources.
- Many feral predators and herbivores will opportunistically invade, spread and increase populations in changed ecosystems. Native fauna will have less protection from vegetation.

- Weeds will also spread opportunistically, especially because heavy rains after the fires deposited sediment plugs and washed large numbers of propagules from infected areas into new areas.
- Mass movement of softened, unconsolidated soils, minerals and ash layer into catchment systems following intense rain periods after the fires.
- Critical forest structures eg hollow trees for owls, gliders and parrots, have been reduced significantly in number and quality. Similarly, the number of stag trees for roosting and breeding sites for bat species is now reduced.
- The return to productivity of food resources for animals will be slow and erratic and dispersed over the area.
- Animal populations will have large reductions in efficiency of food utilisation which will be reflected in drastic reductions in breeding success for many species.
- Ecological values need to be paramount in the large areas which are subject to prescribed burns for hazard reduction. Otherwise the burns will contribute to a decline in ecosystem functions.
- Prescribed burning needs to consider the conservation of soil values with potential loss of soil and soil values.
- Prescribed burning needs to consider the effects of climate through prolonged drying of the soil and vegetation as it can expose habitat to further drying.
- Prescribed burning needs to consider the increasingly chaotic nature of the climate which has a higher energy impact compared to past conditions, resulting in extensive soil loss, soil carbon loss and habitat simplification.

Impacts on biodiversity

Structure and diversity of many vegetation assemblages has been destroyed or will be significantly altered from the pre-fire state. Importantly, soil seed resources have in many cases been depleted or destroyed over considerable areas, significantly changing the species composition from the pre-fire community. The distribution of many plants will become disjunct, with the creation of micro patches that will remain for a long time. However, establishment of viable communities will be retarded by the absence of healthy invertebrate populations which act as pruners and pollinators, seed transporters and nutrient recyclers.

Impact on Species

With major losses of common species of fauna and large-scale habitat destruction the ecosystems are faced with a long-term recovery before many new populations and assemblages become viable. There is no likelihood of a managed large-scale ecosystem redesign such as extensive plantings of trees and shrubs, so what techniques, if any, are possible for active management? Certainly, there is no mention in the interim recovery plan *(NPWS 2020a)* of longer-term management nor a commitment of funds and human resources to initiating a planning process in 2020.

Ecosystem function

It is not only the structures of the ecosystems that have been drastically altered but the major functions as well. Soil carbon will remain seriously depleted and with greatly increased yearly solar insolation, soil drying will be held at high levels preventing the return of a fully structured forest and woodland system. Swamps and wetlands may actually be the local drivers of the ecosystems in some areas. Species balance will remain volatile for a long period and the carnivore to herbivore balance will not return to its previous ratio. Primary production of the ecosystems will be patchy due to soil depletion. One of the major problems is the lack of marsupial herbivores at all trophic levels in the habitats.

Ecosystem integrity

World Heritage status of many NSW conservation reserves requires that the designated area has a high degree of integrity, ie a long-term ability to self-maintain the ecosystem components, numbers of habitats, biodiversity and endangered species. For many of the burnt NSW forests designated World Heritage this long-term ability is seriously in doubt.

Climate change considerations in recovery

The increasingly chaotic nature of the climate will cause erratic and sometimes large swings in plant responses of flowering, fruiting and growth. This will favour opportunistic plants (often weeds), vertebrates and scavengers and will be difficult to predict in space and time. Erratic and chaotic temperatures combined with unseasonal behaviour of flowering decreases the efficiency of pollinating invertebrates with a likely decrease in seed production. Future fires will most likely increase the ecosystem chaos and make difficult to reliably predict ecosystem indices. This dearth of good predictive data will present an impossible task for the land manager to assess ecological effects when planning prescribed fires and other fuel management measures.

Litter accumulation rates have changed in forest ecosystems due to climate change, with trees conserving more moisture within their living structures *(Kirschbaum & McMillan 2018)*. More leaf drop is predicted coupled with lower decomposition rates caused by a reduction in invertebrate activity. This reduces moisture near the ground and increases the accumulation of litter fine fuels, potentially leading to increased fire risk.

Drought effects

The effect of the extended dry period preceding the fires needs to be taken into consideration. Vegetation suffered as evidenced by the death of eucalypts and understory species and the dieback on many of them in usually moist and fertile situations. This was occurring across the large natural areas as well as in remnant patches in rural corridors during the drought and prior to the emergency period. Plants that died in this way have not recovered.

The will to respond

There is abundant goodwill in the community after a fire and this is most frequently shown by the "hey, there are new green shoots" comments in the media, but only for a day or two. There is no real understanding of the ability of nature to re-form the ecosystems that were burnt. Rather there is an expectation that nature will return to the pre-existing condition. It seems people think it is a great natural garden that will respond on its own, which to them is truly comforting, but not based on fact. How can people be educated that this is not the case, to shock the individual and collective security? Yet this is what we, as a community, must acknowledge, so that we can become active nature regenerators. How can this goodwill be harnessed?

There is an urgent need to educate for an understanding of the processes of nature and how we as humans can work with those processes, rather than against them and resulting in climate change, destructive use and extractive processes. There is a need for people to understand that there is no magic bullet and that a long time and a lot of learning will be required. Too often, people respond by feeding the animals that have survived *(WWF 2020; Manyana Matters and Sussex Inlet, Cudmirrah and Berrara FB pages 'Wildlife Warriors')*. This humanitarian activity helps locally at a small scale but does little for the overall ecosystems or populations.

Most of the will-to-respond has been taken on by larger community organisations, NGOs and government departments, essentially NPWS, RFS, Water NSW, and ForestCorp. Crown Lands have a crucial role to play in the long term as many of the areas they manage were unburnt, thus potentially providing an essential breeding area for animals. The size of the recovery task seems too big for this community will and even for the resources of government organisations, but it would be more feasible if there were six things in place before these fires:

- a special force trained not only in fire suppression but ecosystem recovery tasking
- a larger band of trained volunteers
- a much larger group of trained professionals within NPWS and the Department of Agriculture
- the inclusion of recovery planning in all reserve management plans, fire management strategies, Local Government Fire Risk Management Plans (due for review this year) and in the RFS suppression protocols
- the redesign of fire suppression and prescribed burning techniques to optimise the conservation of major conservation values and inclusion in all pre-burning and pre-season fire briefings
- a shared database of biodiversity, including maps showing the core areas for which individual management plans should be prepared and a mandatory element of Local Government and RFS Fire District Fire Risk Management Planning. (This can be achieved almost immediately as all reserve fire management strategies are in electronic format and available online or in pdf format.)

There are some outstanding examples of recovery efforts by professional workers with volunteer help, all of which were for endangered species, notably koalas and brush-tailed rocky wallabies This involved rescue and hospitalisation of individual animals which occurred in some coastal areas, and pre-fire translocation of part of a population eg Kanangra-Boyd and Morton NPs.

Immediate and short-term response

Post fire recovery can be assisted by immediate repairs to disturbance resulting from suppression operations. This has been practised by NPWS in some past fires and is usually done immediately after a fire is declared out but while still within the Section 44 declaration period. Although in the past such repairs did not contribute to recovery over larger regional areas, this may have changed post 2019-20 fires, with much larger areas being damaged by a range of suppression practices as follows:

- Earth moving machinery causes major structural change within bushland and exposes long distances of the forest face to drying and wind throw. In some of these operations the windrows increased the fire hazard. Combined with the soil disturbance, windrows are a source of weed infestation and harbour for feral animals.
- Retardant drops have been extensive over many conservation reserve areas and well beyond the boundary. There appears to be no information or research on the effects on native vegetation and plant pathogens. The effects of the increased phosphate load from retardants on low fertility landscapes and wetlands is unknown for most of the habitats on which they were dropped, but the issue has been raised, as a concern for some time, that concentrated phosphorus levels may impact some sensitive native vegetation species and ecosystems including swamplands.
- Helipad regeneration, rehabilitation of windrows, fire trails, vehicle turn-around areas and lay-bys have been done by NPWS on reserves and adjacent lands in the past.

- Monitoring of heavily impacted critical habitats and vegetation types has also been an integral post Section 44 rehabilitative process in many areas. Due to the impact from the Covid-19 pandemic following so closely after the fires, there has been little opportunity for post fire monitoring of ecosystems, let alone rehabilitation assessment and replacement of damaged infrastructure across the wider landscape *(ABC Illawarra interview with University of Wollongong, Department of Wildlife Ecology, April 2020)*.

- Post fire operations to repair fire breaks, reduce runoff and soil erosion are necessary immediately after the fire has passed. Following this most recent 2019-20 post fire period, heavy rainstorms caused extensive erosion of the soil, especially in areas where crown fire has occurred (canopy destruction) and on steep slopes *(Figure 29)*. This will delay regeneration of these sites, resulting in greater erosion and sedimentation of streams and water storages in many watersheds. Sediment deposits and water-borne weed propagules pose a massive threat of weed invasion.

- Weed removal programs require early commitment of authorities to contain weeds, as they are early colonisers of the ash bed, which is, for a short time, toxic for many native plants. The scale of these fires places a huge additional load on the available personnel including the dedicated volunteer force.

Figure 29: Eroded slopes in the upper Grose Valley (Blue Mountains National Park) following severe fire and heavy rainfall, 26 January 2020.
Source: Ian Brown 2020

Theatre of operations for recovery

A critical conservation role is played by a large volunteer force during non-emergency periods. Numerous local groups (including local Landcare and Bushcare volunteers) and statewide NGOs such as WIRES, ARC, Local Government and Land Services-supported native plant nurseries such as Wildplant Rescue, provide direct care for wildlife and a source of seeds and plants for regeneration. In the current circumstances the immense volume of material required is no doubt beyond their capabilities. Furthermore, the plant material available represents a small fraction of the full species and genetic variation required for ecosystem restocking.

Similarly, for animals such as macropods, bandicoots, and other small mammals; no organisation is equipped to provide the breeding stock to replace the vast numbers of animals killed (*Smith 2020)*. Mechanisms could include:

- animal hospitals and small reserves dedicated to the task
- conservation nurseries for plants
- volunteer gardens.

In practice it would be best to attend to the regeneration of core areas, then work outwards from unburnt patches and along the known flight paths of avian migrants.

The role of Incident Management Teams

The best way to minimise both environmental impacts during the fire and post-fire recovery is to minimise the size and intensity of the fire *(see Section3.1 - Initial Attack for Remote Fires and Section 3.3 - Suppression Strategies for Large Fires)*. Beyond this, bushfire suppression operations often give inadequate attention to environmental issues. A widespread view is that protection of life and property override all other considerations in a crisis. However environmental considerations do not need to unreasonably impede firefighting. It is often just as easy to reduce impacts as it is to cause them. Also, the Rural Fires Act and many bushfire policy and procedural documents impose a mandatory requirement to protect life, property and the environment. IMTs have a major role to play in this imperative. Dedicated ecologists with local knowledge must be included in the Planning/Operations sections of the IMT to facilitate this.

It is often expected that NPWS staff on IMTs will manage environmental concerns. However, the experience has been that they often lack power within the operation and can meet resistance, particularly from other sections, including Operations, as this is seen as a distraction or in some way not as critical as trying to extinguish the active edges. IMTs are obligated to take into consideration fire management strategies for conservation reserves, but do not always do so, citing lack of time or that this additional task being time-consuming and irrelevant to their suppression strategies. Such strategies should also identify vulnerable natural and cultural assets and how they should be protected during fires. These aspects have been considered during some suppression operations in the past but invariably in an ad hoc manner, if at all. Environmental protection and recovery planning should be elevated to key functions within the IMT, together with that of fire prediction. This should include establishing a special role and function for an ecology specialist to assist in the Planning Unit within the structure, particularly in major incidents.

Another area of impact is the construction of containment lines using large plant such as bulldozers. Unnecessary or excessive damage can be caused by inappropriate machinery, unskilled operators, poor technique, inadequate briefing and poor supervision. Some work is poorly conceived and planned. Sometimes bulldozer lines are put in 'freelance', without any authorisation from the IMT and under the cover of an 'emergency'.

Even though standard operating procedures exist, these problems occur in many large fires both on and off conservation reserves *(NPWS Blue Mountains Region Operations Plan 2019/20 S.3 Prevention SOP: 3.1.1 - 'Road and Trail Access Conditions for Other Agencies'; 3.1.1.2 - 'Use of Heavy Plant for Fire Suppression'; NPWS Fire Management Manual 2019/20 S2.2 - 'Fire Roads and Trails'; S4.3 - 'Earthmoving Equipment')*.

Yet the NSW Bush Fire Coordinating Committee has issued 'Minimal Impact Suppression and Rehabilitation Guidelines' which include details on appropriate use of plant and other concerns *(BFCC 2006)*. These guidelines are routinely not applied and are long overdue for revision.

During large fires, the IMT can improve ecological performance by mapping:

- fire severity
- unburnt patches and corridors
- where fire has overlapped with locations of high sensitivity (critical habitats, fire-vulnerable endangered species, cultural values, high soil erosion potential).

This gathered information could then form a base for designing a recovery plan across the landscape. Recovery planning is an important IMT function.

Another issue arises with funding. During a declared Section 44 fire (usually occurring during most large-scale fires) all costs are covered by the State Treasury-managed fund for emergencies. This includes the routine 'make good' plans that restore some, but not all, impacts after the fire. This phase usually includes actions like refilling dams used for water supply and repairing fences breached by firefighting machinery. The focus tends to be on private assets. Impacts to natural values often take longer to assess, organise and carry out, including the repair or restoration of containment lines.

It is then generally considered to be the responsibility of each agency to manage the impact and restoration on their respective lands following the emergency period. It is common for Section 44s to be de-declared as soon as the fire no longer poses a danger and, such repairs do not get done or funded in time. Often agencies are still suppressing pockets of fire or patrolling the fire grounds for some weeks. It is then up to the very limited resources of government land management agencies and others to plan and do this essential work, unless the recovery phase has already been commenced under the Section 44 declaration. This situation is dysfunctional and ineffective for environmental recovery, reflecting a 'blind spot' in the bushfire management system.

Techniques

If reconstruction of ecosystems is to be attempted on any scale it will need to consider the following:

- fauna translocation, to maximise species survival in a now patchy and less productive habitat
- fauna breeding and translocation to repopulate large areas and kick start the grazing regime re-seeding to kickstart the vegetation
- feed spreading to maintain the residual fauna and start their breeding cycles
- fertiliser spread for impoverished soils but only likely to be required in rare situations
- feral animal control and,
- acquisition and installation of coir rolls and other suitable erosion inhibitants to act as erosion controls particularly in steep terrain or adjacent to waterways and catchments, denuded of vegetative cover and humus layers pose a problem to water catchments, where the soft soil and ash layer can be subject to mass movement during intense rain periods.

This simple erosion control method could have been carried out in many areas in the fire-affected locations in 2019-2020, especially when Defence Force personnel were on hand and looking for useful things to do in the later stages of the emergency period.

These programs need to be thought through very carefully as any one of them applied singularly will have unintended consequences and long-term costs.

Resources

It is evident that insufficient resources are available to deal with ecosystem protection during the fires and in the aftermath. This lack of readiness parallels the inability of the fire suppression systems to deal effectively with multiple events. The following might be useful to consider:

- the specialised machinery required to carry out regenerative practices
- modifications to machinery design to benefit the environment, as current earth moving plant does not take this into account
- provision of professional ecologists and carers with special skills for recovery operations
- training of volunteers and RFS personnel in basic ecological principles and recovery techniques
- recruiting of volunteers to assist with post fire recovery
- increasing the role and involvement of NPWS field staff in emergency management operations at all levels, extending their training and building staff numbers to pre-restructuring levels.

The way forward

Major investment is required in:

- post-fire recovery programs
- training
- more staff
- more resources for NGOs and volunteer groups
- more supervision
- education of fire agencies
- make sure fire agencies have the most up to date regeneration status maps, including current sets of reserve fire management strategy mapping and guidelines (not an excuse as they are reviewed annually and available in electronic format)
- real science and a thorough ecological and dynamic database.

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4.3 Community Education

Issue

Since the 2009 Black Saturday fires in Victoria, RFS have made significant commitments to community education. Despite much excellent work, many people in communities affected by the 2019-2020 fires lacked the fire understanding they needed to deal with the situation. This led to unnecessary fear and inappropriate responses.

Opportunity

Significantly expand community fire education in rural and regional NSW while the impacts of the 2020 fires are fresh in the community's mind. This can build both community resilience to fire and informed support for fire management.

Issue Summary

In the period since Black Saturday, the Rural Fire Service has made considerable gains in community education and awareness. Current approaches are detailed in the RFS Community Engagement Strategic Directions 2017-2021 document *(RFS 2017)*. It details a structured approach operating from state-wide campaigns to local engagement exercises. Our intent to not to usurp this work, rather build on it based on our experiences during the fire emergency and previous fire seasons.

During incidents the *Fires Near Me* app is used extensively, indeed compulsively by communities. The RFS website provides considerable information on property and personal preparation, developing and enacting bushfire survival plans, understanding fire danger ratings and alert levels and requirements around construction and clearing. These formal communication channels are supported by RFS Community Liaison Officers and other RFS staff and RFS volunteers especially Brigade Captains. In this context RFS staff and volunteers enjoy considerable respect in rural communities.

Despite this, the enormity of the 2019-2020 fire season left some communities feeling vulnerable and indeed scared. At times this was unavoidable when whole communities faced rapidly moving and life-threatening fires. In other cases, residents in communities not under immediate threat of fire were still very scared and this may be attributed in part to residents' lack of understanding of fire mitigation, behaviour and suppression approaches.

Some communities appear to have been less fearful and better prepared. Wonboyn on the Far South Coast and Mount Wilson in the Blue Mountains are examples. These communities are small and in high risk locations and, in the case of Wonboyn, relatively isolated. These communities have a strong brigade presence and cohesive community dynamics. Both have Community Protection Plans in place.

Many communities in NSW faced the threat of fire for the first time in recent memory. This may happen to more communities as the fire situation gets worse under the influence of climate change. In communities potentially impacted by fire we have heard numerous stories of misinformation and uncertainty which exacerbated people's understandable fears. A lack of understanding of fire underpins many of these fears. The issue was more complicated in communities which had never experienced real fire threat or where there were large numbers of summer tourists.

The recent Bushfire and Natural Hazard CRC report into the Reedy (Tathra) fires *(BNHCRC 2020)* highlighted many key issues regarding community education which have been reinforced by the 2020 fires. Some of the findings include:

- People had not considered that bushfire could impact on Tathra. As noted above this is consistent with our observations that some communities were ill-prepared.
- Interviewees in the study described preparation as something which is done when the fire is threatening, rather than actions taken in advance of a fire starting.

Observations from the 2019-2020 fire season support these findings.

Recommendations for Community Education

- Include education as a formal component of community fire planning
- Further develop training resources which focus on particular issues where community understanding during the could be improved. These include:
  - > A package which considers the key elements of fire behaviour
  - > The difference between ember attack and cold burnt leaves and ash
  - > The difference between spot fires and fire fronts
  - > The role of hazard reduction in reducing risk
  - > The nature of fuels
  - > Property preparation
  - > Leaving and defending
  - > Understanding risk.
  - > Media education
- Establish a system of Community Champions who are given responsibilities for disseminating information during emergencies.

Issue Analysis

The 2019-2020 fires are fresh in the minds of all Australians. The next year or two will give the best opportunities to develop and implement community education programs, before we enter an inevitable period of greater complacency.

Link education to community fire planning

The 2019-2020 fires have increased community awareness and willingness to be involved in community fire planning. This is discussed in more detail in *Section 2.3 - Community Fire Planning*. In some cases, enhanced community fire planning is a consequence of this season's bushfires. In Pambula Beach, a small village on the Far South Coast, residents have agreed to develop a Community Protection Plan under the auspices of the Rural Fire Service. This follows a series of meetings during the fire crisis asking for emergency action, such as the construction of enhanced Asset Protection
Zones.

Such community driven and RFS facilitated exercises will provide excellent opportunities to improve the community's understanding of fire. It will be undertaken through field inspection of the surrounding forest conducted by RFS staff and augmented by RFS training materials.

Further develop formal training materials for use in communities

Fire is complex and often poorly understood. Fire services have prepared and disseminated materials on many of the themes discussed in this section. Nonetheless there are some issues where further work is important. New training materials could focus on particular issues where community understanding could be improved. Some of these include:

- *A package which considers the key elements of fire behaviour* including weather, fuel moisture, fuel loadings and topography ('Fire 101').
- *The difference between ember attack and cold burnt leaves and ash.* Town and villages were subject to significant falls of cold burnt leaves and ash, often some

significant distance from active fire. Many in the community perceived that they were under ember attack and were unnecessarily concerned.

- *The difference between spot fires and fire fronts.* Some people in fire affected areas underestimated the importance and risks of spotting to their safety and to the protection of structures. This issue is reported in the Reedy Swamp study where some Tathra residents were surprised that embers could carry the fire so far into town.
- *The role of hazard reduction in reducing risk.* Many commentators, including members of parliament and others in prominent positions, attributed the scale and ferocity of the fires to a lack of hazard reduction. This view has considerable support in rural and regional communities. The issue is discussed to some extent in *Section 2.2 - Aspects of Bushland Management*, however it is worth reiterating that in this fire season many recent broad scale prescribed burns did little to protect communities. Community education should emphasise that prescribed burning is not a panacea and that fuel management close to assets is critical. It should highlight the responsibilities of residents for effective fuel and property management to reduce risk.
- *The nature of fuels.* There is a view that any woody vegetation contributes to rate of spread and intensity. The importance of fine fuels needs to be understood.
- *Property preparation.* The RFS website provides detailed information on property preparation. This could be augmented by developing videos on preparation and ideally by the RFS doing more property inspections as an outreach service. This is done by RFS brigades in some areas in the state such as the Blue Mountains. Late preparation was the norm in many locations which emphasises the importance of promoting preparation as an ongoing activity rather than something which happens when a fire is approaching.
- *Leaving and defending.* Fire agencies have produced considerable material on leaving/defending decisions and importance of having a fire plan in place. This includes the graphic television advertisement showing the consequences of leaving too late. Despite this, many in the community found the decision difficult and often changed their minds as fire threatened. Others spoke of the stress and fear they experienced when defending. Others left when there was no need to. Education materials should focus on developing a better understanding of when to leave and the difficulties of defending. There remain some unrealistic expectations about the degree of support which can be expected from the fire agencies during emergencies. Education materials aimed at the leaving/defending decision need to reinforce the reality that there will not be an appliance to protect every property.
- *Understanding risk.* The two components of risk – likelihood and consequence are not fully understood in the community. The effect of this is that communities don't fully appreciate the potential catastrophic consequence of an event which may only occur once in their lifetime.
- *Media education.* Local media was particularly important in disseminating information. However, at times certain media was unnecessarily sensationalist or misconstrued some of the basics of fire management. The confusion between backburning and hazard reduction is an obvious example. More active engagement with media prior to summer is desirable. The material should be prepared by expert communicators who can translate complex scientific information into material which can be readily understood by communities.

Upskill community members to support RFS communication during major fire events

Providing timely and accurate information to the community about the location, fire behaviour and likely impact of major fires is extremely difficult. It is particularly challenging for landscape scale fires where fire behaviour can differ dramatically over the fire ground and there is incomplete fire ground intelligence.

The public liaison role in IMTs is critical and there are many examples in this fire season of a very high standard work. However, it is a complex role and needs support. In some locations senior brigade personnel fill this role, however it is too much to expect that RFS volunteers can fill both operational and public liaison roles during fire emergencies.

While the *Fires Near Me* app is used extensively there are concerns that for very large fires it does not provide the level of detail that communities require. The communication challenge is heightened by the extensive use of social media, where there is considerable misinformation. In rural and regional communities, word-of-mouth is particularly important and again we have observed that a significant proportion of word-of-mouth information is incorrect.

There have been success stories which point to ways forward. In some locations informal community meetings were convened during the emergency by retired land and fire management professionals. In others, prominent local leaders took on the role of being the central point for checking and disseminating information for the local communities through mediums such as community Facebook pages and community meetings. RFS 'fire shed meetings' were also effective.

Many of these approaches developed organically during the fire emergency. They could be formalised by establishing a system of Community Champions who are given responsibilities for disseminating information during emergencies. It would be desirable but not necessary for Community Champions to have extensive fire management experience though, what is more important, is that they have significant respect in the community.

The Blue Mountains Heads Up for Fire (HUFF) project is one example of volunteer led processes to engage communities in emergency management. While HUFF is aimed mainly at preparation the principles apply more broadly. At its core the process is driven by trained community facilitators who operate at a street level *(HUFF 2020)*. Implementing a Community Champions approach would require a formal training program to be developed and implemented.

The 2019-2020 fire season tested systems and approaches in all aspects of fire control to their limits. It now provides an unparalleled opportunity to review and improve the way we do things. Community education is no exception. New approaches which might develop from this review need to be implemented as soon as possible while the fires are 'front of mind' in the community.

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Part 5 – Detailed Fire Studies

Fire Studies Summary

The lessons learnt from these fire studies could be applied across all the bushfires:

- The importance of rapid and effective initial attack within 2-6 hours after detection and working overnight when fuel moisture and wind speeds can be favourable for safe ground crew operation.
- Applying effective fire containment strategies using a variety of options instead of over-reliance on backburning (in other words indirect attack).
- The high risk of backburn failures resulting from unfavourable drought fuel conditions, dead fine fuel moisture content and local wind conditions. The need to withdraw from operations when the proposed backburn is outside guidelines (eg RFS Fireground SOP #17, 1999, *see Section 3.3 - Suppression Strategies for Large Fires*).
- These fire studies also highlight the high risks associated with undertaking large scale backburns over kilometres; implementing tens of kilometres of fire containment lines either on one day or over several days and; the potential for backburn escapes due adverse high-severity fire weather conditions, especially during drought and heat-wave conditions.
- These issues and associated factors are discussed in detail in *Sections 2.1, 2.4, 3.1, 3.2, 3.3 and 3.9* of this report.

These fire studies show that backburning is not always the safest and most practical fire tactic when undertaken at a large scale on large bushfires without careful and due regard to local fire landscape conditions. As a local tactic done at the right time of the day and in the right period it can be an important containment option when carried out like a prescribed burn under mild fire weather conditions with due recognition to backburn escape risk factors. These factors include very low dead fine fuel moisture contents (3-10%), winds in excess of 15-20 km/h, unstable atmosphere, high Haines index and severe fire weather events within a 1-3 day period of the burn, often occasioned with significant wind changes across the fireground.

Some of the backburns conducted in the 2019-2020 fire season and those in previous fire seasons were carried out as a very high fire risk strategy. These carried the penalty of loss of property and post-traumatic stress in people affected, as well as a deep division in local communities about their merit or otherwise.

We especially highlight the need for integrated knowledge of fire landscapes, fuel types, ambient drought conditions and fire weather patterns both historical and during the suppression of a bushfire. Much of this detailed knowledge and experience has been lost in the fire agencies as a result of organisational restructures in the last 20 years.

Bees Nest Fire map and notes by Phil Zylstra. All other studies, analysis, reconstruction and mapping by Nick Gellie, with map design by Ian Charles and Nick Gellie.

Introduction to Fire Studies

These fire studies from the 2019-2020 season use analysis, maps and text to illustrate some of the issues raised in this report. Weather data and graphics are included in some of the studies to assist understanding. The studies are 'first cut' analyses, offered as examples that can be improved with more information and work.

Several studies are from the Greater Blue Mountains area, as this region is well known to a number of authors of this report, and more information was available for these fires.

The studies have been prepared under several limitations, including time and not having access to the full range of analytical resources. Available data sources were used including satellite imagery, weather records and informants from the fireground. Some important inputs were not available, such as infrared fire linescans, incident mapping and Incident Action Plans. Other information not available for these studies include the amount and location of resources applied to various strategies and the pattern of aerial attack. Consequently, there may be errors in some details of these studies. The basic events are considered to be correct but could be refined with access to all relevant information.

The fires are presented in terms of factual events with some interpretation. The reasons for various decisions made on the fires, and the influences on those decisions, are mostly unknown. Speculation on these is avoided.

These studies demonstrate the potential for comprehensive post-fire analysis. Such work can identify successful and unsuccessful strategies, and the factors that made the difference. Conclusions can then inform future operations and improved suppression practices. Every major fire should be analysed in this way. By spending a tiny fraction of suppression costs on post-fire analysis, the impacts, trauma and costs of future fires could be reduced.

These studies can be broken into three large fires, with details of backburn escapes and containment problems on those fires, and two other fires as listed in *Figure FS1*. The locations of the fires are shown in this table. The analyses have been restricted to the Blue Mountains, Currowan and Half Penny Hill bushfires *(Figure FS2)* in the south and the Bees Nest bushfire in the north. There are many other case studies still to be investigated in the 2019-2020 bushfire season.

> ***NB:*** *It is recognised that these studies do not consider unknown factors that may have applied in some situations. Operations during the extraordinary 2019-2020 fire season were sometimes hampered by issues that constrained suppression options. These factors included smoke affecting aerial operations, inadequate fireground information and the limited supply of critical firefighting resources such as aircraft and RAF teams. Because it has not been possible to take these constraints into account, these studies should be taken as identifying potential alternative strategies and outcomes. Nevertheless, analysis such as in these fire studies is always valuable.*

No.	Bushfire	Issue	Perspective	Location	Period
1	Green Wattle Creek	Strategic containment	Whole fire	Southern Blue Mountains	05 – 16 Dec 2019
2	Green Wattle Creek- Seabrook Road escape	Backburn failure	Seabrook Road, Balmoral area	Eastern Nattai catchment	19 -20 Dec 2019
3	Gospers Mountain- South-west section	Strategic containment	South-west perimeters	Newnes Plateau and Wollangambe River catchments	07 Dec – 11 Dec 2109
4	Gospers Mountain- Newnes Plateau	Backburn failure	Glow Worm Tunnel Road	Northern Newnes Plateau	07-11 Dec 2019
5	Gospers Mountain- Mount Wilson escape	Backburn failure	Mount Wilson Road	Bells Line of Road at the intersection of Bowens Creek, Wollangambe, and Grose River catchments	14-16 Dec 2019
6	Mount Wilson Road (Grose)	Strategic containment	Southern perimeter	Grose Valley	21-31 Dec 2019
7	Currowan-Tianjara Complex – early stages	Early strategic containment	Currowan State Forest and Budawang National Park	Clyde River catchment	27 Nov – 1 Dec 2019
8	Currowan-Tianjara Complex – Milton-Conjola	Tactical containment and backburn failures	Conjola Park	Eastern escarpment of Milton precinct	27-31 Dec 2019
9	Currowan-Tianjara Complex – Clyde Mountain	Strategic containment	Kings Highway	Monga National Park and Buckenbowra River catchment	17-31 Dec 2019
10	Half Penny Hill	Initial attack	All fire	Byadbo area, Kosciuszko NP	27-28 Dec 2019
11	Bees Nest	Fire modelling and strategies	Moonmerri Creek	North of Dorrigo	Around 9 Sept 2019

Figure FS1: Locations, issues, perspectives and periods of fire studies

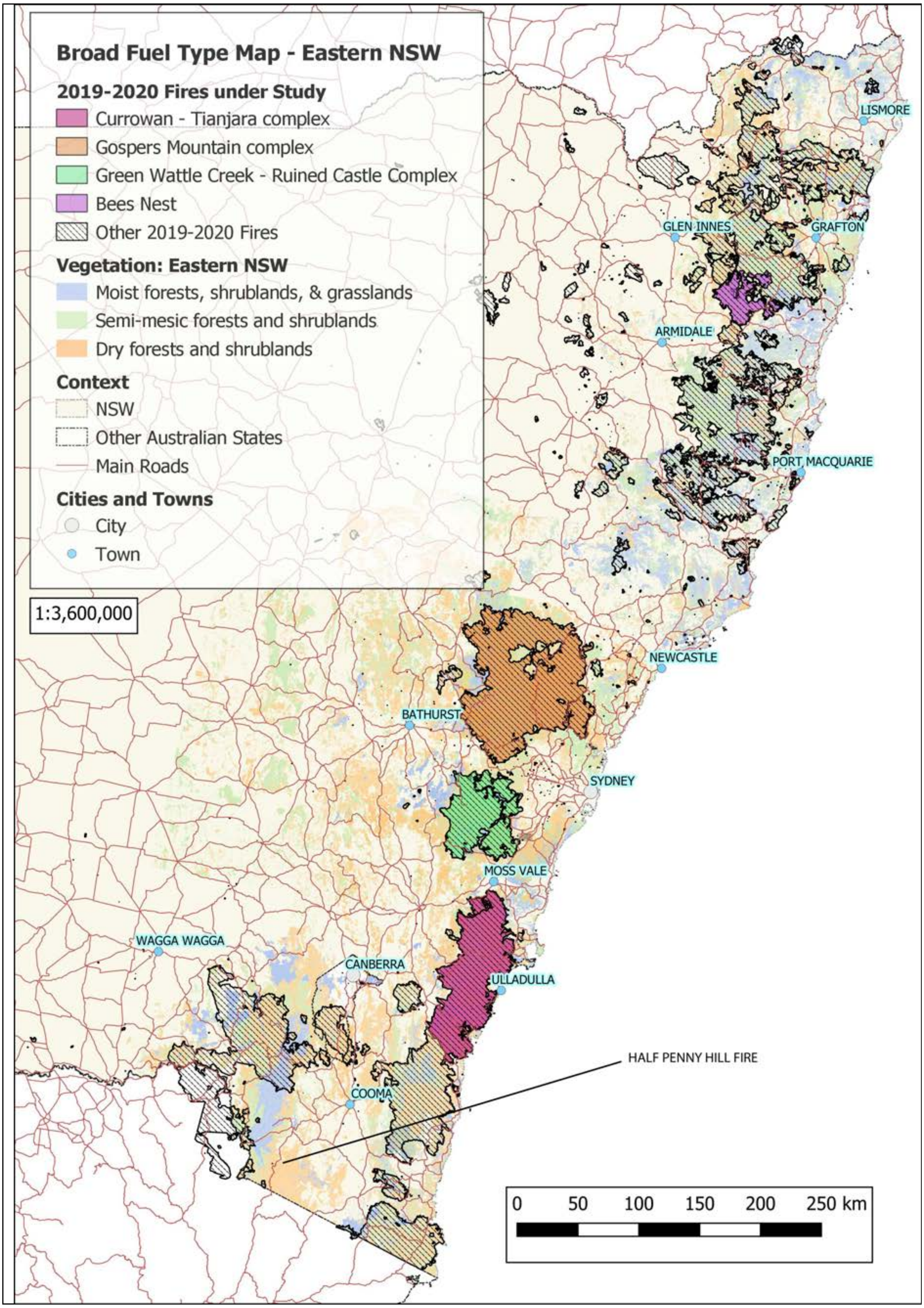


Figure FS2: General location and context of fire studies (vegetation/fuel type mapping by N Gellie)

Notes on fire weather analyses for these fire studies

In these analyses we use estimates of dead fine fuel moisture content (DFMC) and 10-m wind speeds from the nearest weather station as the primary raw indices of potential fire risk. These data can be used for determining whether a backburn is inside or outside management prescriptions. DFMC is derived from the simplified Matthew fuel moisture content equations published in the literature.

We also used the Noble at al equations for the Forest Fire Danger Index (FFDI) in our studies (1-9). In many cases, because of the high atmospheric instability, the drought-affected live and dead fuels did not reflect in many instances the extremely low live fuel moisture contents in these case studies. We have included the FFDI as a comparative index together with wind direction to provide context for the fire studies' analyses. The reason is the Drought Factor with a scale of 1-10 in the FFDI does not reflect the actual 'deep' drought conditions of low dead fuel contents in the coarse woody debris, tree or understorey bark (especially rough-barked tea-tree species) and live fuel moisture contents in the understorey and tree canopy.

Fire weather data was extracted from Weatherzone Pro and pasted into an Excel spreadsheet and the algorithms for DFMC, and FFDI were then added. Line graphs for the periods of each study were then generated to depict the trends for each of the fire weather variables.

Figure FS3 presents the weather stations used for each of the fire studies.

Seasonal drought trends for the three regions of eastern NSW

Drought plays a major role in making fire landscapes susceptible to large landscape fires and to extreme fire behaviour (Gellie 2009). For background in these fire studies, we use the Mount Soil Dryness Index which can be calibrated to a particular station or local area using catchment run-off data. In fact, Mount (1972) developed and calibrated his daily soil water balance model (DSWBM) on Lidsdale run-off data south of Wallerawang in central eastern NSW. It is widely accepted in Australia as an alternative to estimating soil water deficit (SWD) to Keetch-Byram Drought Index (KBDI) still in use in much of Australia.

We present below the trends in SWD, and modelled grass curing and tree canopy moisture content for three representative stations with complete temperature and rainfall records *(see Figure FS4)* in the three main fire-affected regions in eastern New South Wales. We could have analysed SWD to cover the full range of environments in each region. However, we had limited time to complete the extra work involved.

The modelled grass curing is derived from Roger Hosking's model (1981) of grassland curing index for grasslands near Braidwood. The modelled moisture content for trees is an interim model to describe the effect of severe drought on water stress in eucalypt leaves. Both models need further validation in different climate zones.

Detailed trend in SWD for the three regions is presented in *Figures FS5, FS6, FS7* over the period of reliable weather records. An inter-annual trend on a daily basis is presented in (a) and then (b) for the last two years up until May 2020.

In the last four years on the North Coast of NSW, there were three fire seasons in 2015-2016, 2018-2019, and 2019-2020 which had much higher SWD deficits than in comparable severe fire seasons in the past *(Figure FS8)*. The trends indicate that these droughts have become more frequent and intense in the last ten years, suggesting some possible changes in seasonal climate. For the Blue Mountains, the trends in seasonal SWD suggest that intense periods of drought are becoming more frequent mirroring the trends up the North Coast.

Based on the results presented in *Figure FS5*, the 2019-2020 fire season was comparable to 1979-80, 1982-83, 1990-91, 2001-02, 2013-14, 2015-16, 2017-2018. The 2005-6 and 2006-07 fire seasons belonged to a seasonal drought pattern that spanned two fire seasons. For the South Coast from Nowra to Batemans Bay, 2019-2020 came at the end of one of the most prolonged droughts and was comparable to the 2001-02 and 2002-03 and 1979/80-1982/83 sets of fire seasons. Unlike the Sydney Basin, recurrent drought is more of a feature of the Morton plateau and Budawang Ranges (Southern Highlands/South Coast) and can be prolonged over several fire seasons.

No.	Bushfire	Weather Station	Geographic Location	Lat / Long	Elevation (m)
1	Green Wattle Creek	Richmond AWS	Coastal lowlands	33.60°S 150.75°E	14
2	Green Wattle Creek-Seabrook Road escape	Richmond AWS	Northern Nattai	33.60°S 150.75°E	14
2		Moss Vale	Nattai Tablelands	34.55°S 150.37°E	680
3	Gospers Mountain-South-west section	Marrangaroo AWS	Newnes Plateau	33.43°S 150.11°E	961
4	Gospers Mountain-Newnes Plateau	Mount Boyce	Newnes Plateau, Grose Valley	33.64°S 150.28°E	1067
		Marrangaroo AWS	Newnes Plateau	33.43°S 150.11°E	961
5	Gospers Mountain-Mount Wilson escape	Marrangaroo AWS	Newnes Plateau	33.43°S 150.11°E	961
		Mount Boyce	Newnes Plateau, Grose Valley	33.64°S 150.28°E	1067
6	Grose (Mount Wilson Road)	Mount Boyce	Newnes Plateau, Grose Valley	33.64°S 150.28°E	1067
7	Currowan	Braidwood		35.36°S 150.47°E	7
		Ulladulla	Currowan Clyde River basin	35.36°S 150.47°E	5
		Ulladulla	Currowan Clyde River basin	35.36°S 150.47°E	5
9	Currowan-Tianjara Complex	Braidwood	South Coast Escarpment	35.71°S 150.17°E	7
		Moruya Airport	South Coastal Lowlands	35.91°S 150.08°E	10
10	Half Penny Hill	Nil – no weather data or analysis used			
11	Bees Nest	Nil – no weather data or analysis used			

Figure FS3: Details of weather stations used in study

No.	Region	Station	Elevation (metres above sea level)	Length of Record	Fires
1	North Coast	Pilot Head	0	1910 - 2020	Bees Nest
2	Blue Mountains	Bilpin	630	1971 - 2020	Gospers Mountain
3	South Coast	Braidwood	800	1971 0 2020	Currowan-Tianjara Complex

Figure FS4: Representative Weather Stations to estimate SWD by regions

In addition, the results for the three stations show that the deep drought period (SWD>140 mm) occurred one month earlier at Yamba Head (North Coast) during late October compared to Bilpin (Blue Mountains). The SWD for the Braidwood station (Monaro) had a much longer drought period than the other two stations in the Sydney Basin and in the North Coast starting well back in the 2017-2018 fire season. The exposed Morton plateau soils and heathy woodlands were therefore in much deeper state of moisture stress in the vegetation than the forest vegetation at the start of the fire season. Two years of below-average rainfall in the Nerriga area created a much more flammable fuel state than in the other two locations. The near-surface and understorey fuels in the heathlands and heathy woodlands became even more highly desiccated during the prolonged dry period from about mid-December onwards.

In the Blue Mountains understorey dieback from prolonged lack of rainfall in the peak summer period was prevalent in heathland, eucalypt dry shrubby forest and eucalypt semi-mesic forest in the upper Blue Mountains from early to mid-January 2020 *(see Figure FS8)*.

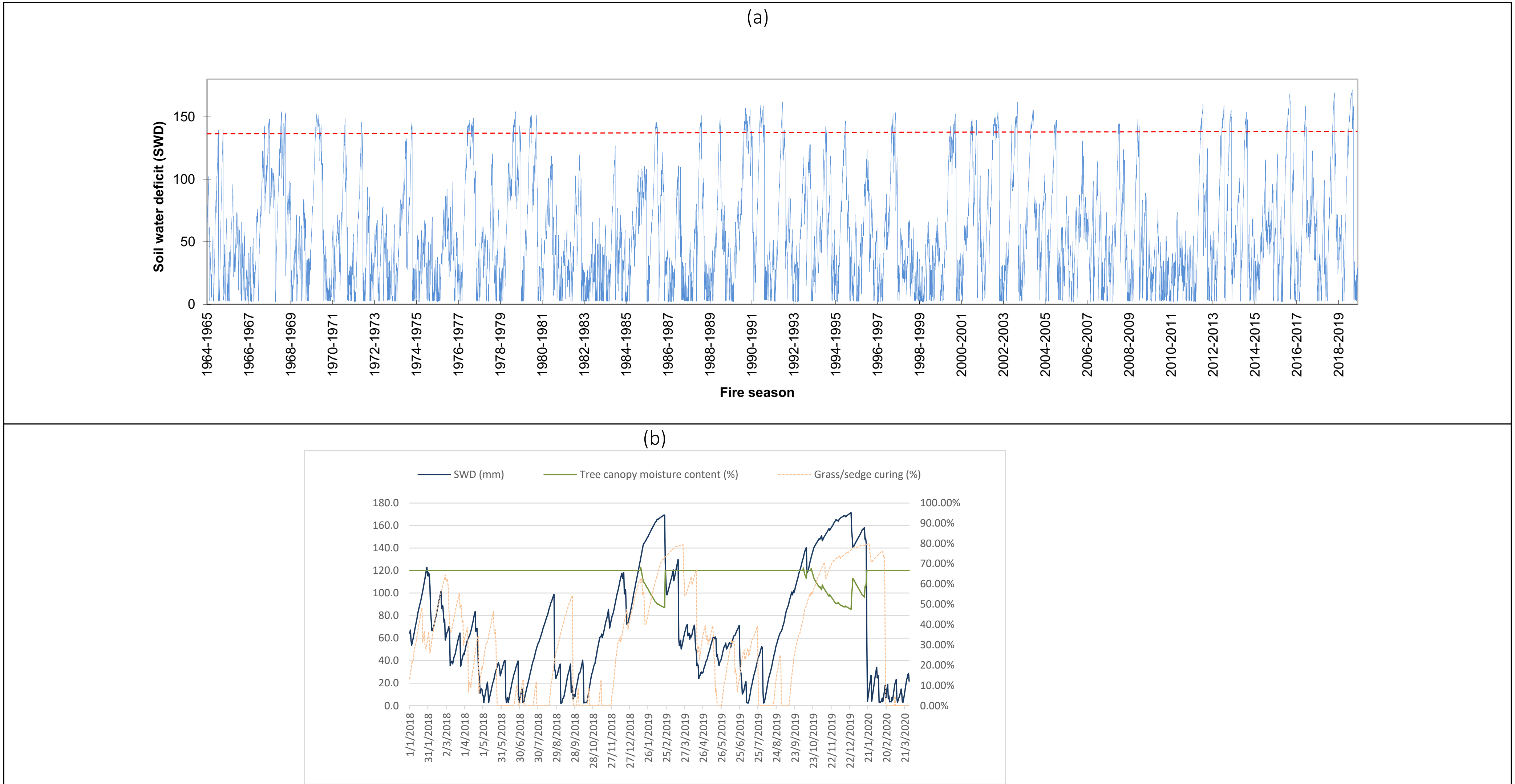


Figure FS5: (a) Trends in annual soil water deficit (SWD) in mm for Yamba head (North Coast) 1964-65 – 2018/2019 (b) Modelled trends in SWD< tree canopy moisture content, and grass/sedge curing 2017/18 – 2018/2019

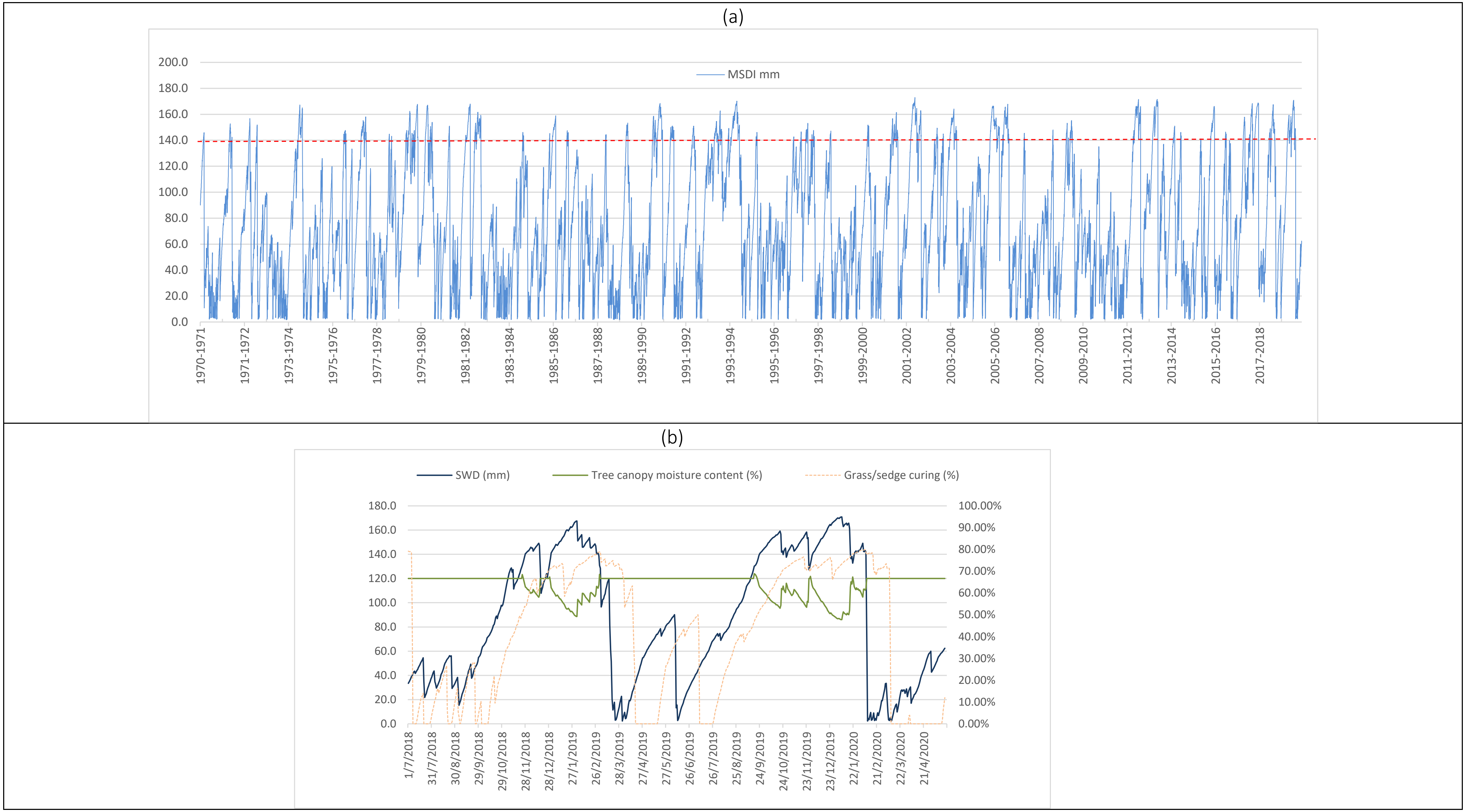
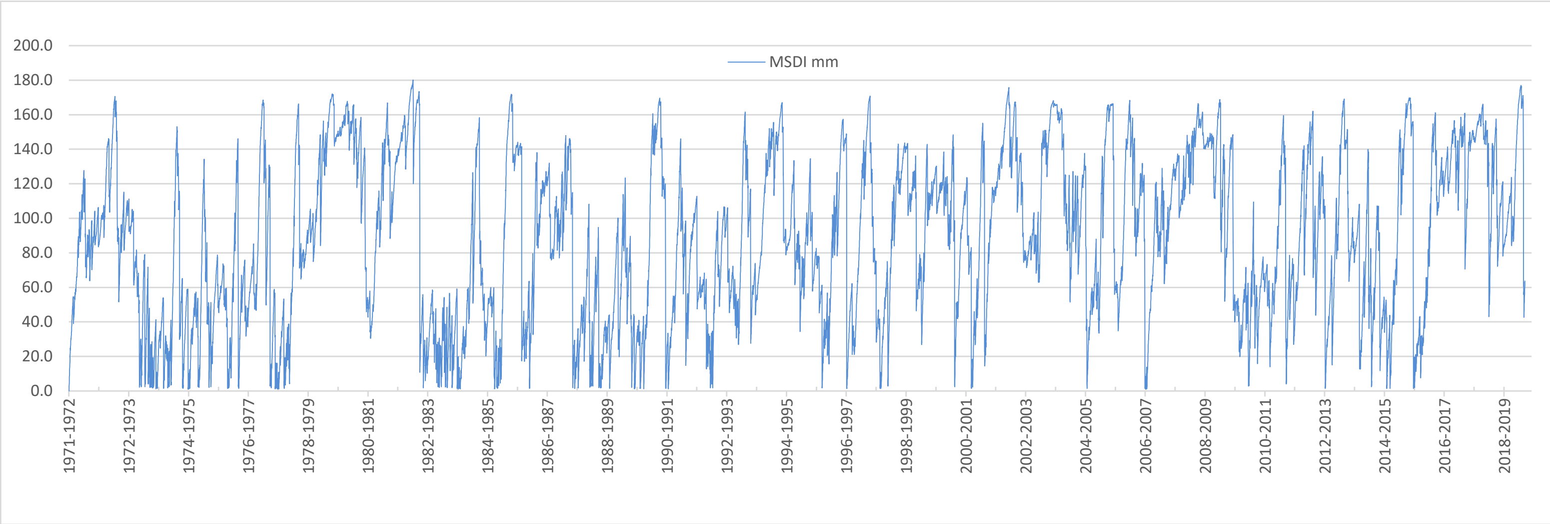


Figure FS6: (a) Trends in annual soil water deficit (SWD) in mm for Bilpin (Blue Mountains) 1970-71 – 2018/2019 (b) Modelled trends in SWD< tree canopy moisture content, and grass/sedge curing 2017/18 – 2018/2019

(a)



(b)

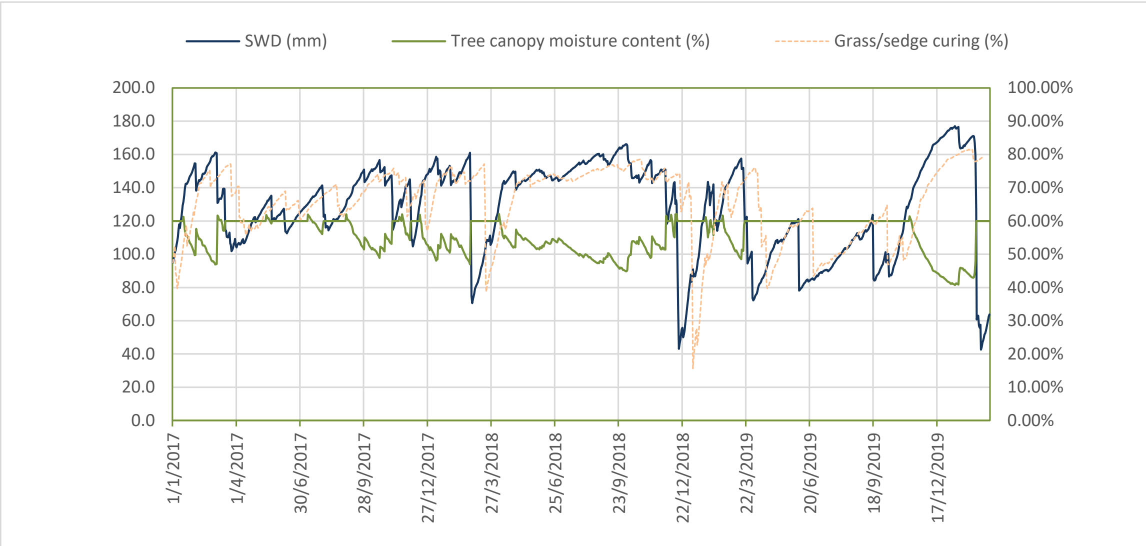


Figure FS7: (a) Trends in annual soil water deficit (SWD) in mm for Nerriga composite (South Coast) 1971-72 – 2018/2019 (b) Modelled trends in SWD< tree canopy moisture content, and grass/sedge curing 2017/18 – 2018/2019

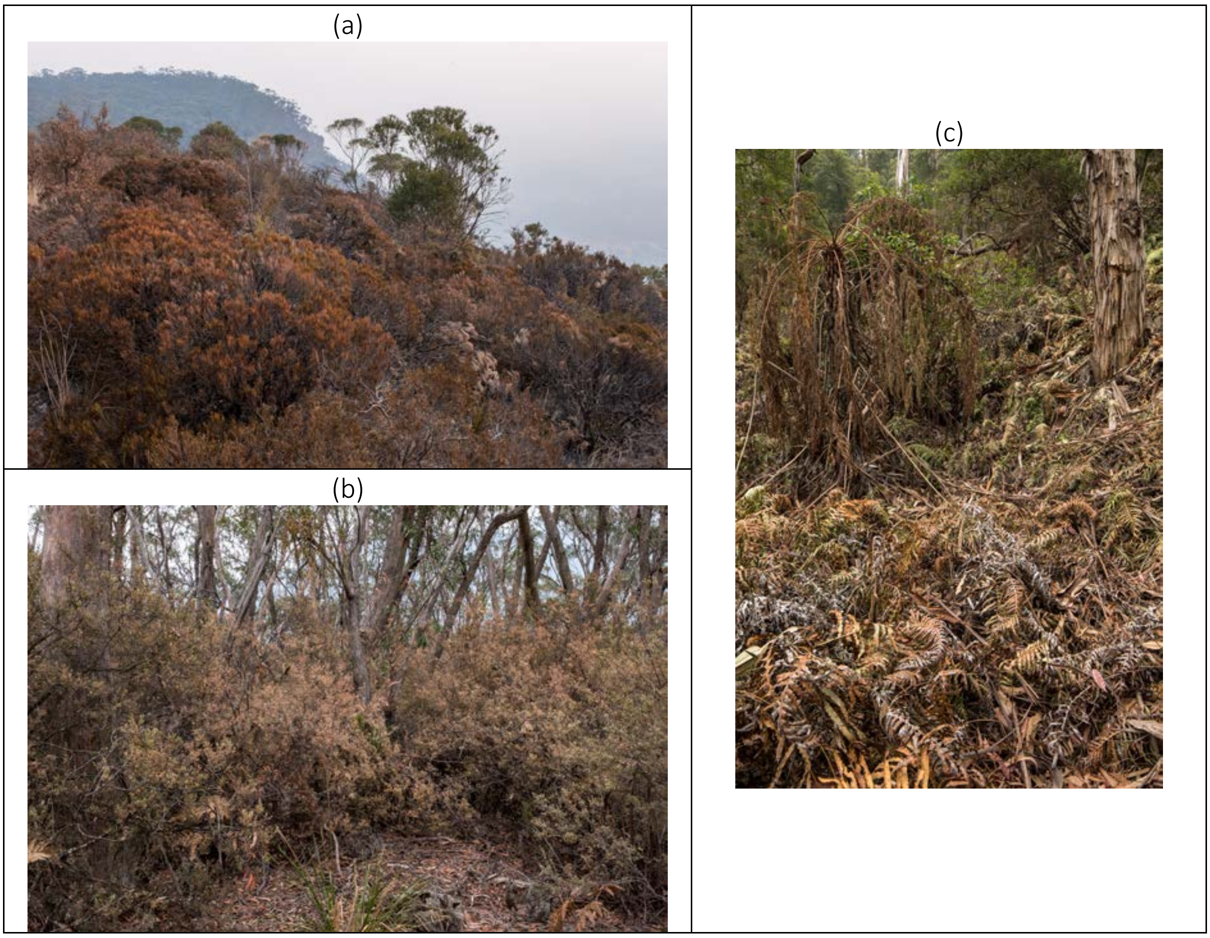


Figure FS8: Understorey dieback due to prolonged drought in (a) heathland at elevation c1040m (b) dry shrubby forest at elevation c1020m (c) semi-mesic eucalypt forest at elevation c750m, all at Mount Victoria (Blue Mountains) in late December 2019 (Photos: I. Brown).

Fire Study 1: Green Wattle Creek-Kowmung Complex bushfire
Issue: Strategic Containment
Period: 05 -16 December 2019

Introduction
The purpose of this fire study is to highlight where strategic containment could have occurred to limit the impact and severity of the Green Wattle Creek-Kowmung Complex bushfire through these considerations:

- identifying critical sections of the containment strategy to be worked on, avoiding backburns when running into severe fire weather patterns and when the actual fire was burning in low fuels
- recognising when, where and how various fire advantages in the landscape can be used to slow or even break up a fire's momentum and impact
- prioritising water catchment values when working up current and future fire containment strategies.

This is an example of a fire that became very large, complex and damaging when initial attack on remote lightning strikes did not succeed. Many control strategies were used at different times in different places with mixed success leading to 80% or more of the Warragamba inner catchment and almost 90% of the southern Blue Mountains and Kanangra-Boyd National Park being burnt in this bushfire complex.

The Green Wattle Creek-Kowmung complex bushfire began on 27 November 2019 and burnt for 64 days until 29 January 2020, with a final size of 278,722 ha (a figure which may include the 'Erskine Creek fire' breakout). About 40 homes were destroyed during the fire, mainly from two fire runs: the first, on 5-6 December from a spot-over on 5 December into Orangeville (this study); and the second, from an escaped backburn later on 19 December that hit Balmoral *(Fire Study 3)*.

See map *Figure FS9*.

Situation
Two fires, Kowmung River and Green Wattle Creek, began from lightning strikes in remote national park west of Lake Burragorang. The fires were not contained and spread in all directions. By 26 November, after burning for nine days, they had almost merged into one fire complex. They were approaching critical containment lines which if breached would lead to the two fires enlarging and burning more forest areas in southern Blue Mountains and Nattai National Parks.

Important fire landscape features

- There is a high diversity of dry, semi-mesic, and mesic eucalypt forests and woodlands in the inner Warragamba catchment resulting from: (1) the geodiversity of rocks from the Devonian, Permian, and Triassic geological periods, with a scattering of limestone and Porphyry, and (2) the strong gradients in rainfall between the Burragorang dam at low elevation rising to over 1100 m on the Boyd Plateau and Cloudmaker in the western part of the landscape. Semi-mesic and mesic eucalypt forests occur on the higher sheltered parts of the plateau and escarpment while drier shrubby woodlands and forest predominate on the lower sandstone and Permian mudstone plateaux on the Nattai, Tonalli and Bimlow Tablelands.
- Low-fuel mosaics occur naturally in the lower, sheltered elevations of the Kowmung, Green Wattle, and Wanganderry Creek catchments ideal for RAFT fire operations. Typical fuel types include Box and Ironbark open eucalypt forests with a sparse surface litter and understorey fuels.

- Medium range fire spotting eastwards across Lake Burragorang has been a prominent characteristic of earlier bushfires in the Warragamaba inner catchment including the 1965 and 1968 Blue Breaks bushfires and the Mount Hall bushfire in 2001, particularly in the Tonalli Tableland and W5 fire trail areas. This risk has been successfully managed in the past by using aerial ignition to burn out the plateaus west of the lake under benign conditions, to prevent intense fire behaviour and spotting. Examples include the Tonalli Tableland and Wanganderry bushfires in December 1997 and later in 2007 in another fire on the Tonalli Tableland.

Fire weather patterns

- Fire behaviour 'spike' days occurred on 5, 6, 10, and 19 December. Otherwise fire weather was more benign between 7 and 9 December and between 11 and 19 Dec *(see weather charts in Figure FS10)*. There were many days on which DFMCs recovered to over 20-22% from moist easterly sea breezes and gradient winds during the study period in this case study.
- Fire runs were under west or south-west fire winds, more typical of earlier in a Sydney Basin fire season. Therefore, the fire runs were not likely to progress rapidly south towards townships under perceived threat to the south and south-east of the fire complex (eg Bargo, Balmoral, etc).

Containment strategies

- We have not investigated in detail why initial attack on the lightning strikes was either not attempted or did not succeed. It is likely that availability of RAFT crews and fixed wing and helicopter aircraft and possibly fire behaviour were key issues.
- The two fires spreading unchecked through the Warragamba catchment created a higher fire risk and threat as each day passed.
- The 5 December medium range spot-over across Lake Burragorang occurred at one of the narrowest parts of the lake from a small patch of dry eucalypt forest left burning and local wind turbulence coming over the Tonalli Tableland. The typical range of spotting from small patches of rough-barked eucalypt can be 1-2 km during the passage of very dry air masses from a localised fire eruption. It is likely that other embers landed in the lake elsewhere.
- It is not known if the risk of these spot-overs was identified or could be reduced with aerial ignition.
- The potential southern containment line along the Oberon-Colong Stock Route was breached in several places from spot fires resulting from a 'blow-up' fire caused by the backburns lit the day before and into the early part of the of 10 December. It would have been forecast that a very dry turbulent westerly air mass would create very high – severe fire weather conditions (DFMCs 2.5-3% and 10-m average speeds in excess of 30 km/h) and high severity fire in the Ruby Creek catchment.
- This breach led to a very large expansion of the fire to the south within southern Blue Mountains National Park. The Oberon-Colong Stock Route is relatively remote and resource constraints may have been an issue relative to the more populous threat in the east of the fire.
- The south-west section of the Kowmung River bushfire ran into a 2018-2019 prescribed fire. On 10 December the main fire hardly moved because of the 'low' fuel types in the lower parts of the upper Kowmung River catchment.
- An obvious objective was to keep the fire west of the Lake Burragorang-Wollondilly River corridor. This did not succeed due to the backburn escape east of Yerranderie (Colemans Bend) and the spot over across Lake Burragorang.

- Indirect containment strategy missed the potential to directly attack the fire on the Bimlow Tableland and south of Wanganderry, leading to larger than necessary areas being burnt in a critical water catchment for Sydney.
- Timing and necessity of backburns led to blow-outs across Colong Stock Route and from Colemans Bend onto the eastern side of Wollondilly River.

Potential lessons

- Give high priority to initial attack on remote fires that pose medium to long-term significant threat to water catchment and populated areas.
- Apply a more proactive and strategic approach to containment using a variety of tactics based on a thorough appreciation of local landscape, fuel conditions and fire weather, particularly in highly diverse fire landscapes.
- Avoid conducting backburns in the 1-3-day period before a severe fire weather event with likely easterly or south-easterly fire run creating high-severity fires in a water catchment or in a National Park or Nature Reserve or State Forest.
- Use partial containment tactics to check any active sectors of a bushfire particularly where it is burning in 'low' fuels in sparse eucalypt fuel types.

Key events *(as shown on map Figure FS9)*

1. 5 Dec after midnight: A significant single spot fire spotted 1.5 km from a small patch of remnant unburnt Eucalypt forest across the Nattai Arm of Lake Burragorang and impacted Orangeville and other villages to the east of the lake later on 6 December.
2. 5-6 December: A backburn east of Yerranderie (Colemans Bend) escaped and later spread eastwards the following day across the Wollondilly River onto the Wanganderry Tablelands.
3. 10 Dec: A large backburn near Mt Werong overran the potential containment line along the Oberon-Colong Stock Route (aka Yerranderie Road).
4. 12 Dec: The wildfire overran the Oberon-Colong Stock Route potential containment line on the Bindook Plateau.
5. Between 5 and 7 December, Lake Burragorang and the lower reaches of the Cox River acted as significant natural fire advantages to stop most of the eastern front of the wildfire.
6. Between 6 and 18 December, the Coxs River acted as a natural fire advantage to hold most of the northern advance of the fire (later breached when the north-western corner of the wildfire burnt eastwards across the Coxs River).
7. 13-15 Dec: A long backburn using trails and pasture edges successfully contained the western edge of the fire from Boyd Plateau to Mt Werong.
8. 16-18 Dec: A potential containment line along Moorara Fire trail and Jenolan River was not used (fallback backburn strategy around western side of Jenolan caves was later used, leading to severe impacts on Jenolan Caves Karst Conservation Reserve and infrastructure). Fire trails could have been used as a partial containment tactic on the higher parts of the northern Boyd Plateau to stop the Kowmung River bushfire's westerly progress.

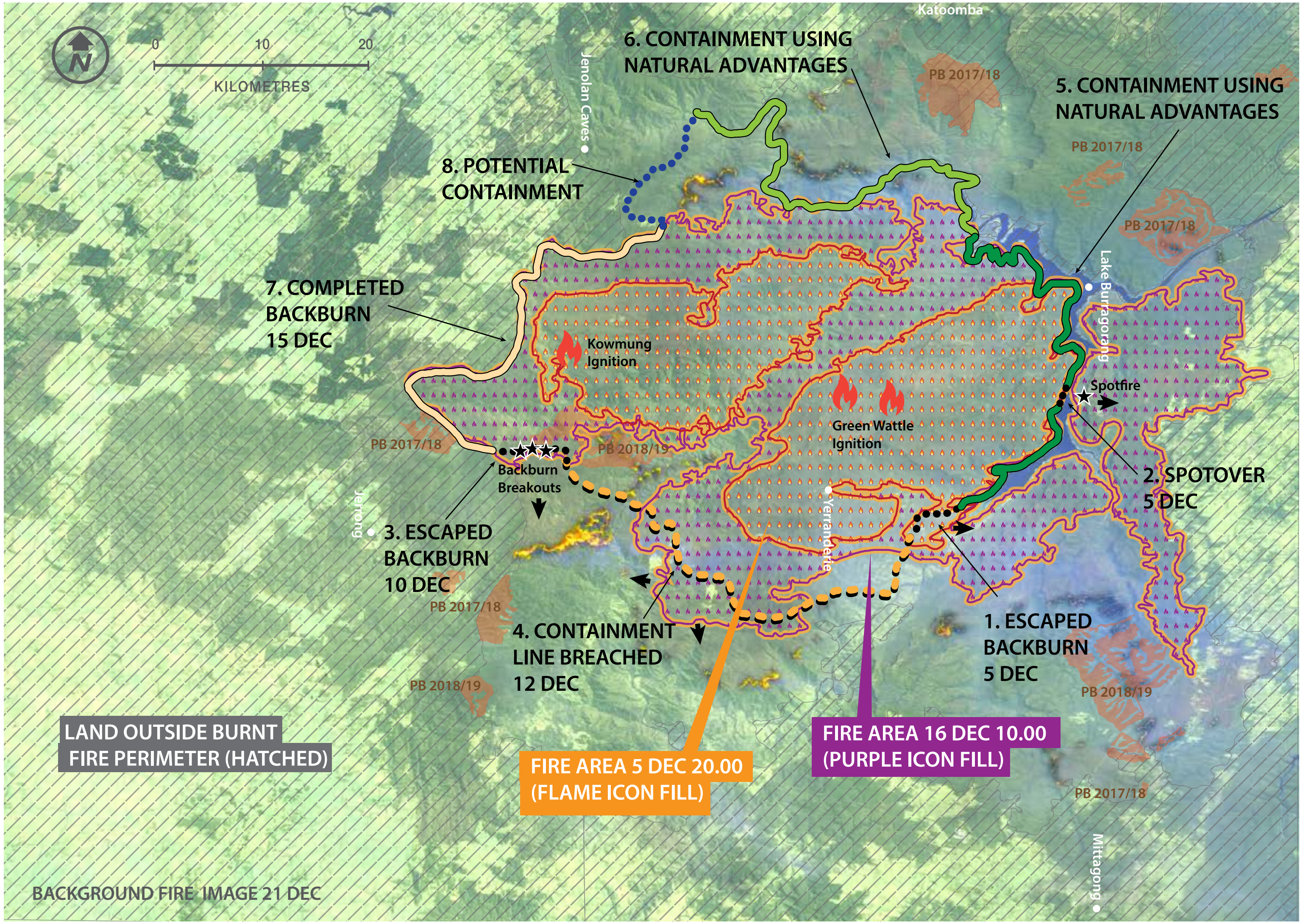


Figure FS9: Green Wattle Creek-Kowmung complex showing ignition points, final extent (hatched area = unburnt) and fire progression and containment strategies up to 16 December. NB: Ruined Castle fire and 'Erskine Creek' fire (a breakout from this fire later on 19 December) are not shown.

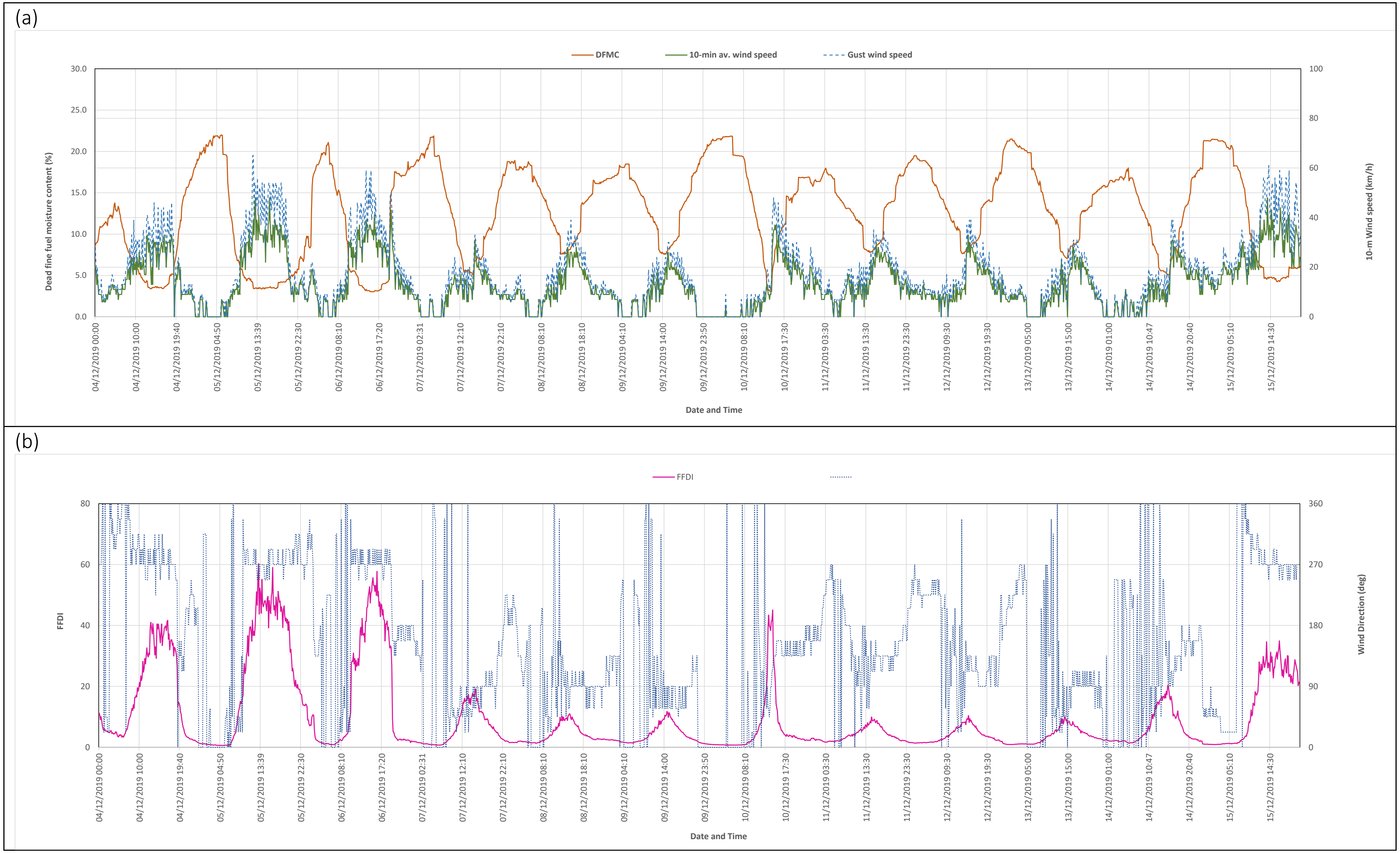


Figure FS10: Fire Weather – Top panel (a) (DFMC and 10-m wind speeds) and bottom panel (b) (FFDI and Wind Direction) for Moss Vale AWS, 4-15 Dec 2019.

Fire Study 2: Seabrook Road backburn, Green Wattle Creek fire
Issue: Backburn failure south-west of Balmoral
Period: 16 – 20 December 2019

Introduction
The purpose of this fire study is to analyse why the backburn ignited on the 19 December 2019 'spike' day on the eastern edge of Nattai National Park failed when fire weather conditions deteriorated before the passage of a cool change on mid-afternoon on the same day.

The backburn was apparently carried out to contain the Green Wattle Creek fire to the north-west but escaped eastwards and seriously impacted Balmoral and surrounds. See map *Figure FS11*.

Situation
Important fire landscape and fire behaviour features

- Naturally low-fuel mosaics in the upper reaches of the Wanganderry Creek catchments are ideal for water bombing and remote area fire operations.
- Indirect fire containment strategies involving backburning before a blow-up day have resulted in numerous past bushfires in backburn escapes becoming a new fire event in themselves (eg 2001 eastern Wollemi bushfires; 2003 Canberra bushfires; 2006/07 Upper Grose bushfire).
- The fire hardly moved in the Wanganderry Tableland area for almost ten days previously and continued to burn slowly despite the onset of severe weather 'spike' days. We estimate the ROS was between 0.1 to 0.2 m/min (200 m/day) and the fire went out on about 50% of its length.
- The recent (May 2019) prescribed burn of some 5,000 hectares was not used as an important strategic feature to tie the backburns back into the more remote Wanganderry Tableland sector and the fire activity on the Bindook Highlands *(refer to Figure FS11)*.

Fire weather patterns

- Fire spike days occurred on 5 and 10 December, with otherwise pretty benign fire weather between 7 and 9 December and between 11 and 19 Dec *(refer to weather chart Figure FS12)*.
- Fuel moisture recovery to over 20% occurred every night for the previous three nights resulting in slow fire spread of backburns overnight.
- DFMC fell to below 3-4 % at mid-day on 19 December while average 10-m wind speeds were approximately 20-30 km/h from the south-west prior to the southerly cool change. The winds accompanying the passage of the southerly wind change were 30-40 km/h. This very low fuel moisture occurred before and after the southerly wind change because of the slow take up in fuel moisture of 1-2 hours meaning severe fire behaviour conditions persisted for a short time after the passage of the southerly wind change.

Situational comments

- Many other in-bush backburns conducted in NSW before and on 19 December had escaped (see Fire Studies 1 and 9).
- On 19 December there was no imminent threat from the Green Wattle Creek fire, which was 15 km distant, 6 km behind a recent planned burn and burning slowly at a rate of 200-400 m/day and, in places, self-extinguishing because of the high nocturnal DFMCS in excess of 20%.
- The main Green Wattle Creek wildfire met the earlier backburn north of Seabrook Road backburn on the night of 19 December, as a result of the southerly wind change driving the backburn to the north-west. It had taken over 13 days to close the gap.

Potential lessons

- Backburns are likely to fail if not thoroughly mopped-up and secured several days before a blow-up event involving very high to severe fire weather.
- Specific fire threat warnings to the local community are needed to cover possible backburn failure.
- Prescribed burns can assist bushfire suppression if recent enough and in suitable fire conditions.

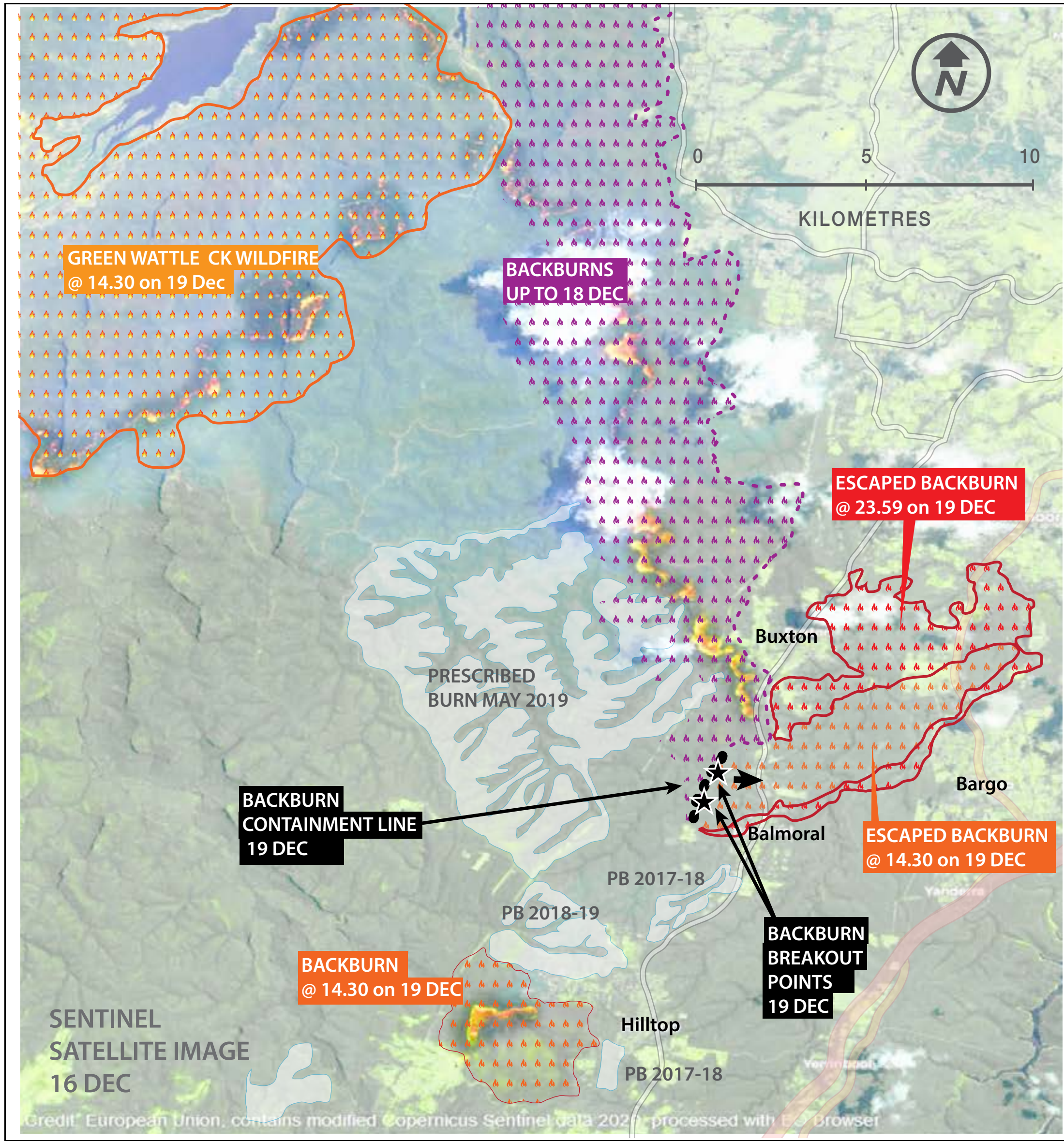


Figure FS11: Fire context map for Seabrook Road backburn escape, Green Wattle Creek fire.

Figure FS12: Fire Weather (DFMC and 10-m wind speeds 1st column) (FFDI and wind direction 2nd column) – 12 Dec to 16 Dec 2019 for (a) Richmond RAAF AWS (first row) (b) Moss Vale AWS (second row).

Fire Study 3: Gospers Mountain, south-west section
Issue: Strategic containment
Period: 05 -16 December 2019

Introduction
The purpose of this fire study is to highlight where strategic containment could have occurred using these considerations:

- recognising when, where and how various fire advantages in the landscape can be used to slow or even break up a fire's momentum and impact
- understanding how a backburn failure on the Newnes Plateau (outlined in Fire Study 4) led to a chain of events resulting in later fire blow-outs in the Wolgan and Lithgow valleys on 12 Dec and on 21 Dec
- prioritising Blue Mountains World Heritage values and fire frequency and severity of previous bushfires in fire containment planning.

The Gospers Mountain fire became very large, complex and damaging when initial attack of a remote lightning fire did not succeed. It was reported as the largest single forest fire in Australia's historical record. The fire burnt for 79 days from 26 October 2019 to 12 January 2020 and covered 512,626 ha (including the distinct Grose fire). Many control strategies were used at different times in different places with mixed success.

The Mt Wilson Road fire (Grose fire) from the escaped backburn on the Mt Wilson Road burnt for 53 days and was declared out on 4 February 2020 with an official RFS estimate of final area of 19,896 ha. Our own analysis reveals that the fire actually burnt 63,700 ha of which 41,800 ha burnt the Grose Valley and 21,900 ha in the upper Wollangambe catchment. This was a completely separate bushfire and is separate from the Gospers Mountain bushfire (see Fire Study 6).

This study examines the problematic south-western part of the fire from Capertee Valley to Mt Tootie. Either side of this zone the fire was successfully contained as it emerged from the Wollemi National Park and reached settled areas.

See map *Figure FS13*.

Situation
Important fire landscape features

- Limited fire advantages are available once the Glow-Worm Tunnel Road backburn failed in the northern Newnes Plateau.
- Surface, near-surface, and understorey fuel levels were low in the Wollangambe River and Dumbano Creek water catchments from the 2013 State Mine Gully bushfire.
- Bungleboori Creek was a significant fire advantage which had previously been used as a tactical fire advantage.

Seasonal dryness indicators
The Mount Soil Dryness Index (MSD) a week before in late November indicated that the soil water deficit in most forest and heathland soils had exceeded a value of SWD>140 mm on a scale of 0-165 in the middle Blue Mountains *(see Figure FS6)*. This SWD threshold in most dry eucalypt forest types on the tablelands of NSW has been found to be associated with increased leaf mortality in understorey shrubs and eucalypt leaf drop, which can shed up to 40-60% of the eucalypt tree canopy (2-4 tonnes of newly shed leaf litter). This recently shed litter is also highly flammable and combustible in a fast-spreading bushfire and adds to the existing surface fuel loads.

Fire weather patterns *(see weather chart Figure FS14)*

- Fire weather 'spike' days occurred on 12, 15 and 21 December, with some significant periods of less severe fire weather in between these events.
- Fire runs under west or south-west fire winds mirrored fire spread patterns of historical bushfires in 1979/80, 1997/98 and 2012/13 in the Wollangambe in a Sydney Basin fire season. Therefore, the Gospers Mountain bushfire was not likely to progress south towards Mount Wilson and Mount Irvine.
- Fuel moistures recovered most nights to above 20% between 6 and 21 December except on 15 and 20 December when they rose only to 12-14%.
- Minimum DFMCs decreased to below 6-7% during most days because of a dry westerly airstream during this period, particularly in the higher parts of the Blue Mountains.
- Critically low DFMCs occurred on 6, 7, 14, 15, and 19 December combined with 10-m winds reaching 20-25 kph during the mid to late afternoon on these days.

Containment strategies

- It is not known for certain that the unattempted RAFT-natural advantage containment strategy from southern Newnes Plateau to Mt Tootie *(see map Figure FS13)* was the IMT's preferred plan, but it seems likely.
- This strategy would have utilised as advantages the gorge of Bungleboori Creek (which did actually stop the fire) and the low fuel area of the 2013 State Mine Gully fire that extended from Bungleboori Creek to Newnes Plateau.
- This strategy, if successful, would have saved a large area of burnt country and impacts on communities extending from the Capertee Valley in the north-west, through Lithgow and Clarence to Blackheath and Bilpin in the east.
- As noted in Fire Study 4, the Glow Worm Tunnel Road backburn did not succeed for uncertain reasons and, in Fire Study 5, the Mt Wilson Road backburn was an unwise strategy.
- The northern Glow Worm Tunnel Road backburn was a critical tactic in the overall strategy to contain the Gospers Mountain bushfire.
- Later backburns failed in the Newnes Plateau area westwards, leading to the Gospers Mountain fire running unchecked to the west and south-west, somewhat advanced by backburns.

Potential lessons

- Utilise fire advantages and tactical remote area fire-fighting work to limit fire spread south towards northern Blue Mountains townships.
- Timing of backburns is critical to fire containment strategies.
- Aerial incendiary work under benign conditions has proven to be a useful strategy in previous major incidents on the plateaux to the north of Mount Wilson and Bungleboori and Wollangambe Creeks. This can be used to play for time by bringing the active fire down from the ridges into the convoluted creek systems and where the active edges are more sheltered from eastward and southern movement.

Map notes (*Figure FS13)*

- The northern part of the map shows the initially successful containment from Glen Davis to Newnes Plateau. This containment linked a RAFT line from Glen Davis along the Pipeline Pass walking track to the Wolgan River and then via a 2017/18 prescribed burn in Rocky Creek to the northern end of Newnes Plateau.
- The eastern part of the map shows the successful containment via a backburn along Mountain Lagoon Road, Bells Line of Road and Mt Tootie Road to Mt Tootie (purple line labelled 'Completed backburn').

- Between these two successful containments the map shows the escaped backburns on Mt Wilson Road and Glow Worm Tunnel Road (green line labelled 'Backburn with low intensity fire' as the objective) and subsequent fire spread west and south to eventual containment at the edge of settlement.
- Between the green line and the purple line are two segments in orange (labelled 'Remote area fighting') and blue (labelled 'Containment by natural advantages'). This is the containment option that was not apparently attempted, as it was circumvented by the backburn escapes.
- Remote area firefighting (orange segment) could have linked the Glow Worm Tunnel Road backburn into Bungleboori Creek and then Bowens Creek (both blue segment) to the completed backburn near Mt Tootie.

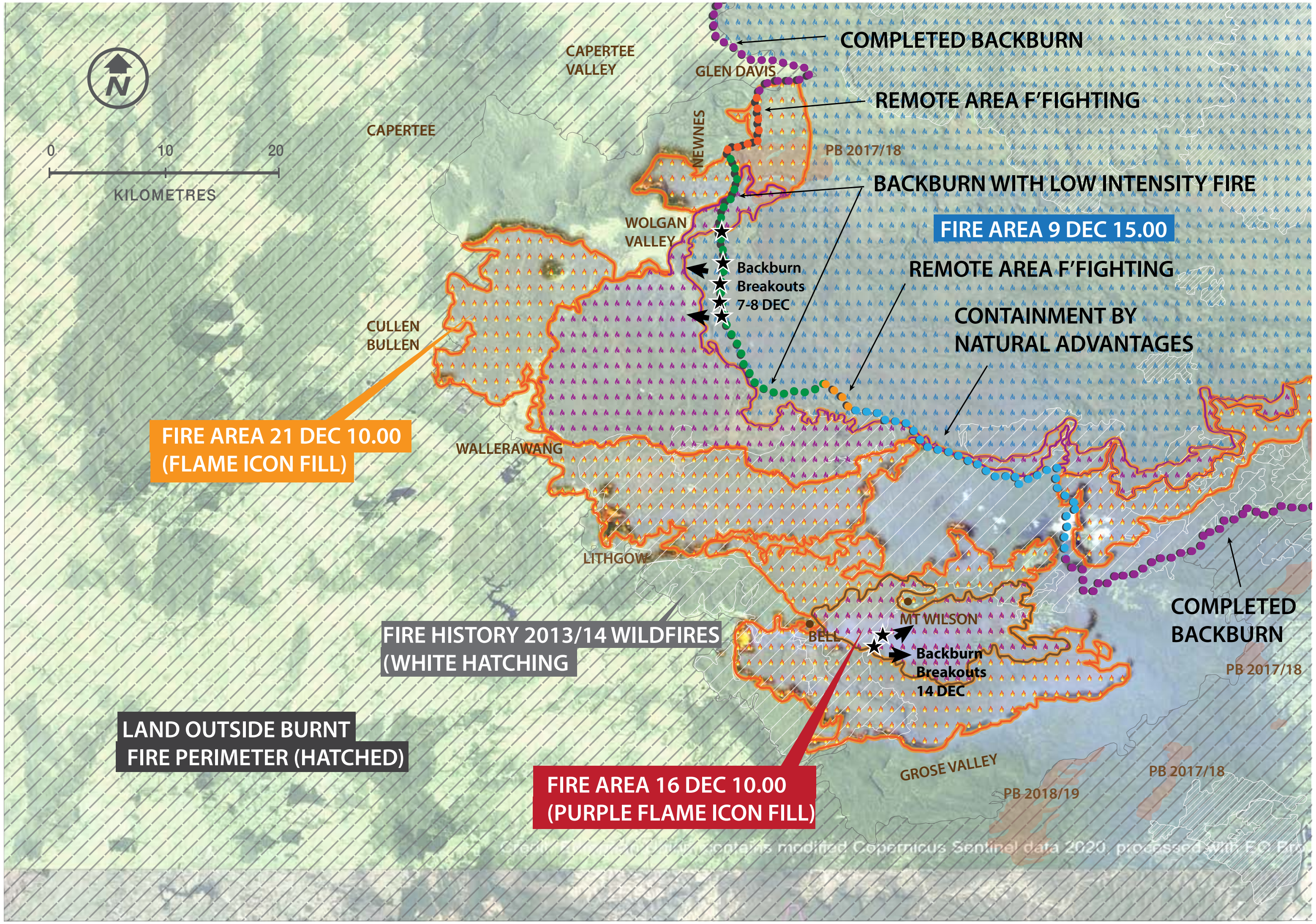


Figure FS13: South-western part of Gospers Mountain fire, showing final extent (green stippled line), Mount Wilson backburn escape (light purple stippled line)*, and strategies which failed or were not attempted.*

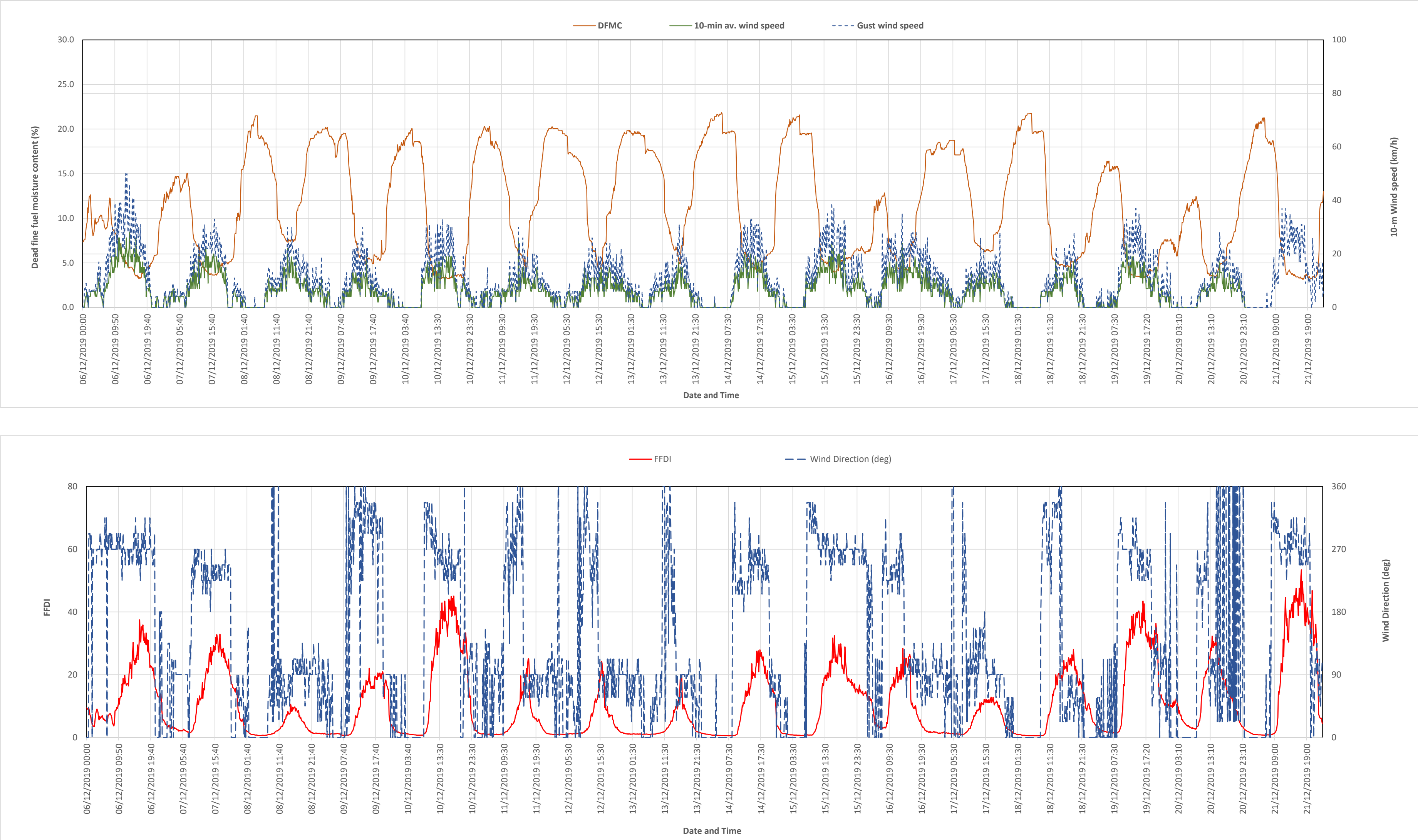


Figure FS14: Fire Weather – (a) DFMC and 10-m wind speeds (top panel) (b) FFDI and Wind Direction (bottom panel) for Marangaroo AWS north of Lithgow, 6 Dec to 21 Dec 2019.

Fire Study 4: Glow Worm Tunnel Road backburn, Gospers Mountain fire
Issue: Backburn Failure because of timing of light-up under SW dry air mass
Period: 7 – 11 December 2019

Introduction
The purpose of this fire study is to analyse why the eastern backburn on the Newnes Plateau failed on the evening of 7 December and why the timing of the backburn was critical to the potential containment of the Gospers Mountain bushfire. See map *Figure FS15* for details of fire spread and fire impacts.

Situation
A 17 km length backburn was conducted between the old Newnes pine plantation and the northern end of the Newnes plateau during the late evening of 7 December between approximately 19:00 and 23:00.

Fire Weather Patterns (Figure FS16)
- The backburn was conducted when there was a very dry air mass (dewpoint temperature less than 3-10 °C) over the fire ground on 7 December resulting in DFMCs decreasing to 4-5% late into the evening of 7 December when a moister ENE airmass broke through the WSW dry air mass
- There was a highly unstable turbulent middle level atmosphere aloft.
- The burn was conducted under high to very high FFDIs.
- Had the burn been conducted a day or two later, if possible, then it would have been within planned burned prescriptions when DFMCs were between 13 and 20%, under stable north-easterly winds between 15-20 km/h.

Sequence of events
- This long backburn was commenced on the evening of 7 December to contain the westward advance of the Gospers Mountain fire which, according to information available for this analysis, was at that stage 4-5 km away and spreading at 500-700 m/day in a westerly direction.
- The backburn linked at the north end to a successful containment line extending northwards to Glen Davis and beyond *(see Fire Study 3 for details)*.
- The southern extension of the proposed backburn containment line is unknown. The plan may have been to extend the backburn into Bungleboori Creek (on the southern edge of the map).
- Once lit, the backburn spread successfully and rapidly to the east, initially under the influence of a dry westerly wind.
- At some point during the night, and possibly owing to the easterly wind change, the backburn crossed the containment line to the west and was not contained.
- The escape may have occurred after the wind changed to the east and before humidity increased. Information from the fireground has also suggested the escape may have been caused by inappropriate light-up methods.
- By 0800 the next morning (8 December) the crossover was some 5 km in length.
- The escaped burn continued westward to a subsequent attempted containment line/backburn on Maiyingu Marragu (Blackfellows Hand) Trail, which also failed.

Containment strategies
- The backburn was a valid response to the situation at the time. If it had succeeded (and been extended southwards) it would have prevented the fire burning a very large area to the west and south and impacting several communities.

- The reasons for the backburn escaping are unclear and require detailed analysis with more information, especially from firefighters on the ground.
- It is also unclear as to what fire advantages it was going to be tied into to the south.
- Our analysis shows that there was a high-severity zone to the east of the backburn containment line. Based on fire weather at Marrangaroo (15-22 km SW of the backburn containment line) the backburn would have created high-severity fire to burn through Sydney Peppermint-Silvertop Ash dry shrubby forest fuel type under the very dry air mass conditions.
- The intense burning conditions under more or less severe wildfire conditions created intense pyro-convection over the fire ground which usually results in unstable and erratic fire behaviour and even drier and stronger middle-level atmospheric winds to interact with the backburn. The backburn in effect created a high-severity wildfire. The results were detected on the radar at Sydney over 100 km away *Figure FS17*.
- The three-day period after 10 December were more suited to less intense backburns under milder fire weather conditions.

Post fire impacts

- Because the Glow Worm Tunnel Road backburn created high fire-severity effects on the plateau forest to the east of the Glow Worm Tunnel Road *(see dark brown burn patterns in Figure FS15)*, the forests' recovery is likely to be slow because of the drought stress on the trees and understorey at the time.
- Severe thunderstorms on 8 and 10 February produced over 350 mm of intense rainfall that would have impacted on the surface soils and created massive soil movement and loss in that fire landscape.

Potential lessons

- Backburns need to be timed and implemented during periods of stable easterly fire weather with higher dead fine fuel moisture content and 10-m wind speeds Timing of backburns in relation to weather and fuel conditions is critical.
- Sometimes it is better to observe and carefully consider the options rather than losing a backburn or creating high severity fire behaviour. In this case the intense fires created pyro-cumulus clouds as seen late evening on the Sydney radar *(Figure FS17 (a), (b), and (c))*. Lighting up a backburn with a high-severity fire was also outside RFS SOP 17 guidelines.
- Anchor points as part of a partial containment strategy need to be considered early on the western and southern sectors of a bushfire, particularly in its early stages. The Gospers Mountain fire was allowed to cross key fire advantages such as the Colo River and the Wollemi Creek and take high-severity fire runs unchecked for most of its duration. This backburn strategy could have been a late in the day key anchor point had it been implemented with due concern for the local environment and nature conservation values.
- There is a distinct difference between the air masses in the western and eastern Blue Mountains on most severe fire days. The fire weather in the upper Blue Mountains is often drier and windier with dewpoints falling to below 0°C much earlier in the day and remaining so until late in the evening.

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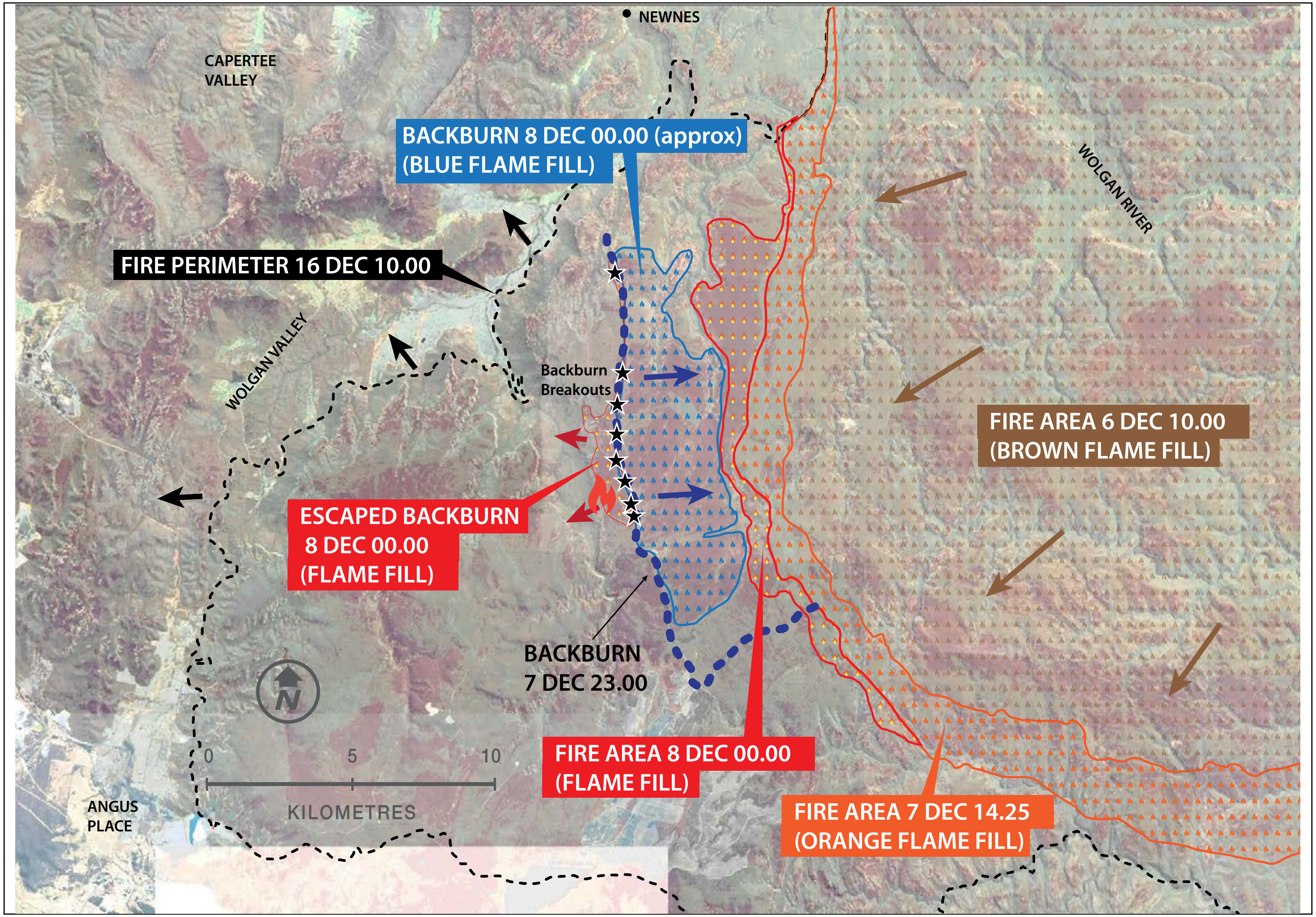


Figure FS15: Progression of Glow Worm Tunnel Road backburn and associated front of Gospers Mountain wildfire 6-16 December 2019.

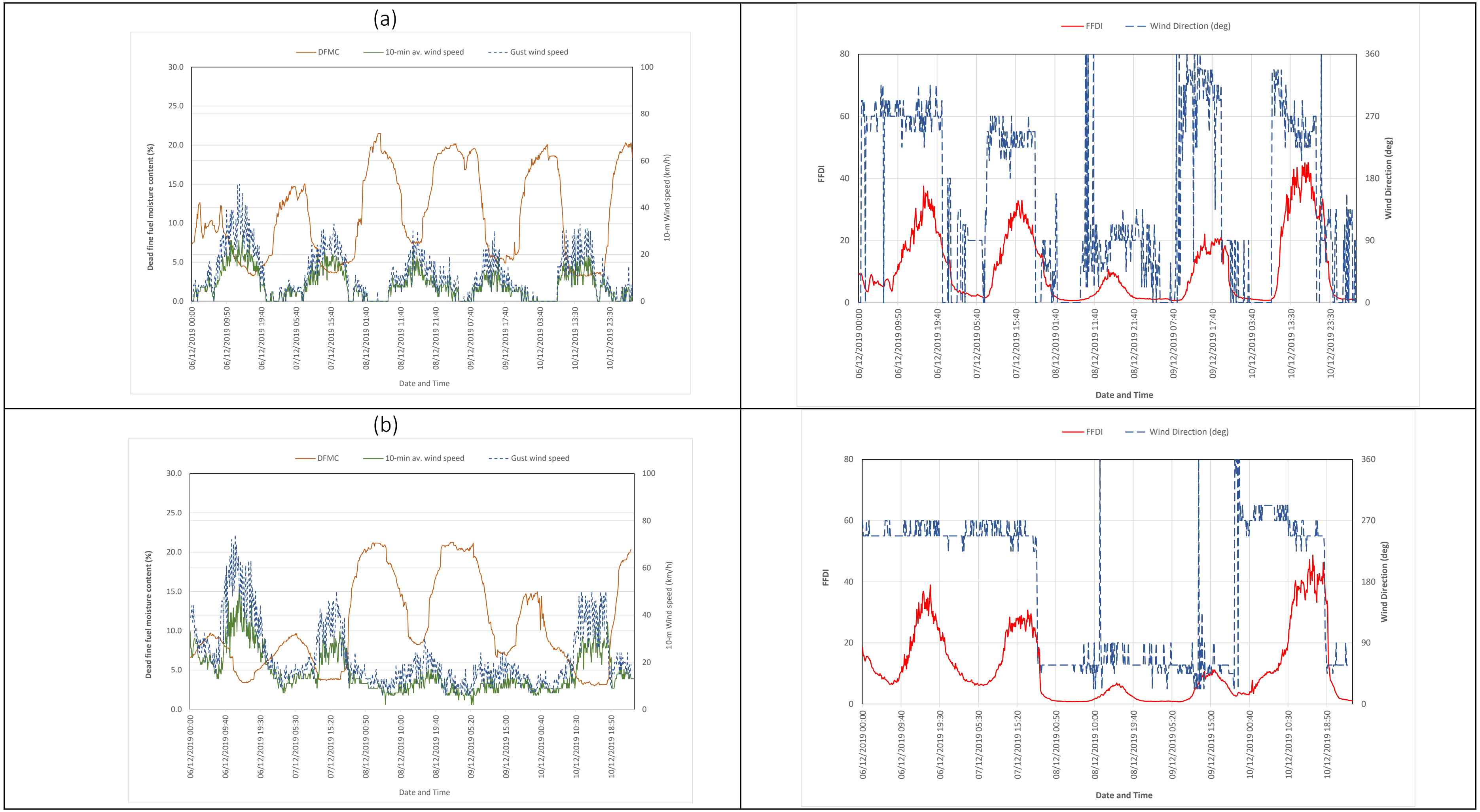


Figure FS16: Fire Weather (DFMC and 10-m wind speeds 1st column) (FFDI and wind direction 2nd column) – 6 Dec to 10 Dec 2019 – (a) Marangaroo AWS north of Lithgow (first row) and (b) Mt Boyce AWS (second row).

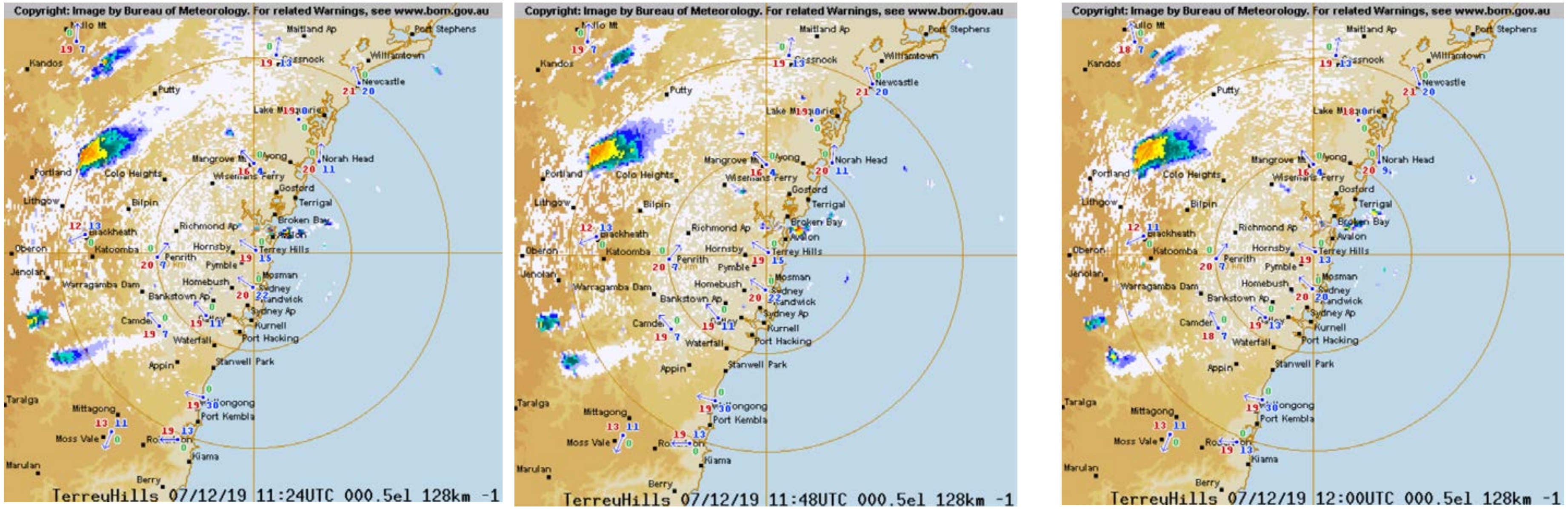


Figure FS17: Radar Images from Sydney Radar (a) 22:24; (b) 22:48: and 23:00 07 Dec 2019 AEST showing pyro-cumulus clouds (main plume between Portland and Putty) forming over the Glow Worm Tunnel Road backburn at the time of possible coalescence of backburn with the Gospers Mountain bushfire.
Source: Bureau of Meteorology

Fire Study 5: Mount Wilson Road backburn (Grose fire), Gospers Mountain fire
Issue: Backburn Failure because of timing under SW dry air mass
Period: 14 – 16 December 2019

Introduction
The purpose of this fire study is to analyse why the Mount Wilson Road backburn failed when lit up under low fuel moisture conditions on 14 December 2019. The backburn was undertaken to contain the Gospers Mountain fire to the north. The backburn escaped eastwards and went on to cause substantial impacts. The escaped backburn was initially named as part of the Gospers Mountain fire and later the southern part (south of the Grose River) was named the Grose fire. This operational division has led to some confusion in media reporting and public understanding of the extent of the fire which came from the Mt Wilson Road backburn.

The Mt Wilson Road fire from the escaped backburn on the Mt Wilson Road burnt for 53 days. The Grose fire section had an official final area of 19,896 ha and was declared out on 4 February 2020. The rest of the area burnt by the backburn was absorbed in the official hectare tally of the Gospers Mountain fire. Our own analysis reveals that the escaped backburn fire actually burnt 63,700 ha of which 41,800 ha was in the Grose Valley and 21,900 ha in the upper Wollangambe catchment. This was a completely separate bushfire and we have not included its area in the stated extent of the Gospers Mountain bushfire in this report.

See map *Figure FS18*.

Situation
A backburn was conducted along the western side of Mount Wilson Road between 10:00 and 14:00 on 14 December under very dry fuel moisture conditions. As the west to south-west winds increased in strength and humidity fell through the middle of the day, spot-overs occurred from about 15:00 eastwards across the Mount Wilson Road. Another spot also landed south-west of Mt Wilson, within the planned containment lines but before the backburn reached that section. The northern-most fronts of the escapes then threatened property on Mount Wilson in the late afternoon.

Following a cooler easterly change between 18:00 and 18:30 the breakout to the east settled although the change started a westerly fire run towards Bell that nearly crossed the Bells Line of Road in the evening.

The fire weather deteriorated on 15 December resulting in some intense fire runs on the southern flanks of the Bowen Creek catchment. Property on Mt Tomah and in Berambing came under threat and some property was lost or damaged. After the fire crossed Bells Line of Road, it spread to the east, south and west in the Grose Valley. On 21 December during a severe-extreme fire weather day and subsequently, the fire impacted Bilpin, Kurrajong Heights, Blackheath, Mount Victoria and Bell *(see Figure FS18)*.

Important fire landscape and fire behaviour features
- The eastern part of the southern front of the Gospers Mountain fire was holding in the deep gorge of Bungleboori Creek where it later self-extinguished and never crossed the creek.
- The western part of the southern front of the Gospers Mountain fire towards Newnes Plateau was burning slowly at 700-1,000 m per day southwards through light fuels (2013 wildfire) and broken rocky terrain in the headwaters of Bungleboori Creek. This part of the wildfire was merged with an earlier backburn on Newnes Plateau.
- The consequences of a fire crossing Bells Line of Road into the Grose Valley are well known.

- Several previous fires in the upper Grose Valley area have either been caused or exacerbated by escaped backburns.
- In 1994 a 'first response' backburn in almost the same location on Mt Wilson Road accelerated and extended a nearby arson ignition on Bells Line of Road. The fire became the damaging Bell Range fire (aka Grose Valley fire). In 2006 a backburn along Darling Causeway west of the 2019 event crossed into the Grose Valley on a multi-kilometre front, greatly expanding the actual wildfire.

Fire weather patterns (see Figure FS19)

- The broader temporal context for fire weather during the this backburn strategy depicts periods of more settled fire weather both before and after the backburn was carried out.
- The graphs presented in *Figure FS19* tell a reasonably consistent story about the fire weather conditions at the time of the backburn. There is no evidence of a change in the weather.
- On the day of the backburn DFMC decreased to 4-5%, latent conditions for a severe bushfire and potential spot-over across a containment line. The likelihood of short-range spotting from a backburn increases exponentially below a DFMC threshold of 6-8%.
- The forecast weather for the 15 December suggested worsening fire weather conditions and if the backburn failed there would be consequent impacts on people and property downwind of the fire, such as Berambing, Mount Tomah, and Bilpin.

Containment strategies

- The fire weather was settled in periods before and after the backburn escape. There was no imminent threat to be countered. The backburn was an appropriate strategy under the right circumstances but could have been abandoned at this time.
- Backburning has failed numerous times before along the Bell Range. It is a highly tricky strategy to implement because of the interaction between the local fire winds, fuel types and dissected topography on either side of the Mt Wilson Road and Bells Line of Road.
- The backburn strategy overlooked the state of low fuels in the Wollangambe and Dumbano catchments.
- The escaped fire went on to burn a large area, impact a number of communities and significant environments (including the Blue Gum Forest). It caused major damage to rail, road and electricity infrastructure. The fire absorbed a large resource commitment over many weeks (see Fire Study 6).
- The backburn was extended over following days around the northern side of Mt Wilson absorbing scarce resources needed elsewhere in the Blue Mountains.
- The Gospers Mountain fire burning very slowly south and the backburn burning very slowly north from Mt Wilson never joined. The gap between them was eventually filled in by mainly the backburns burning northerly and easterly from the escaped Mt Wilson backburn in the lower Wollangambe and the backburns put in between Bell and Clarence burning eastwards into the upper Wollangambe.

Potential lessons

- Backburning is likely to fail if conducted while fuel moisture conditions are well outside safe backburn prescriptions (DFMCs between 10 and 15%, settled stable weather conditions).
- Avoid risky backburning when the threat is low and distant.
- Local knowledge and understanding of previous fire histories is essential for sound strategies.
- Backburning well away from the main fire represents a high-risk strategy with potentially catastrophic consequences to local communities downwind of the bushfire, especially carried out just before a major blow-up day without thorough mop-up and patrol for several days previously (ie blacked out). Not many firefighting crews are trained thoroughly in this

technique. Not doing so can result in high-risk backburn failures like what occurred at Mt Wilson on 14 December.

- Backburning along roads at the intersection of three fire catchments, such as the Wollangambe, Bowens Creek and the Grose valley means escape into all three catchments is likely and resource intensive to suppress. This was also seen along the Kings Highway in Fire Study 9.
- Prescribed burns and past wildfires can assist bushfire suppression if recent enough and in suitable fire conditions.

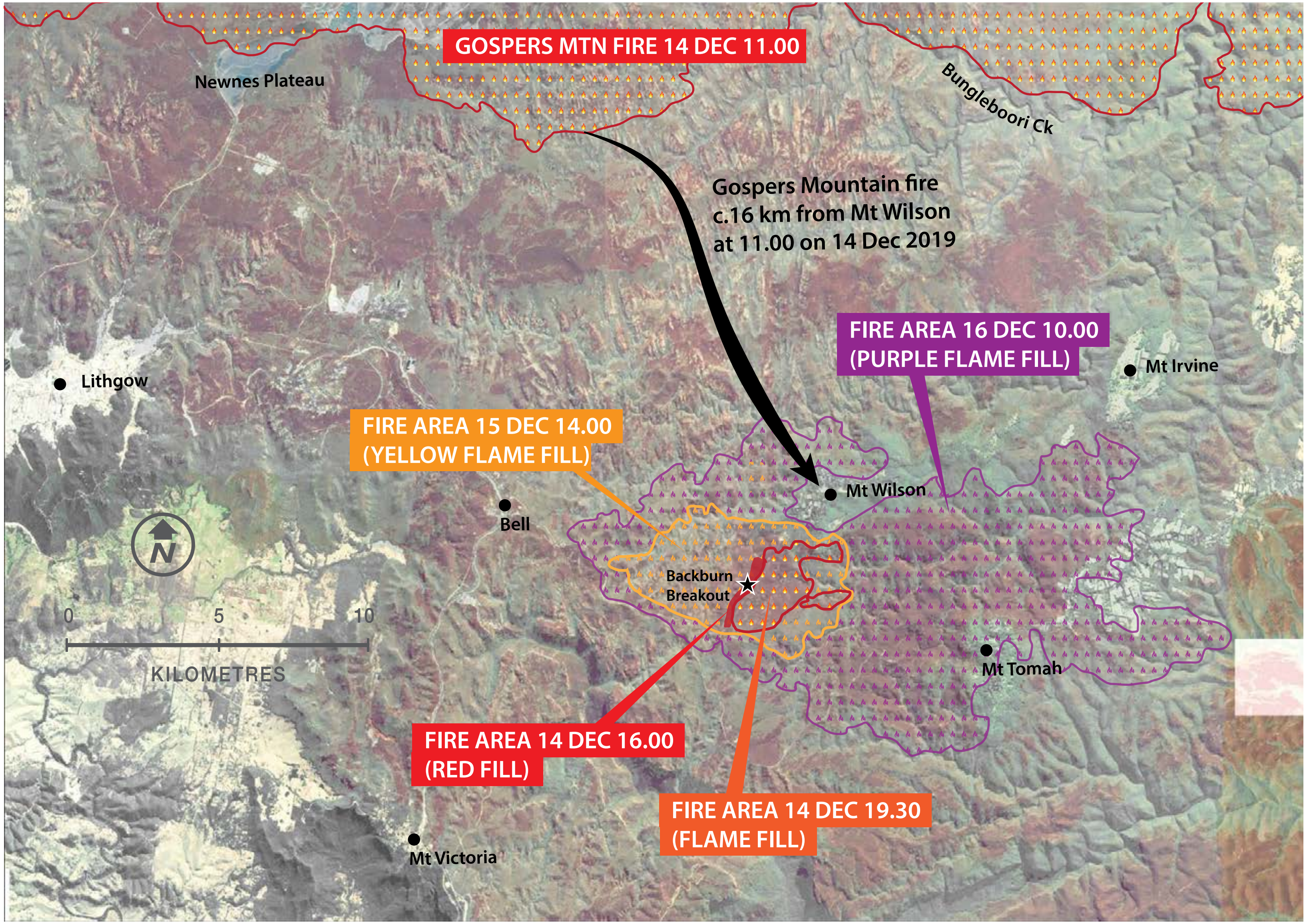


Figure 18: Progression of the Mt Wilson Road backburn 14-16 December 2019.

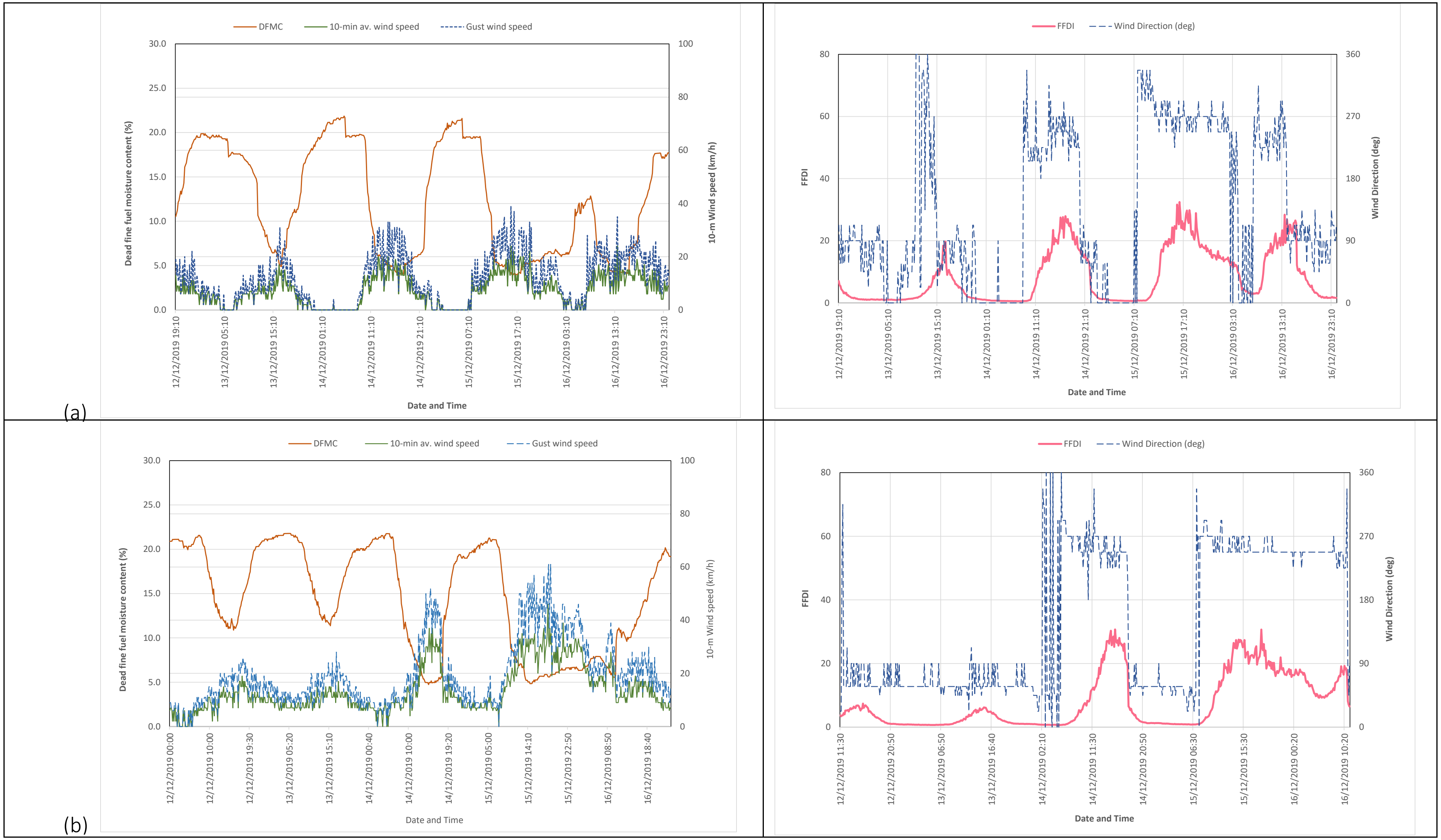


Figure 19: Fire Weather (DFMC and 10-m wind speeds 1st column) (FFDI and wind direction 2nd column) – 12 Dec to 16 Dec 2019 – (a) Marangaroo AWS north of Lithgow (first row) and (b) Mt Boyce AWS (second row).

Fire Study 6: Mt Wilson escaped backburn fire southern and eastern containment

Issue: Successful backburning and remote area fire strategy in the Grose Valley ("Grose fire")

Period: 16 – 21 December 2019

Introduction

This fire study examines containment of the southern and eastern flanks of the Mt Wilson Road escaped backburn fire (aka Grose fire) from Mt Victoria to Kurrajong Heights through the core of the Grose Valley.

The purpose of this study is to highlight the success of well-conceived fire containment strategies that used a variety of tactics to control this bushfire. The combination of fire strategies worked because they aligned with the fire weather and opportunities to limit the risks to the National Park and to adjoining local communities in the lower Blue Mountains.

This is an example where strategies limited the spread and impact of the fire, without any major fire expansion caused by operations. An effective mix of backburns, property protection, aerial attack, natural fire advantages and RAFT methods was used.

The Grose fire commenced on 14 December 2019, from an escaped backburn near Mt Wilson in response to the Gospers Mountain fire *(see Fire Study 1)*. By 16 December the fire had spread rapidly eastwards to Mt Tomah and Berambing and crossed Bells Line of Road into the Grose Valley. The southern part of the fire (south of the Grose River) was then named the Grose fire and placed under the control of Katoomba IMT. Over subsequent days the Grose fire spread in various directions under several wind changes.

The Mt Wilson Road fire (including the Grose fire) burnt for 53 days. The Grose fire was declared out on 4 February 2020 with a final area of 19,896 ha, but the total area burnt by the Mt Wilson Road fire was 63,700 ha. The fire involved major air and ground operations for much of that period and impacted communities at Mt Wilson, Mt Irvine, Mt Tomah, Berambing, Bilpin, Kurrajong Heights, Blackheath, Mt Victoria and Bell. Some 20 dwellings were lost in the northern villages and property was also damaged at Mt Victoria and Blackheath. Substantial damage was caused to rail, electricity, national park, communications and road infrastructure.

See map *Figure FS20*.

Situation

Important fire landscape features

- Fire burning eastwards through the Grose Valley is an historical fire path. The terrain is difficult and remote with road access on the fringes only.
- Backburning from Mt Victoria to Yarramundi has been an historical response to fire burning in the Grose Valley, along the 'Northern Strategic Line' (colloquially known as the 'Black Line').
- The Northern Strategic Line had been used previously but was formalised after the 1994 Bell Range fire (Grose Valley fire). 1994 was the last time the line was used in its entirety.
- In recent times serious fires have impacted the Grose Valley in 1982, 1994, 2006, 2013 and now 2019-20. Backburn escapes were implicated in 1994, 2006 and 2019. Burning the whole valley, including the eastern valley, has been avoided since 1994.

- Backburning along the entire Northern Strategic Line was averted in 2013 and 2019 by adopting alternative strategies. The full length backburn was a fallback strategy in both cases. It is recognised as a risky option because for large parts of the line there are substantial bushland areas between the line and suburbia (backs of houses), with few intervening control lines.
- Wentworth Creek and Wilderness Brook in the eastern section of this bushfire have deeply incised, well-protected gorges lined with rainforest for most of their length.
- Property protection between Medlow Bath and Mount Victoria, through carefully conceived backburn and defensive strategies timed with periods of higher fuel moisture, limited the risk of backburn breakouts.

Fire weather patterns (see Figure FS21)

- Fire weather in the lower Blue Mountains over the period from 21-28 December was relatively benign and suited the implementation of the remote containment of the Grose section of the Mt Wilson backburn escape fire.
- The fire weather deteriorated significantly from the 29-31 December as dry westerly 'fire' weather continued until the late afternoon of 31 December when a cool change reverted the westerly back to an easterly weather pattern.

Containment strategies

- Fires in the Grose Valley have been historically difficult to contain and are recognised as a major threat to communities. The Bells Line of Road area has a history of backburn failures such as the 1979 Wollangambe bushfire, the January 1994 Bell Range bushfire and the October 2006 Darling Causeway (Lawsons Long Alley) bushfire.
- The 2019 Mt Wilson Road escape fire impacted a number of communities north and south of the Grose Valley on the one day, 21 December, straining available resources. Before that, it made a significant run on 15 December over Mount Tomah.
- On 21 December the south-eastern front of the fire burnt rapidly eastwards over Mt Hay Range and into the deep gorge of Wentworth Creek, where it largely self-extinguished, assisted in the southern part by a 2018-19 prescribed burn on the eastern side of the creek (Lawson Ridge).
- The fire crossed Wentworth Creek at one point on 31 December. This breakout was contained by RAF crews with support from aerial water bombing, essentially as a distinct remote fire.
- The southern flank of the fire was contained by asset protection, aerial attack and backburning from Mt Victoria to Leura, and then by backburning along Mt Hay Road, Rock Lily Ridge fire trail and a hand-tool trail (RAFT) into Flat Top Brook to the north, which joins Wentworth Creek.
- The northern part of the south-eastern flank of the fire was contained by backburning along a hand-tool line construct by RAFT out of the Grose River, then Browns Ridge fire trail and Burralow fire trail to asset protection at Kurrajong Heights.
- The Blackheath-Rock Lily Ridge and Browns Ridge-Burralow backburns along trails were some of the few large-scale backburns carried out in the bush in the Blue Mountains in the 2019-2020 season which did not escape (compared with backburns from the edge of the bush that had a higher success rate, because of cleared land or property behind).
- For the section between Kurrajong Heights and the Grose River, this fire containment strategy only used backburning where it was necessary. Some of the natural advantages and backburn lines had been used in previous fires.
- These strategies prevented the eastern part of the valley from being burnt and putting many more communities at threat.
- During this fire the 'Northern Strategic Line' was prepared in its eastern part to Yarramundi as a fallback strategy.

Potential lessons

- Alternatives to continuous lengthy backburns can be successful when good understanding of local landscape, fire weather, vegetation, fire behaviour and past fire events is combined with strong strategic thinking and opportunity.
- RAF techniques can be very tactically effective, even critical, on appropriate parts of large fires.
- More ground and aerial remote firefighting resources are needed to apply such alternative approaches to fire containment, rather than relying on large-scale backburning which was found to be problematic during the 2019-2020 fire season on many of the bushfires for much of eastern NSW.
- Large strategic backburns can be a successful option in the right conditions and supported with enough resources.

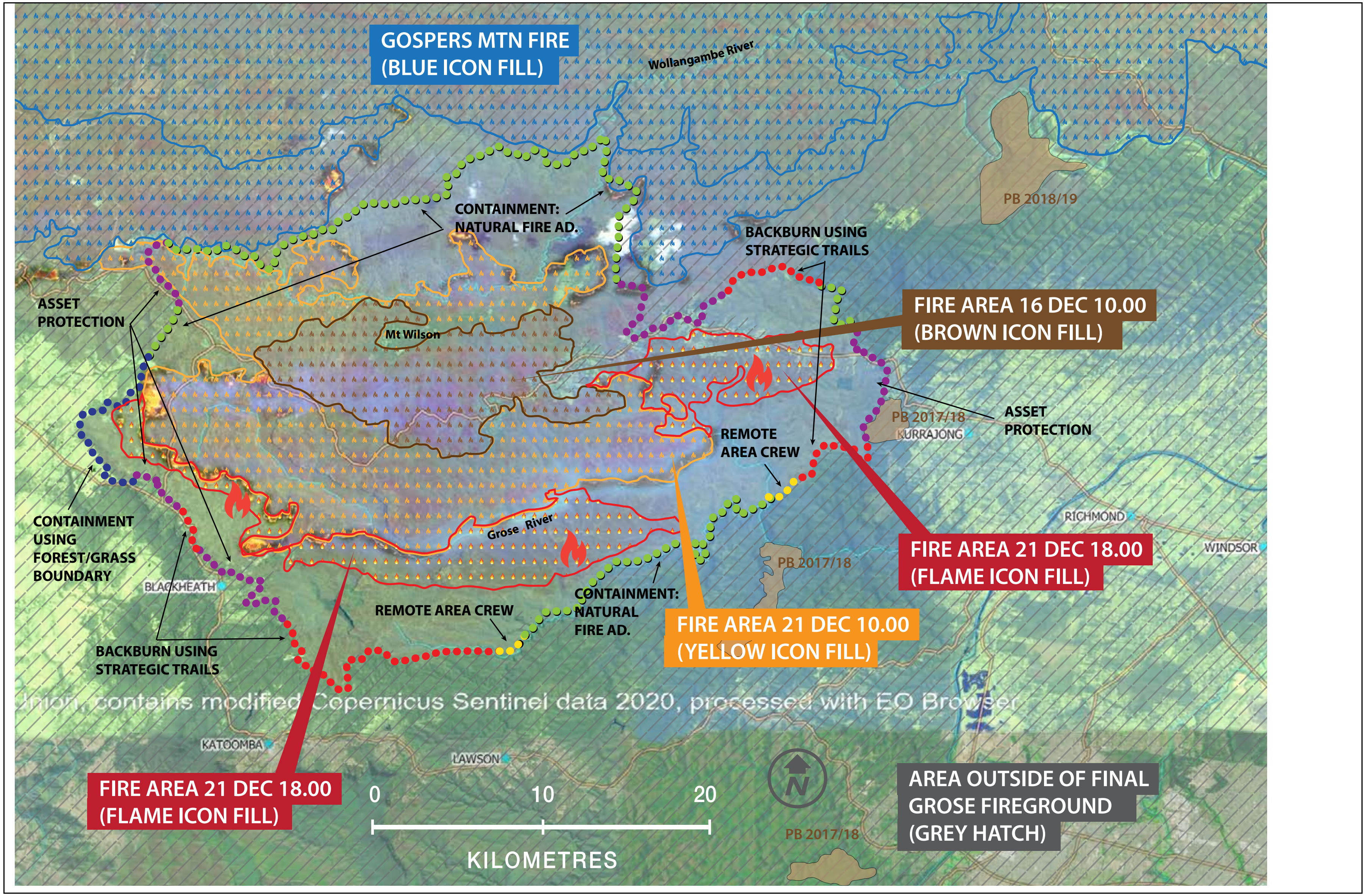
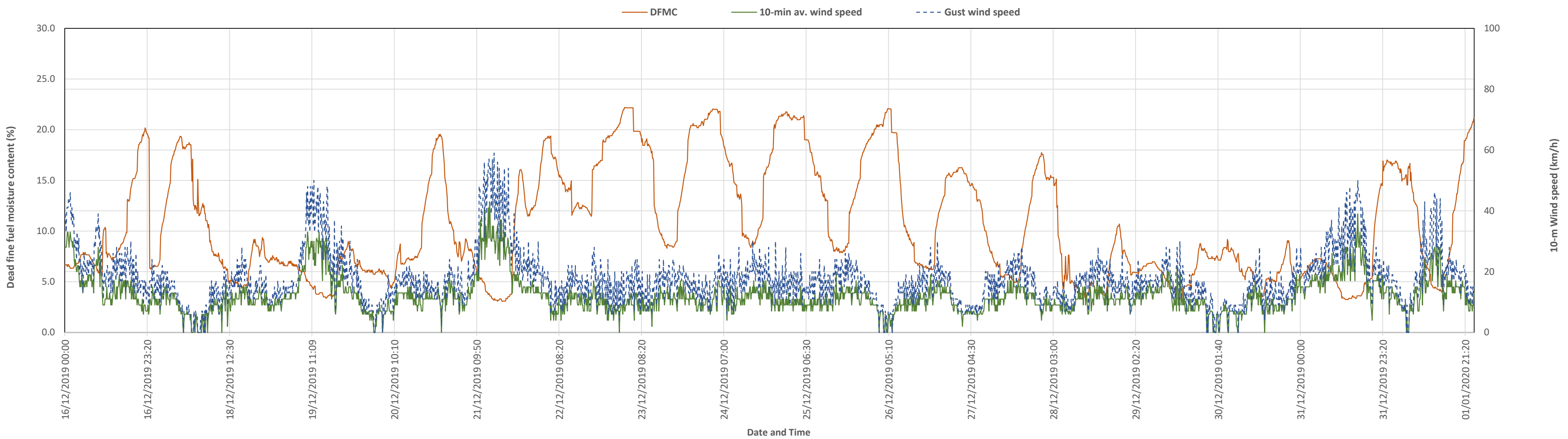


Figure FS20: Fire Containment strategy overview map for Mt Wilson backburn escape bushfire (inc. Grose fire).



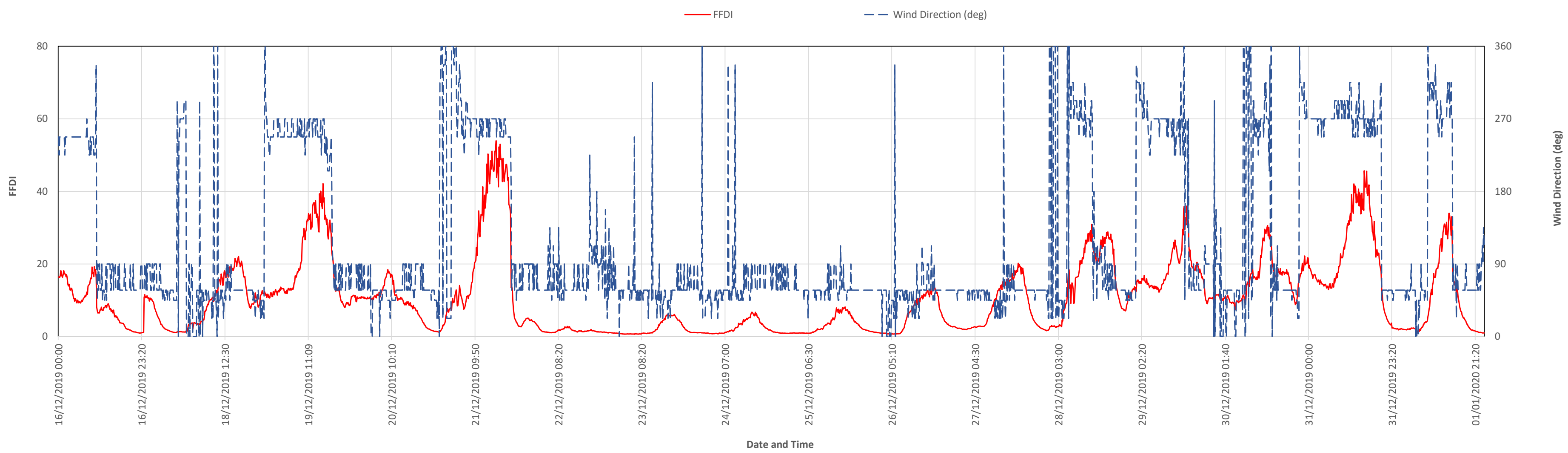


Figure FS21: Fire Weather: (a) DFMC and 10-m wind speeds (top panel) (b) FFDI and wind direction for Mt Boyce AWS, 16 Dec to 01 Jan 2020.

Fire Study 7: Currowan-Tianjara Complex
Issue: Strategic containment in early stages of fire
Period: 27 November – 1 Dec 2019

Introduction
The purpose of this fire study is to review the containment of the Currowan bushfire in its early stages based on a strategic focus.

As mentioned in the Fire Studies Introduction, access to IAP maps, photographs, and other resources stored on the RFS's Icon web platform would have added considerable accuracy and depth to our analysis.

See map *Figure FS13*.

Situation
Important fire landscape features

- Fire was located in the Clyde River basin below the Budawang ranges about 20 -30 km inland from the coast.
- In this area there is a mosaic of eucalypt heathy woodland, eucalypt semi-mesic forests, and rainforests, becoming more mesic near the coast near Termeil and in Kioloa National Park.
- There have been very few wild or prescribed fires in Currowan State Forest in the past 20-30 years resulting in higher than-average surface fuel loads and possibly a more open heathy understorey.

Seasonal dryness indicators

- Based on the Braidwood SWD charts presented in *Figure FS7*, this part of the South Coast had depleted soil moisture reserves from two years of below-average rainfall. The dry eucalypt forest types in this area were likely stressed from very high soil water deficits (SWD). The semi-mesic forests and rainforests were also likely more flammable and combustible under these prolonged drought conditions.

Fire weather patterns (see weather charts Figures FS22 and Figure FS23)

- There were two distinct air masses overlying the Currowan bushfire in its early stages of development. The first is the westerly dry and warm air mass detected at the Braidwood AWS and the second is the east to northerly-easterly cool and moist air mass detected along the coast at the Ulladulla AWS. These two systems competed during this period and influenced the pattern of spread in the fire's early stages.
- The lightning ignition accompanied thunderstorms with the passage of a pre-frontal trough. The fire spread quickly to the east under very high fire danger indices of between 35 and 45.
- During the period of the backburns between 27 and 30 December, the fire weather conditions possibly made it difficult to implement the backburns effectively because of the competition between the two air mass systems. The westerly dry and turbulent air mass would have made it at times too dry to burn sometimes in the afternoon and then too moist for the burns to get substantial depth overnight. There was possibly wide variation in DFMC between day and night during this period.

- Being on the lee side of the Budawang Ranges escarpment, the Currowan bushfire was exposed to the lee wave effect which exacerbated the spread of the bushfire on 2, 3, and 4 December. This is where the bushfire's convection column entrains even drier air and turbulent air masses from middle level winds that reach the fireground having come over the South Coast escarpment. This possibly explains the faster rate of spread of the Currowan bushfire on these otherwise less severe fire weather days. The FFDI was comparatively much lower at both the Braidwood and the Ulladulla weather stations.
- The actual weather on the fireground is therefore difficult to interpret accurately from the very different fire weather patterns detected at the tablelands station at Braidwood and the coastal weather station at Ulladulla.

Containment strategies

- Broad area containment using backburning was applied early on with the Currowan bushfire to halt its westerly spread from late on 27 December till late afternoon on 28 December. These were carried out mainly in Silvertop Ash heathy woodland and forest along the wind-exposed spines of the ridges. This creates a high propensity to produce short-range spotting under low to very low DFMCs because of the Silvertop Ash bark.
- These early backburns were extended well to the north, about 5 km past the immediate westerly fire flank of the Currowan bushfires. While this intended tactic halted the westerly spread of the bushfire, both the southern parts of the backburn and its northerly extension had significant spot-overs later on 28 December which burnt apparently uncontained.
- The resultant effect of these backburn escapes is that there were no significant fire advantages left to backburn from, in the steep slopes leading up over the Budawang Range escarpment. As it spread westwards after 1 December, it meant that the fire would become more and more exposed to the influence of the dry and unstable hot airmass high up on the ranges.
- The northerly backburns were 8-9 km off the bushfire's northern flank on the afternoon of 29 November. The fire had spread northwards averaging 0.8-1.0 km per day since the afternoon of 27 December about 1.5 – 2 km north from where it was on the evening. A considerable gap remained between the backburn and the main fire.
- The eastern and southern sectors had no clearly identifiable fire advantages. The easterly flank and separate spot fire could have been brought down together to the Clyde River using judicious aerial ignition and close-in tactical burns during late evening of 27 or 28 November to limit the fire's potential to spot over the Clyde River.
- Spotting did occur across the Clyde River sometime on 30 November which was subsequently contained by the morning of 1 December. Unfortunately, this spot fire broke its containment lines later and proceeded to run on 2 and 3 December across the Princes Highway and into Kioloa National Park *(see map Figure FS24)*.
- The backburn extension to the north increased the likely exposure risk of further fire runs to the coast and breakouts to the north and west which did occur later on 4 December. There was over 40 km or more of containment line perimeter to be mopped and patrolled. If there was a scarcity of firefighting resources for mop up and patrol, this backburn strategy could have been reconsidered and possibly an alternative partial containment fire strategy used from the start of the bushfire.
- The Sentinel image on 1 December suggests that no coherent tactics and strategies for a partial containment strategy were applied.

Potential lessons

- As a broad fire strategy, the overall early aim could have been to keep the fire contained under the coastal influence of easterly air masses. The most critical anchor points for this stage of the bushfire were the westerly fire trails used as backburn lines. This was lost very early on 28 November, a day later, which meant that the fire then went on to increase in size largely unchecked to the north and west over the next 40 days and become a 500,000-ha bushfire.
- From the start of this bushfire, tactical rather than broad area backburning could have been applied on most of the flanks to check its easterly and southerly spread. Those flanks are where future fire runs could and did come from later on 2 and 3 December from spot fires already on the eastern side of the Clyde River.
- Large scale backburns involving lengthy fire perimeters have had a history of failing when fire weather conditions deteriorate. The classic case of the 2003 Canberra bushfires involved several different backburning operations which all failed the day before 18 January 2003. The combined effects of these operations caused a massive pyro-cumulonimbus cloud to form from several high-severity fires converging in the mid-afternoon in the Cotter catchment.
- Thorough mop-up and patrol of backburns are essential to success and need time to implement before any significant deterioration in fire weather conditions. In some cases, a three-day lead time before a significant fire weather event may be needed to limit possible reignitions and spot-overs.
- A watch-out for the lee-wave effect of middle level dry air masses descending on the lee side of mountain ranges should be carefully considered along the length of the NSW coast and hinterland. This has been observed and modelled for Victorian bushfires occurring in central and eastern Gippsland (eg Aberfeldy-Donnellys bushfire in February 2013).

Map notes *(Figure FS24)*

- Backburning commenced in the western sector of the Currowan fire overnight on 27 November along roads in its western sector to contain the westerly spread of the Currowan bushfire.
- On 28 November the westerly backburns had spotted over in several places.
- Further backburns were conducted in the northern sector on or before 29 November on fire trails 8-9 km north of the northern flank of the Currowan bushfire.
- By 30 November there were still many gaps in the overall fire strategy on the eastern and southern flanks of the Currowan bushfire.
- A spot-over on the eastern side of the Clyde River occurred on 30 November was contained with a backburn overnight on 1 December. This subsequently escaped and caused a major fire run through Kioloa State Forest into Bawley Point on 2 and 3 December.
- A second spot fire crossed the Clyde River on 1 December to the south of the first spot fire. It was detected on the Sentinel image on 1 December at about 11:00 am.
- These two spot fires then commenced fire runs towards the Coast on 2 and 3 December.
- A further fire run commenced towards Termeil on 4 December from a breakout from backburns well to the north of the original bushfire extent on 27 November.

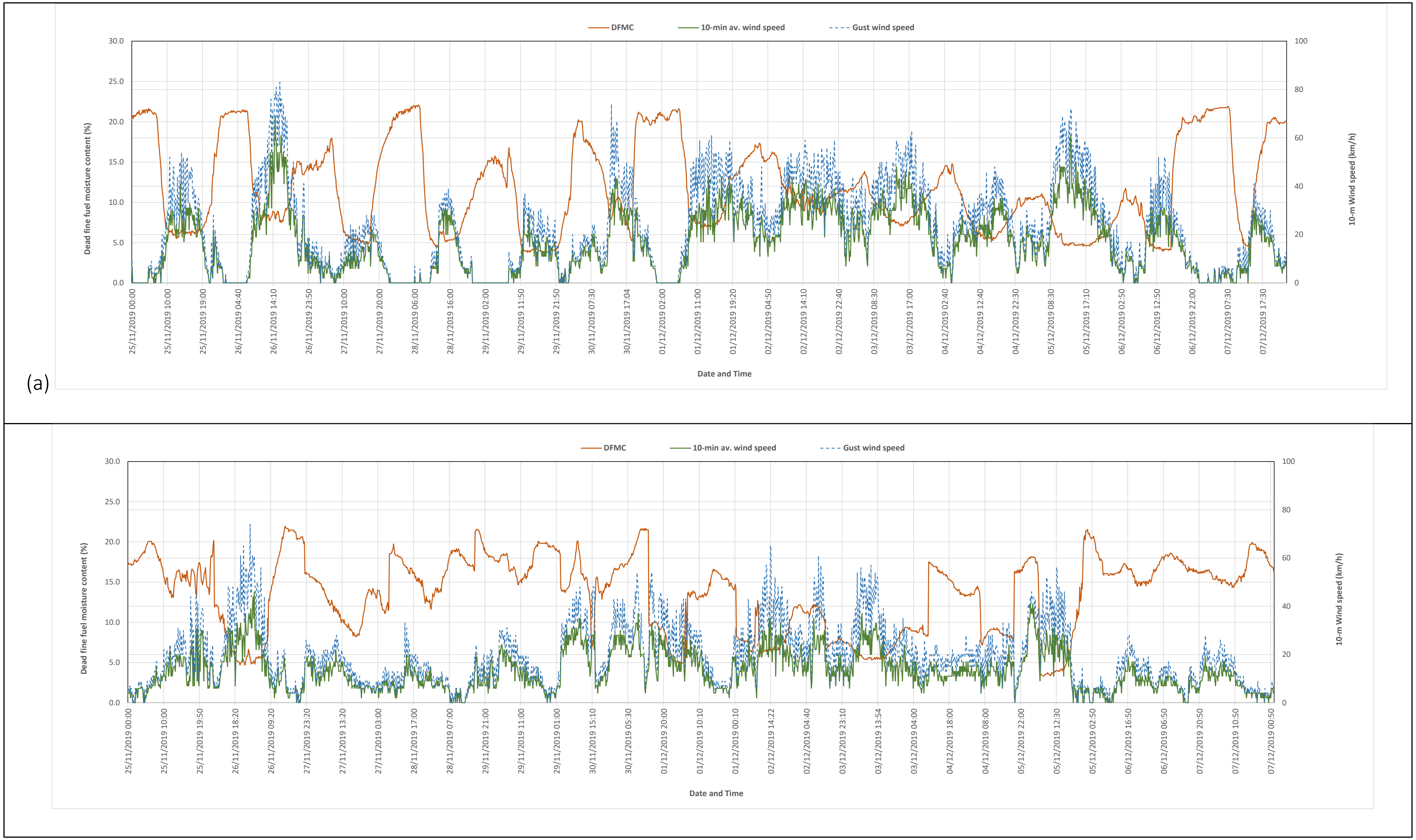


Figure FS22: Fire Weather – (a) DFMC and 10-m average Wind Speed for Braidwood AWS (b) for Ulladulla AWS (bottom panel), 25 Nov to 6 Dec 2019.

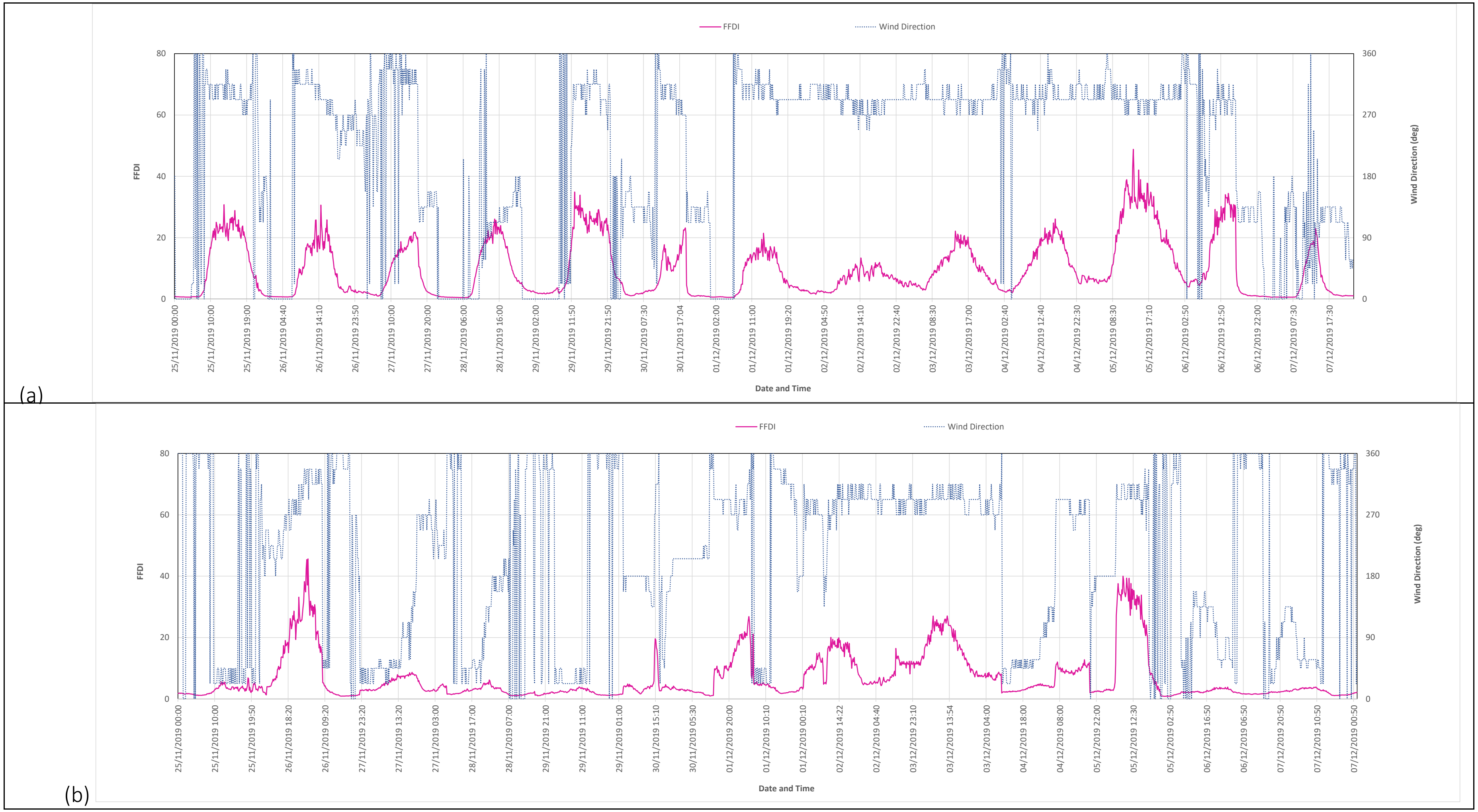


Figure FS23: Fire Weather – (a) FFDI and 10-m average wind speed for Braidwood AWS (b) for Ulladulla AWS (bottom panel), 25 Nov to 6 Dec 2019.

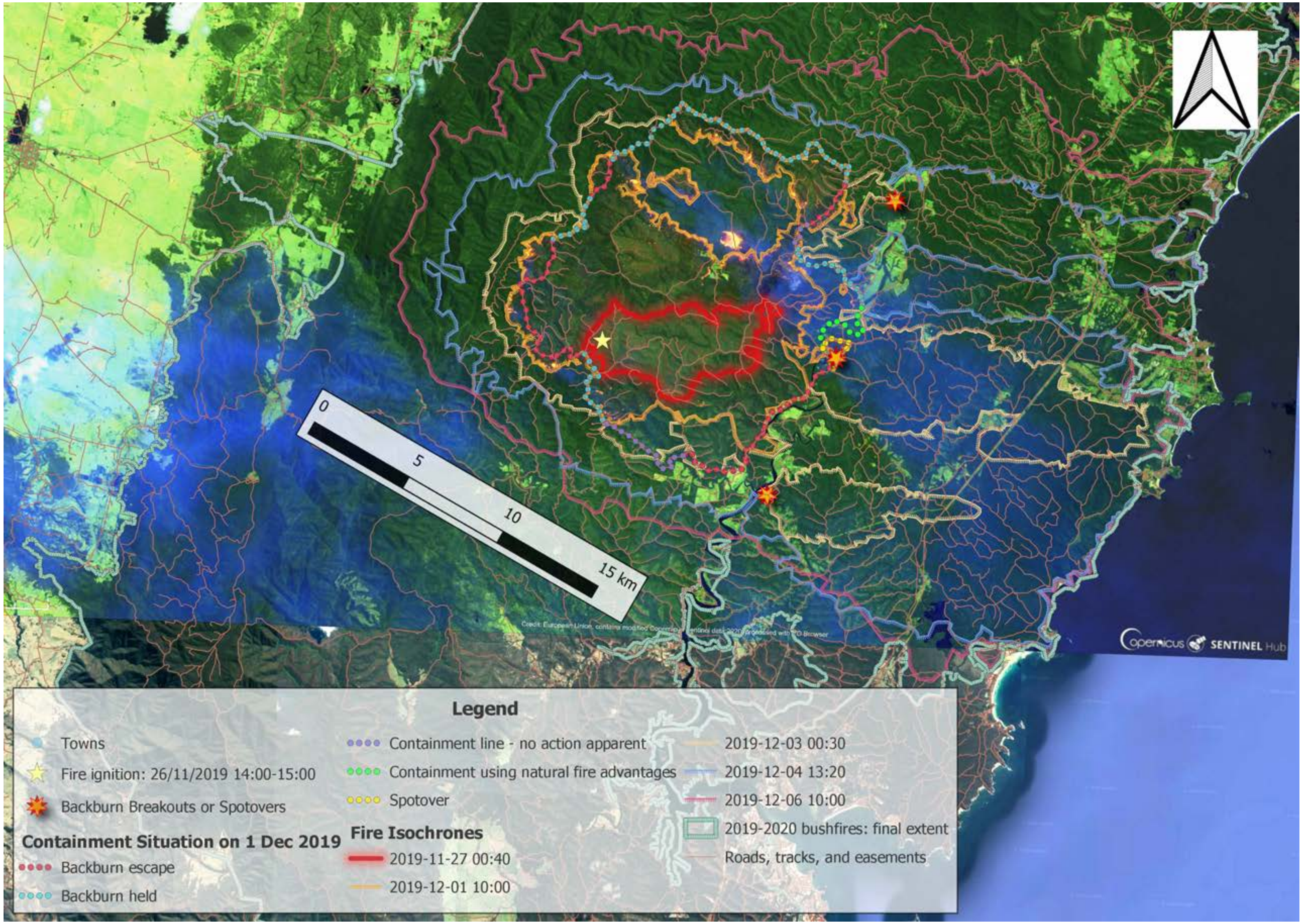


Figure FS24: Fire Containment strategy overview map for the early stages of the Currowan bushfire.

Fire Study 8: Conjola Park and Milton backburn containment strategy, Currowan-Tianjara Complex
Issue: Backburn Failure because of limited time between completion and blow-up conditions
Period: 7 – 11 December 2019

Introduction

The purpose of this fire study is to analyse the failure of the containment strategy in the Milton to Conjola section of the Currowan-Tianjara bushfire complex. This analysis includes the Conjola Park fire escape and the containment line escapes further south towards the western side of Milton along the escarpment.

The fire reconstruction is a preliminary first step towards understanding the fire dynamics and fire strategies that either diffused or exacerbated the fire's behaviour on this sector of the bushfire. It will be enhanced using residents' information and photos taken on the day.

Situation

Prior to 31 December the Currowan and Tianjara fires were converging, the latter from the north and the former from the south. By 27 December the Currowan bushfire had reached the Porters Creek Dam Rd and Pointer Gap Rd which were later used as part of the backburn line on 30 December. The Currowan Fire was approaching the Yatte Yattah precinct from the north and met up with a backburn along the western side of the Princes Highway.

The Currowan part of the bushfire continued to burn slowly downhill between 27 and 30 December. Parts of it never met up with the backburn. On the early morning of 31 December there was still a 500m to 1000m gap between it and the backburns conducted to the south.

Easterly moist air masses dominated the coast and hinterland during this period. DFMCs ranged between 15 and 22% for most days prior to 31 December, the exception being 30 December when DFMCs were in the range of 8 and 22%. Even early morning on 31 December until the breakdown of the inversion at about 08:00 the easterly mass was still present over the fireground.

Fire reconstruction on the day

The breakout of the Currowan bushfire in the Yatte Yattah sector came from two active edges not suppressed since 27 Dec about 1-1.5 km to the north of the backburn. We have identified three ignition points based on fire linescan data obtained from a meeting with local residents on 7 May 2020 *(Figure FS25)*. The first fire spot fire started up at about 09:05 from a small eruption event at 08:50 back near the start of the southern front fire front resulting from the fire re-ignitions. The wind was from the west at this time – it later veered to the NW from about 10:00 onwards until close to the arrival of the strong cool southerly wind change.

The initial three fires spread easterly at 18-25 m/min until about 10:00 when they reached the edge of a flat hill and started to spot into Bloodwood Road and the area either side of the Princes Highway at 10:15. These new spot fires started separate fire runs across the Princes Highway about 1.5-2.0 km east of the initial fires run, further back up on the main hill to the west. The fire spread on two fronts either side of Myrtle Gully in an SSE direction north of Conjola Park. It is estimated that the Currowan bushfires started to spot into Conjola sometime between 11:15 and 11:30. The Conjola Park fire run also likely spotted across the lake between 11:30 and 11:45 as well as into the Narrawallee Nature Reserve between 11:30 and 12:00. The vigorous southerly change came through at about 13:00 and swept these fire runs to the north. The wind went around to the WSW and then finally settled at SSW. The fires moved north, on several different fronts on both the southern and northern side of Conjola Lake.

Sometime between 08:00 and 09:00 further south of the Conjola Park fire runs, another series of separate fire fronts started up to the south- east of Pointer Gap and west of Milton, all as a result of spot-overs on the fire containment lines. In between the Conjola Park and these more southerly fires, another set of fire runs caused further spot-overs between Pointer Gap and Yatte Yattah along the full length of the containment lines.

Important fire landscape and fire behaviour features

- The Milton escarpment contains semi-mesic Turpentine-Red Mahogany forest which had built up some fuel moisture recovery in the days preceding the 31 December breakout. This is a very different fuel to the heathy woodland and heathland on the Morton plateaux.
- It is difficult to work out from the information available whether the main fire or the backburns contributed to the spot fires that occurred at 10:30 on 31 December. It is possible that the interaction of the two coalescing fire fronts contributed to increased fire intensity, energy release, and release of fire brands from the dissipating convection column after the two separate sets of fires coalesced.

Fire weather patterns (see Figure FS26)

- The fire weather was relatively benign from 25 to 29 December before some of the worst fire weather on the South Coast on 30 and 31 December. Fire 'spike' days also occurred on 26 December. Fire weather was otherwise reasonably benign between 7 and 9 December and between 24 and 30 December (refer to weather chart).
- Fuel moisture recovery in most fuel types on and below the escarpment occurred overnight on most nights as a result of easterly air masses over the fireground, except on 5 and 10 December. The fire weather at Ulladulla was overall milder than at Nowra during this period.
- Fire weather deteriorated significantly from the morning until mid-afternoon of 31 December for about 2 hours. The FFDI was 89 at Nowra whereas at Ulladulla it was about 60.

Containment strategies

- Direct attack could have been a viable option to suppress the line of fire active to the north-west of Conjola Park given the benign fire weather conditions before 31 December. This could have been lower-risk fire tactic than to implement a backburn the night before without much community consultation about the potential risks of fire escape.
- The containment lines on the escarpment and slopes west of Milton were highly convoluted and as a result were more likely to be breached on the morning of 31 December.

Potential lessons

- The key containment strategy used throughout the Currowan bushfire was indirect backburning which did not account for changes in fuel type varying between heathland, heathy woodland, dry shrubby eucalypt forest, and mesic and semi-mesic eucalypt forests, local topography, and drought effects.
- Nor did it apparently allow for variations in tactics, such as partial containment or direct attack in fire sectors close to the coast where easterly moist and stable air masses predominated.
- Instead of such reliance on backburning in the top-level Currowan fire strategy, local people with detailed knowledge of firegrounds, fuel types and topography could be used to develop local fire strategies and tactics. This could be said of any of the bushfires that impacted on local communities across the breadth of eastern NSW.

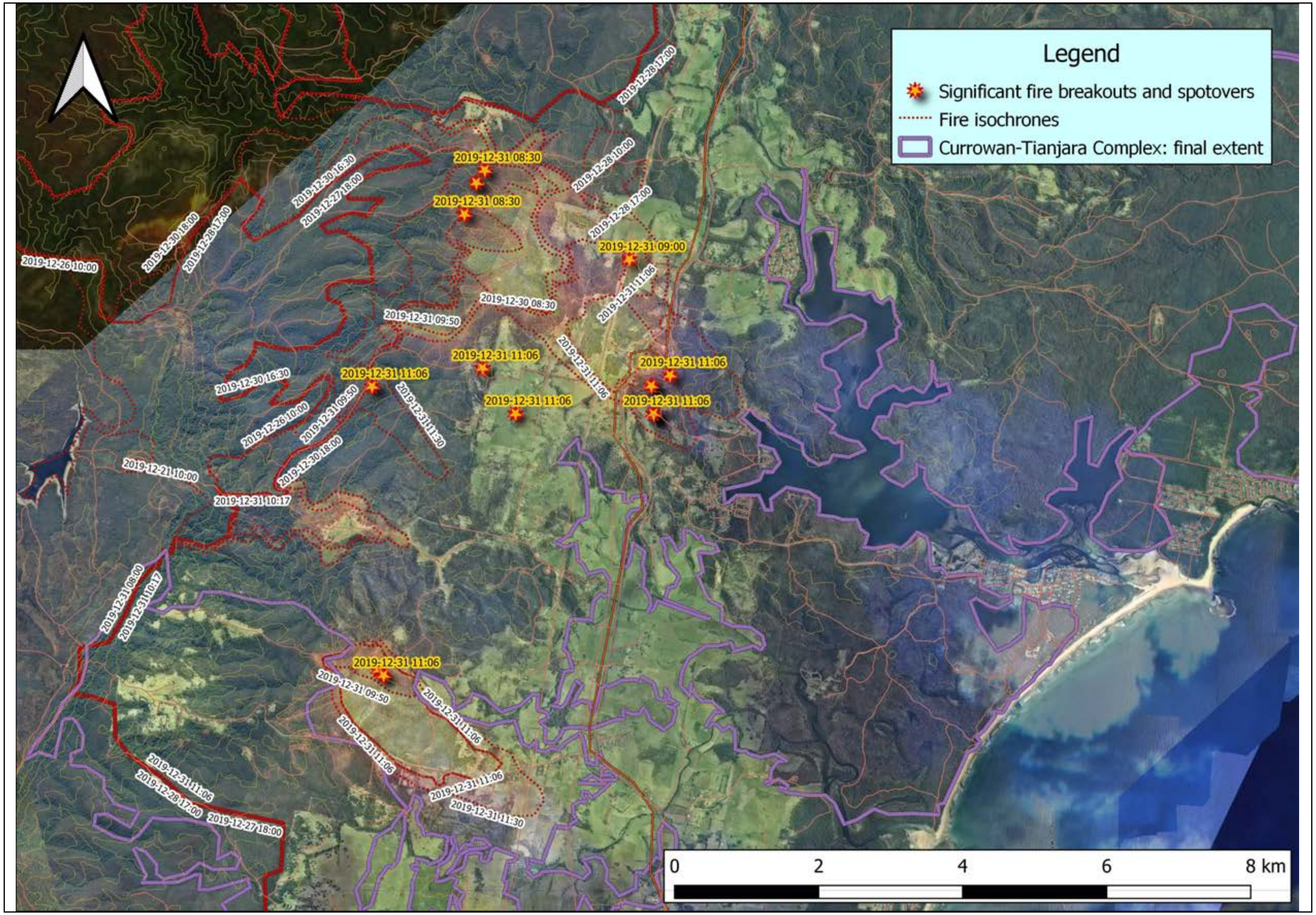


Figure FS24: Fire containment strategy overview map for Milton-Conjola section of Currowan-Tianjara Complex fire.

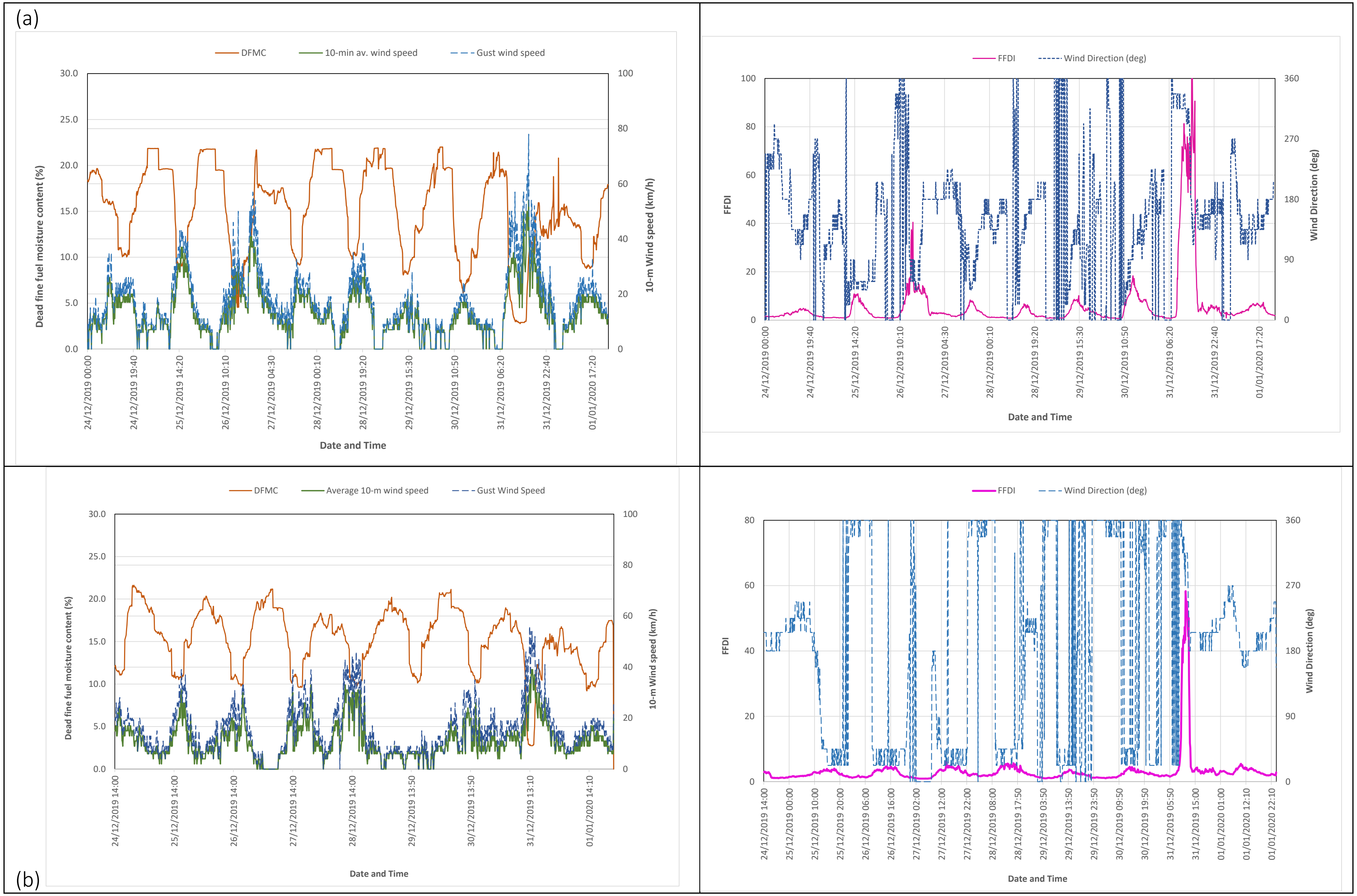


Figure FS26: Fire Weather: DFMC and average 10-m and gust wind speed (left panel) and FFDI and wind direction right panel) for Nowra and Ulladulla AWS – 24 2019 to 1 Jan 2020 for Nowra AWS.

Fire Study 9: Clyde Mountain backburn containment strategy, Currowan-Tianjara Complex

Issue: Backburn failure related to moist fire weather conditions and fuel types on Clyde Mountain Pass

Period: 17 – 31 December 2019

Introduction

The purpose of this fire study is to analyse the failure of the fire containment strategy in the Clyde Mountain Pass section of the Currowan-Tianjara bushfire complex along the south-western part of the fire *(Figure FS27)*.

Backburns were conducted between Nelligen and the middle section of Clyde Mountain Pass between 15 and 17 December, stopping short of Clyde Mountain Pass. On the morning of 19 December 2019, the backburn spotted across the Kings Highway and then a fire run over the Budawang Ranges to the west occurred later in the afternoon.

In the meantime, the main south-west sector of the Currowan bushfire was still back in the dissected rocky ranges to the north, hardly spreading east because of the moist forests and rocky areas retarding its spread. Further to the north the Currowan bushfire had burnt across the Budawang Ranges to meet up with backburns conducted to prevent the bushfire spreading onto grassland.

Some of these backburns were later to fail causing the Currowan bushfire to make incursions through private forest, shrubland, and grassland towards Mongarlowe.

Situation

Fire reconstruction

A fire reconstruction was completed using all available Sentinel and Himawarri satellite images, local knowledge of fuel types and terrain, and piecing together the fire weather from two automatic weather stations, Braidwood and Moruya for the period from 14 December-2 January.

Important fire landscape, weather patterns, and fire behaviour features

- A strong moisture and temperature gradient exist between the coast and the hinterland escarpment along the Budawang Ranges. Moist easterly winds often produce mist and strong fuel moisture recovery in the Clyde Mountain area where the backburns were conducted. In the late afternoons or evening mist or cloud can often be seen forming on the higher parts of the Budawang, Monga, and Deua mountain ranges.
- This meant that as the backburns went west up the Kings Highway towards Clyde Mountain Pass, they were being undertaken in damper and wetter eucalypt and, on occasions, cool and warm temperate rainforests. In these more mesic and semi-mesic forests, the surface fuel moisture contents of the surface and near-surface fuels retarded the spread and sometimes stopped the backburns.
- The point where the backburns crossed back over the Kings Highway to the south in the early morning was in damp montane forest about a 1 km to the west, along the road where the backburns had stopped on 17 December.
- Later, on 19 December the fire reactivated to the north of the spot-over and spread westwards under the influence of an easterly and spotted west of the Kings Highway into Monga National Park sometime between 14:00 and 15:00.
- This spot fire was not controlled for the next ten days within essentially a forest dominated by rainforest and montane mesic forest in the gullies and drier open forest on the ridges. The terrain is flat to undulating with some small ridges rising above the gully system.

- It is not clear whether further backburning was involved in the lead up to 30 December in the southern of Monga National Park leading to the major high-severity fire run into Batemans on 30 and 31 December.

Fire weather patterns (Figure FS28 (a) and (b); Figure FS29 (a) and (b))

- While there were 'spike' days of high to very high fire danger high up on the Monga plateau, on 19 and 21 December, the lower parts of the coast had low-moderate fire danger for most days during this period with the severe-extreme fire weather day just before and after the arrival of the southerly wind change on 31 December.
- There was no evidence of any severe fire weather detected at Moruya Airport on 30 December that saw the Currowan fire spread downhill that afternoon from the Monga escarpment. The best explanation could be a lee-wave event which also saw the Badja Road fire further south in the Wadbilliga make its run towards Cobargo later the same evening.
- Moruya airport detected a severe-extreme fire danger between 08:00 and 12:30 on 31 December when DFMCs fell to 2-3% and average 10-m wind speeds ranging from 35 -45 km/h. The period of severe to extreme fire weather did not last for more than 5 hours before the higher air moisture in the southerly cool change increased the fuel moistures to over 20%.
- Fuel moisture recovery in most fuel types on and below the escarpment occurred overnight on most nights between 19 and 30 December based on DFMC from both tableland and coastal weather stations (Braidwood and Ulladulla respectively). Daytime DFMCs did sometimes decrease to 6-8% based on observations taken from the Braidwood AWS.

Containment strategies

- The Kings Highway through the Clyde Mountain escarpment, like the Mt Wilson backburn escape in Fire Study 5, carried a high risk of spot-over into the steep and dissected Buckenbowra River catchment to the south.
- Backburning through a range of different fuel types will inevitably be difficult where problems of getting a deep enough backburn in semi-mesic or mesic fuel types is very likely.
- Active suppression of the spot fire whilst still small on the evening of 19 December should have been undertaken whilst DFMCs rose to over 15-17% at Braidwood AWS and were probably even higher on the South Coast escarpment.

Potential lessons

- The overall fire strategy objective should be to reduce the severity and extent of a bushfire, not enlarge it with high-risk backburns. During droughts it is even more critical to minimise the likelihood and size of large fire runs on blow-up fire days. In other words, the key objective is to reduce convective energy release particularly during the passage of pre-frontal troughs.
- Roads, even main roads, have shown to be not very successful containment lines for backburning during the 2019-2020 fire season. Like the Glow Worm Tunnel Road and the Mount Wilson Road backburn escape fire studies, the attendant risks of escape and consequent impact on Batemans Bay and local adjoining townships could have been avoided had well-conceived fire containment strategies been considered on this and in earlier stages of the Currowan bushfire.
- Successful suppression of the spot-over across the Kings Highway in eastern Monga National Park on the evening of 19 December could have avoided the devastation that followed 10-11 days later.

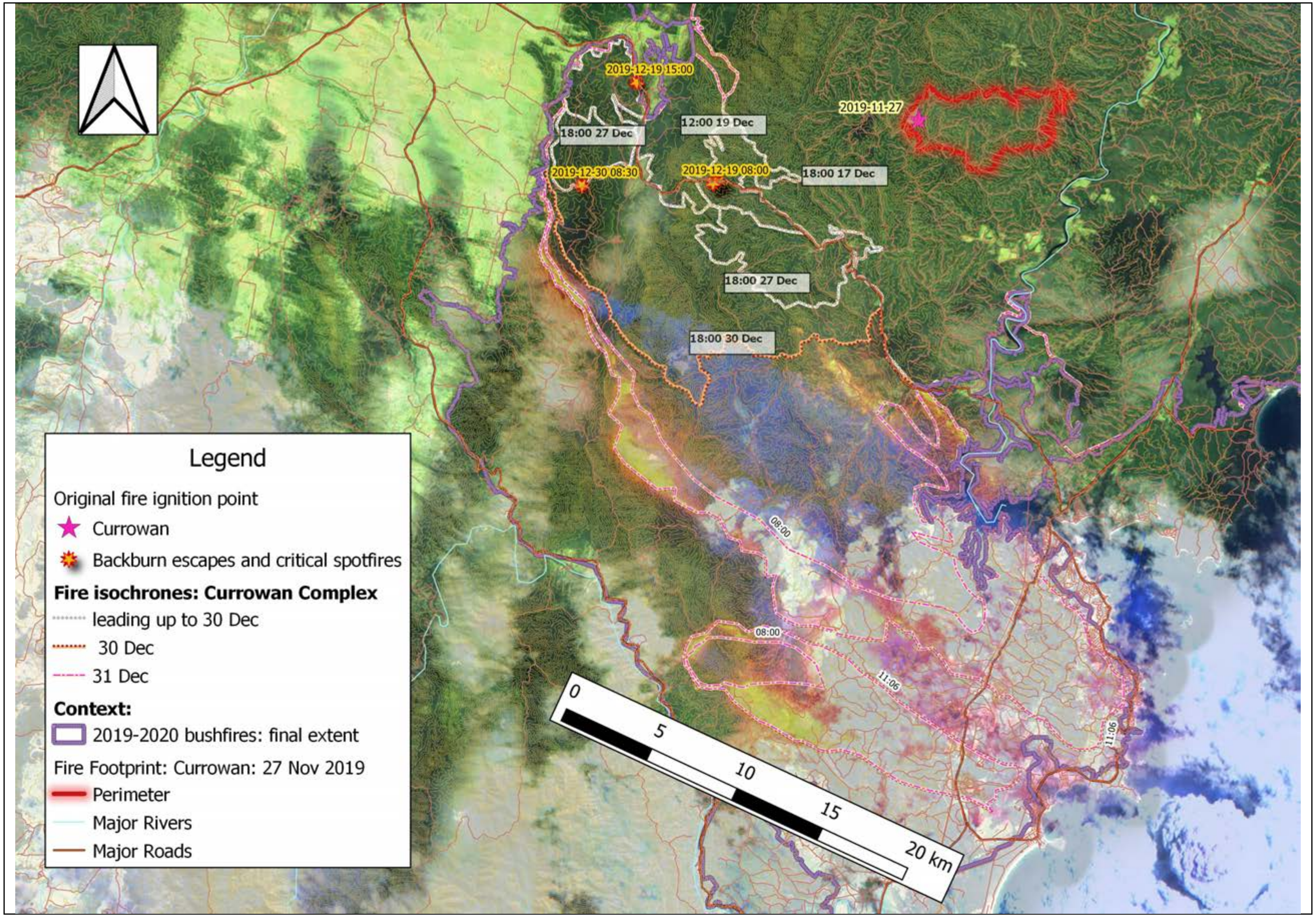
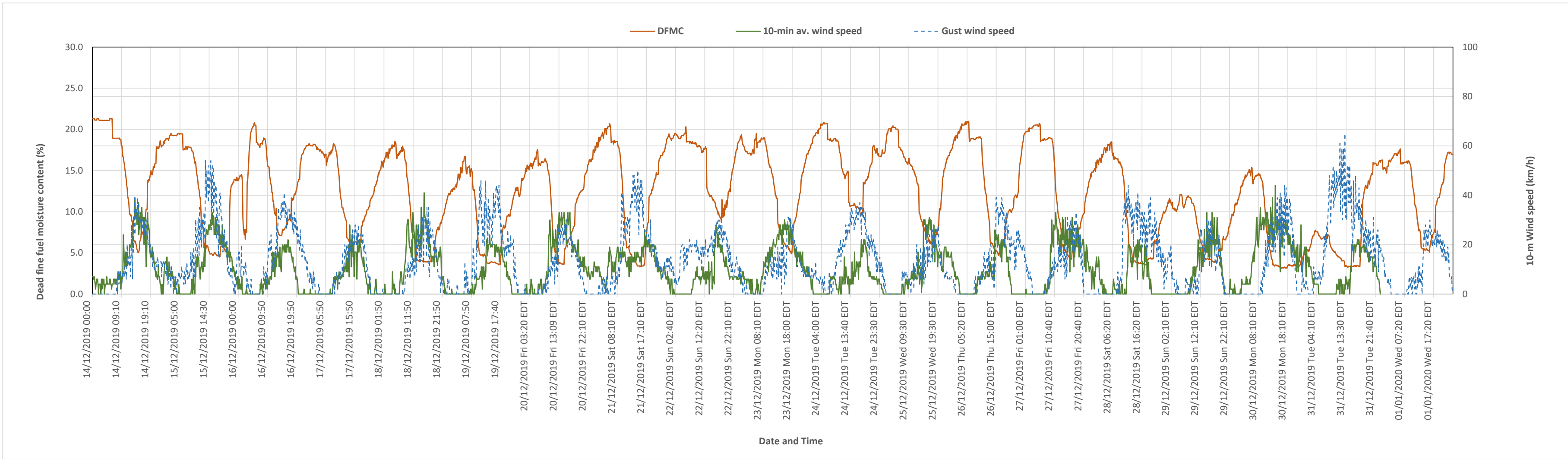
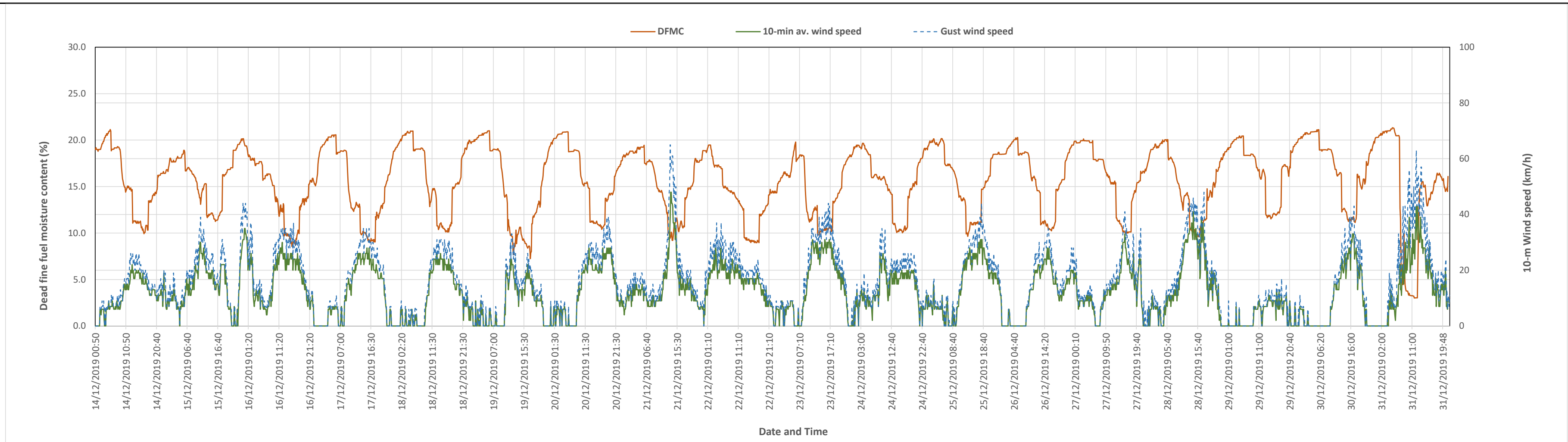


Figure FS27: Fire Containment strategy overview map for south-west section of the Currowan-Tianjara Complex bushfire.

(a)





(b)

Figure FS28: Fire Weather – (a) DFMC and 10-m average Wind Speed for Braidwood AWS (b) for Moruya AWS (bottom panel), 14 Dec to 1 Jan 2020.

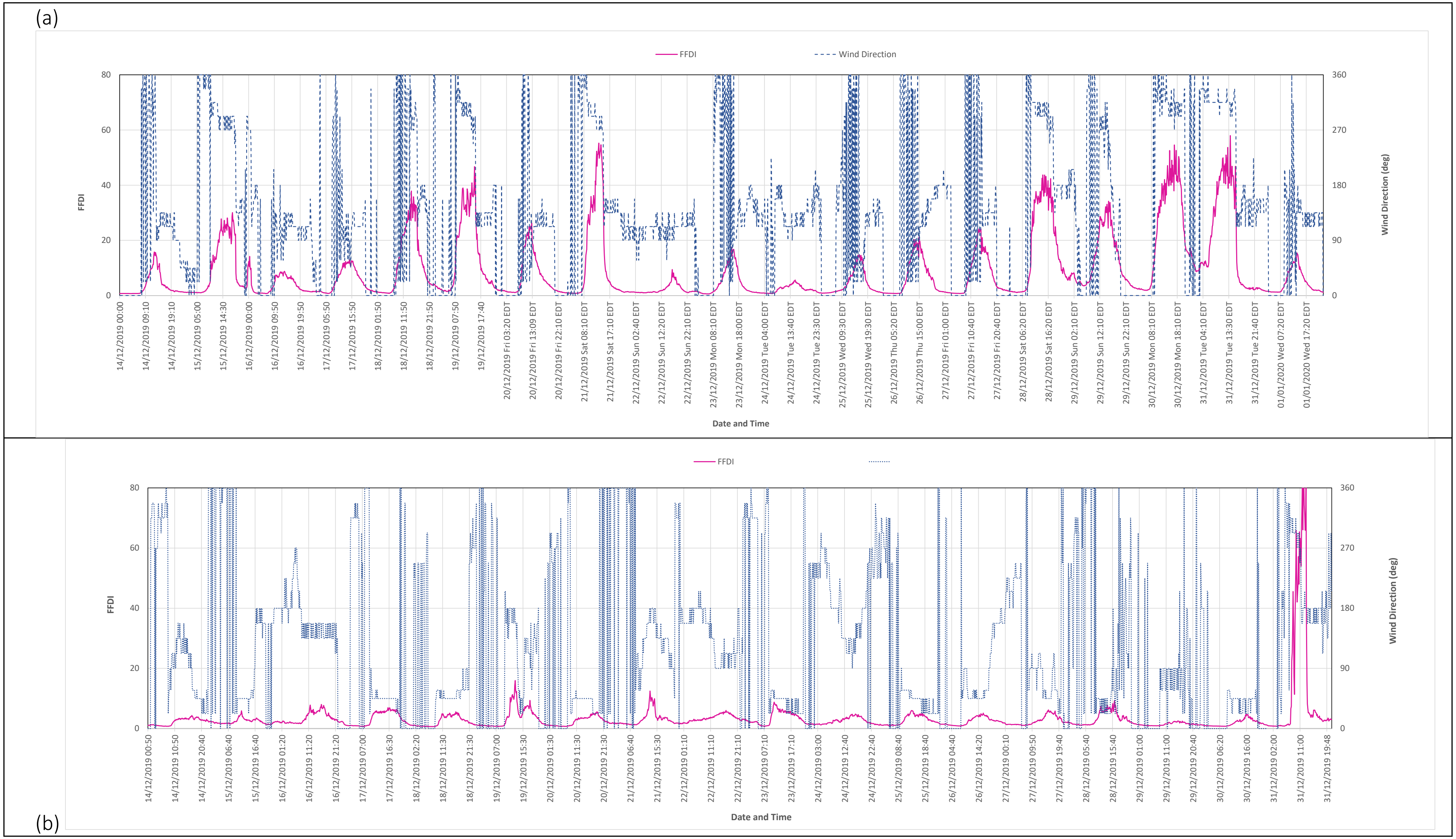


Figure FS29: Fire Weather – (a) FFDI and 10-m average wind speed for Braidwood AWS (b) for Moruya AWS (bottom panel), 14 Dec to 1 Jan 2020.

Fire study 10: Half Penny Hill fire, Kosciuszko National Park

Issue: A successful example of strong initial attack with aerial attack and RAFT
Period: 27-28 December 2019

Situation

The Half Penny Fire *(Figure FS30)* was confirmed on 27 December 2019 from a linescan taken on 26 December. The cause was lightning.

Victorian air attack planes initially responded on 27 December with a retardant drop from a LAT. In total there were four LAT drops that day from airbases at Albury and Canberra. These were followed by numerous drops from single-engine planes. Water bucket drops also occurred from a heavy helicopter and three medium helicopters. The results were very effective in knocking down any running edges and keeping the burnt area to about 15 hectares.

It is understood that a combination of weather conditions and the unavailability of a helicopter with winch prevented RAFT crews being inserted on 27 December.

On 28 December RAFT from NPWS and RFS were deployed using a combination of winching and hover exit to land crews. These crews thoroughly extinguished hot logs and mopped up the whole fire perimeter with support from helicopter water bucketting.

Containment strategies

RFS and NPWS IMT staff with local knowledge knew that extinguishing this fire by keeping it small was a high priority and worthy of substantial efforts. Previous fire history in this area has shown that small lightning fires need to be extinguished very quickly as the terrain makes it very difficult to work remotely on a fire greater than about 25 hectares. Fires that are not kept small will rapidly grow into large and long-term campaign fires, especially when ignition occurs in early summer and fuels are extremely drought stressed.

This fire could have easily burnt for months, reaching more than 150,000 hectares in size and threatening many rural communities in the Ingebyra, Paupong, Numbla Vale and Delegate areas.

Although the air attack costs alone would probably have exceeded $200,000, the direct cost of containment of the potentially massive fire would have greatly exceeded this, not to mention the impacts to communities, and biodiversity and catchment values.

Potential lessons

- Future risk, costs and impacts can be minimised if priority is given to strong initial attack.
- Remote lightning fires can be extinguished if attack is rapid enough and of sufficient weight.
- Initial knockdown from the air can be an effective strategy before the insertion of ground crews to extinguish the fire.

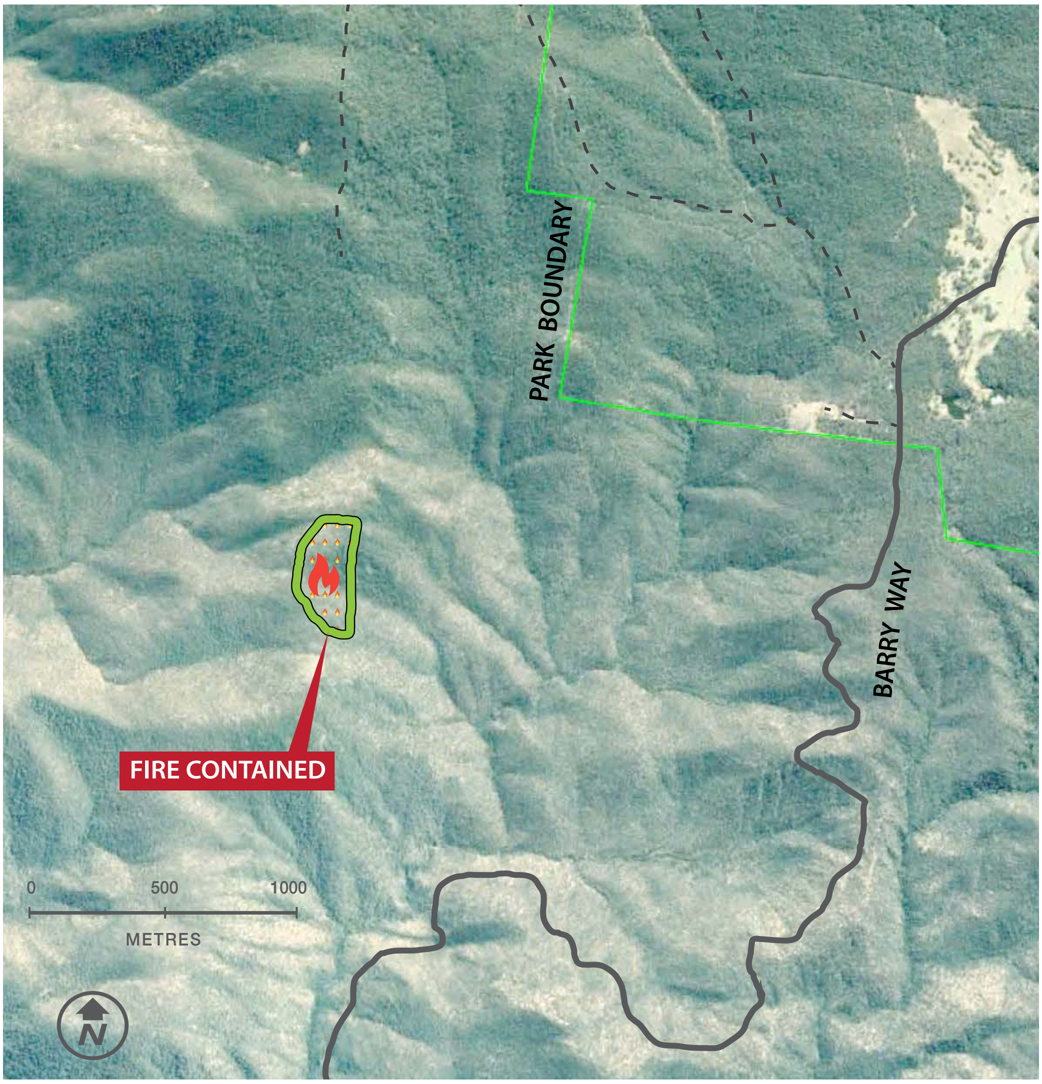


Figure FS30: Half Penny Hill fire, Kosciuszko National Park

Fire Study 11: Bees Nest fire, Northern Tablelands

Issue: Inadequate fire behaviour modelling can lead to flawed strategies
Period: Around 9 September 2019

The effect of poor fire behaviour modelling can be illustrated by examining the Bees Nest fire, north of Dorrigo, NSW.

Situation

On 9 September 2019 the fire reached an area of very long unburnt (~700 years) North Coast Wet Sclerophyll Forest (Keith 2004) with a canopy of tallow wood and brushbox. The long-unburnt history of the forest had enabled a rainforest understorey to develop, with a dense sub-canopy dominated by coachwood over a tall but sparse shrub layer. It had also allowed a litter layer of about 20 tonnes per hectare to be maintained. Considering this along with the tall shrubs, both the McArthur and Project Vesta models predict flame heights of 4-6m for the mild weather conditions of the 9 September.

However, the weight of surface litter has no bearing on overall flame height (Zylstra et al 2016). Old-growth tallow wood forest is also markedly different to young regrowth jarrah; the shrubs for example are far less dense because there has been no recent disturbance. They are also mesic species with high moisture contents that make them slow to ignite. Their foliage is sparse because they grow in shade, and the base of the shrub canopies is high above the ground. Based on these and other factors such as the slow wind speeds beneath the dense mid-storey, FRaME modelling indicates that the shrubs were very unlikely to ignite, so that flame heights would generally be less than one metre in height.

Following the event, satellite measurements of fire severity *(Figure FS31)* found that fire impacts on vegetation were undetectable through the tallow wood forest and the core of true rainforest[2]. Heat signatures were however detected by other satellites (Geoscience Australia 2019) through the tallow wood, but not the rainforest. Together, these indicate that the tallow wood did likely burn, but at a severity that was undetectable by the post-fire satellite measurements of vegetation.

The contrast between predictions made using McArthur and Vesta and what was modelled in FRaME and measured by satellite underpin contrasting options for controlling such a fire. The small flames predicted by FRaME and shown by satellite measurements can be contained using direct or parallel attack by RAF crews or by using tankers along fire trails. If large flames as predicted by McArthur and Vesta were expected, these would generally need to be contained with an indirect backburn. Backburning can be less successful than direct attack and more likely to inadvertently advance the fire front through escapes. A decision to backburn rather than direct attack would result in the burning of the long-unburnt tallow wood forest. (It is not known what action was taken with this fire, as records have not yet been obtainable).

FRaME modelling indicates that, even though many of the rainforest trees would not have been scorched, heat would have penetrated through the thin bark into the cambium, resulting in girdling and death of coachwood and other such trees. This would significantly increase the flammability of the site for decades. Tree death allows more sunlight to reach the forest floor to stimulate shrub growth, create drier conditions allowing more frequent fire spread and favouring drier, denser shrubs. Reduced canopy and understorey density will allow more wind access when fires are burning. The impact of burning this forest with a slow, low-severity fire is that the next fire is likely to be far more severe.

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[2] *Data available at: https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm*

Potential lesson

- Faulty models for bush fire behaviour can misrepresent expected fire behaviour leading to inappropriate strategies and more impact on natural values, especially moist forest types which are desirable to maintain as natural moderators of bushfire.

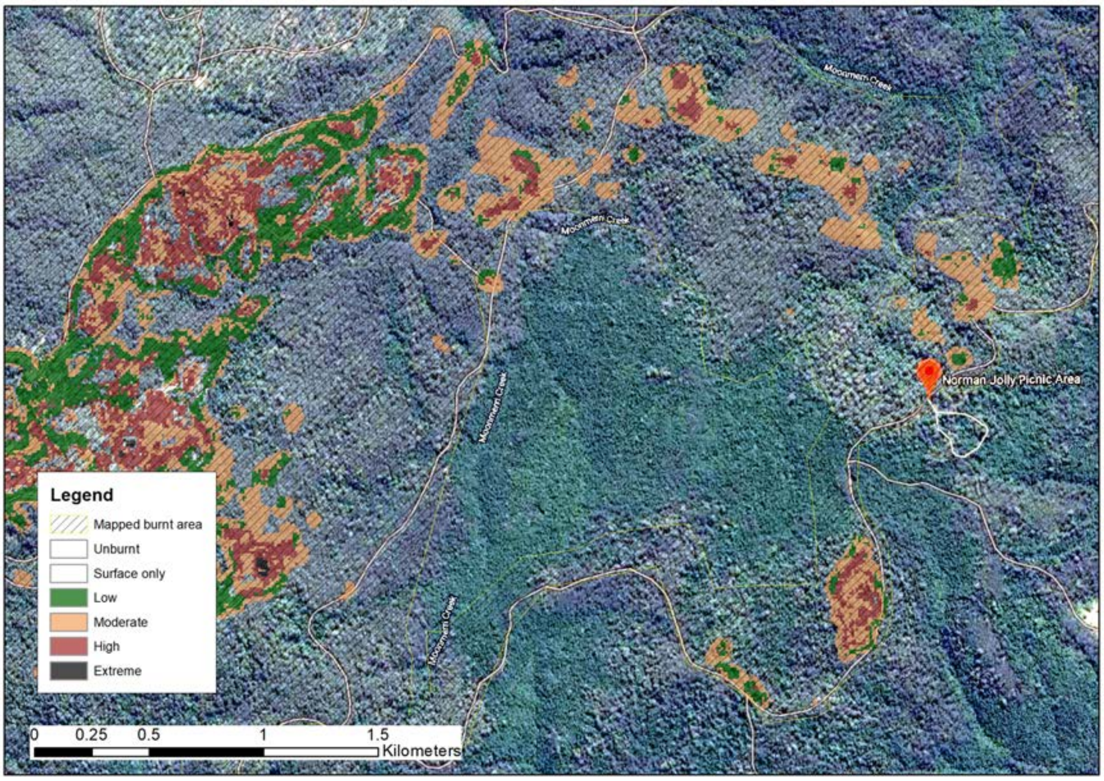

Figure FS31: Fire impacts in the tallow wood study area. Dark green areas in the air photo show rainforest patches, predominantly surrounded by the lighter coloured wet sclerophyll. The hatching indicates the area that was mapped as burnt, and the coloured overlay indicates the areas where the severity of the burn was detectable and could be mapped by satellite. Source: https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm

Appendix A

Report Authors

Denise Allen

BSc Forestry

Denise Allen is a professional forester with over 39 years' experience in land management. Denise spent 15 years working for the Forest Department and the Department of Conservation and Land Management in Western Australia, nine of those years as District Manager Jarrahdale, just 60km south-east of the Perth CBD. There she was responsible for implementing broadscale aerial burns and fire suppression activities within close proximity to a large and vocal populous. Working for the NSW National Parks and Wildlife Service, Denise has had roles managing the fire management program at an Area, Region and Branch level. She assisted in establishing the Enhanced Bushfire Management Program on the north coast of NSW and has been involved in overseeing its implementation. Denise most recently acted as Manager of Booderee National Park, a park jointly managed by the local indigenous community of Wreck Bay and Parks Australia staff.

Ian Brown

OAM, BA Earth Sciences, National Fire Medal

Ian Brown worked in national park management for 20 years and was involved in over 100 fires in roles from crew member to Incident Controller. He was the planning leader for the 1994 Bell Range fire emergency in the Grose Valley (Blue Mountains National Park) and Deputy Incident Controller for the emergency declaration phase of the 1994 Gospers Mountain fire (Wollemi National Park). He worked on planning for the Northern Strategic Line in the Blue Mountains. He managed bushfire programs across the Blue Mountains park system and served on two district bushfire management committees. In recent years he has been an independent environmental consultant, maintaining a keen interest in bushfire issues.

Dave Darlington

BA Earth Sciences, DipEd, National Fire Medal

Dave Darlington is a retired NPWS Regional Manager from the Snowy Mountains. Dave helped to develop and refine the incident management system in the 1990s and was a key IMS instructor for NPWS. In the Snowy Mountains fires of 2002-03 he was the Section 44 incident controller continuously from mid-December 02 to March 03 (for which he was awarded Australia Day Citizen of the Year by Snowy River Shire Council). He has also managed numerous smaller incidents. He was the NPWS representative on several Bushfire Management Committees from the mid 90's until his retirement in 2013. Dave is an active member of the Jindabyne RFS Bushfire Brigade and is Brigade President. He assisted the Rural Fire Service to develop a Community Fire Protection Plan for some key rural residential estates in his Brigade area.

Stephen Dovey

BSc, National Fire Medal

Stephen Dovey has been actively involved in fire management and suppression over 35 years in the NPWS. For the past 20 years as Area Manager he has been actively involved in cooperative firefighting with other agencies on the Bega Valley District Bushfire Committee. He has applied fire for ecological purposes as well as protection of life and property.

Nicholas Gellie

BSc Forestry, MPhil

Nicholas Gellie is a landscape ecologist and fire scientist with 37 years' experience in fire management, fire research, fire ecology, fire risk planning and vegetation mapping. He has an in-depth knowledge of landscape and bushfire processes in south-east Australia, having reconstructed over 100 major bushfires, including 2003, 2007 and 2009 (Black Saturday) in Victoria, 2003 in Canberra and 2019-2020 in NSW, as well as in Portugal and in California. He has undertaken many consultancies and published many scientific papers. He has worked extensively on fire behaviour analyses and the effectiveness of planned burning programs. He was a pioneer of community fire planning in NSW, has been involved in suppression strategies and aerial ignition for numerous wildfires and has planned and implemented many prescribed burns. From 2009 to 2014 he worked with Victoria's Department of Sustainability of Environment and the Bushfire CRC on analysing the Black Saturday fires. He was a key consultant to the House of Representatives Select Committee's inquiry into the 2003 Australian bushfires, A Nation Charred.

Lyndsay Holme

DipTeaching, TeachingCert, AssocDip (Environmental Control), MAppSc (Environmental Management), National Fire Medal

Lyndsay Holme has worked as a teacher in the Australian education system and for several decades as a ranger, field officer, forest fire fighter, ecologist and educationist with both the National Parks and Wildlife Service and the Rural Fire Service in New South Wales. He is the principal of Blue Labyrinth ECOServices, a private consultancy, where he undertakes ecological survey and bushfire risk assessment and prepares land system fire management plans for both government and the private sector. For 18 months in 2016-17 he worked as an Australian Government volunteer in the Kingdom of Bhutan, assisting with forest fire fighter training and advising Bhutan's Department of Forests and Park Services on strategic fire management and planning. He is also an active member of his neighbourhood CFU which was activated a number of times during the recent fire emergency period.

Wyn Jones

BAgSc

Wyn Jones is a wildlife ecologist and botanist with 50 years' field and research experience across a variety of landscapes. He is regarded as an expert on the ecology and wildlife of the Blue Mountains, where he has undertaken many studies on endangered species of flora and fauna, examined bushfire impacts and mapped vegetation. He has also created numerous community-based education and engagement programs founded in the natural values of the area. He is a photographer and a poet.

Geoff Luscombe

BSc (Hons)

Geoff Luscombe worked for 30 years with the NSW National Parks and Wildlife Service, 23 years as Regional Manager for the Blue Mountains and then Central Coast. He was involved in fire management and fire operations throughout his career, often at a high level in one of the most complex fire management areas in Australia. He played a key role in developing NPWS fire policies, managed strategic burning programs, developed many fire management plans and was Incident Controller for many emergency-level fires, some involving significant property loss, coronial enquiry and litigation. Geoff has served on many bushfire management committees.

Tim Shepherd

BSc (Hons), Grad Dip Mediation and Conflict Resolution

Tim Shepherd is a former NPWS Regional Manager on the NSW Far South Coast. His firefighting career began as a seasonal fire fighter in the late 1970s with the then Victorian Forestry Commission. As Regional Manager he held senior IMT roles and worked in coordination roles between agencies and other IMTs during major incidents. He formed the first Aboriginal fire team in NSW NPWS and worked with the Boards of the Aboriginal owned Gulaga and Biamanga National Parks to develop approaches to cultural burning. Under his leadership the NPWS Far South Coast region doubled its hazard reduction output in terms of numbers of burns and hectares treated. In the 2019-2020 fires he served as a volunteer in the Incident Management Team based in Bega.

Bill Shields

Bill Shields is a Bilpin orchardist who as a volunteer with the Rural Fire Service for more than 50 years has been involved at every level of fire fighting since the 1960's. He served as Captain of Bilpin RFS for 30 years and as a Group Officer in the Hawkesbury for 16 years. Over this period, he was involved in every major fire in the Bilpin area, including as Divisional Commander for all the big fires until 2013. He has been a Divisional Commander and Strike Team Leader on numerous fires outside the Hawkesbury in NSW. He has managed the planning and implementation of many backburns and planned burns. He was a pioneer in community fire planning and education long before it became more widely adopted.

Marg Turton

BSc

Marg Turton is a Blue Mountains based ecologist who has been employed in various roles within the NPWS, Blue Mountains City Council and as an environmental consultant for over 25 years. Marg has written several threatened species recovery plans, has studied the fire ecology of numerous endangered plant species, prepared Fire Management Plans, worked on various post-fire monitoring studies and also worked with the NCC Hotspots program. Marg has an extensive knowledge of the Blue Mountains environment, it's varied habitats and its wildlife.

Philip Zylstra

B App Sc (Environmental Science), PhD (Mathematics in bushfire modelling)

Phil Zylstra is an Adjunct Associate Professor at Curtin University (WA) and an Honorary Fellow at the University of Wollongong. Phil worked in fire management across the Snowy Mountains from 2002-2012 and again in 2017, where he was one of NSW's first fire behaviour analysts. He combined management with research starting in 2004, to develop FRaME (Fire Research and Modelling Environment), which is the only peer-reviewed fire behaviour model in Australia for forests other than West Australian jarrah, the only existing model showing species' effects on fire behaviour, and the only model for first-order fire effects on wildlife. Phil now combines these mechanistic approaches with empirical analyses of fire history to understand what drives flammability in Australian forests, and what new thinking is needed to mitigate the increasing fire risk posed by climate change.