Bushfires and Knowledge Forest, Fire and Regions Group

Science Catalogue 2018-19

Forests, Fire and Regions Group

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Section 1: How DELWP's science has shaped Victoria's bushfire management

Foreword

Over the past century, Victoria has amassed a wealth of science based knowledge about bushfire behaviour and management that has fundamentally changed the way bushfire is managed across the state. This science is nationally and internationally significant and has led to Victorian communities being safer.

It has enabled the Department of Environment, Land, Water and Planning (DELWP) to minimise the impact of bushfire on human lives, communities, infrastructure, industries, the economy and the environment while maintaining and improving the resilience of natural ecosystems and their ability to provide services such as biodiversity, water, carbon storage and forest products to Victoria.

Currently, DELWP invests or leverages more than $5 million a year in forests and emergency management research projects through its bushfire science program. However, the value of this science, the knowledge it generates, and the capacity it has to inform DELWP practices is often obscured by its subtle and cumulative influence over time.

In charting the history of DELWP's long-term commitment to invest and use science-based research, we begin to understand its powerful influence on our learning and behaviour. This knowledge is built up over decades, often shaping outcomes unforeseen when the science was commissioned years before.

> *"There is a 20-year gap between conducting an experiment and the knowledge being embedded in practice " Dr Leon Bren and A/Prof. Kevin Tolhurst, personal communication*

Bushfire science contributes to policy and operations in a multitude of ways and in various time frames.

By bringing together the most significant historical directions in Victoria's bushfire management and science in this narrative, we better understand:

- the contribution of science to the development of fire management policy and operations on public land in Victoria
- how science-based knowledge is informing current approaches
- how science will continue to influence future planning and help protect Victorian communities.

Established as a narrative around major bushfire events as drivers for research, this history is not intended as a comprehensive list of all science or research generated or used by DELWP. It is a snapshot of critical events and activities that demonstrate how scientific endeavours by generations of researchers have answered key questions about bushfire and its impacts. It shows how far DELWP has come in our understanding of bushfires, the risk they pose, and how we manage that risk. It also reminds us that continuing investment in science is needed to ensure we continue to improve our bushfire management.

None of this would have been possible without the generous support of the many researchers and DELWP staff, past and present, who gave their time, memories and archives to assemble this history. Our sincere thanks must go to them. They are the heroes of this history.

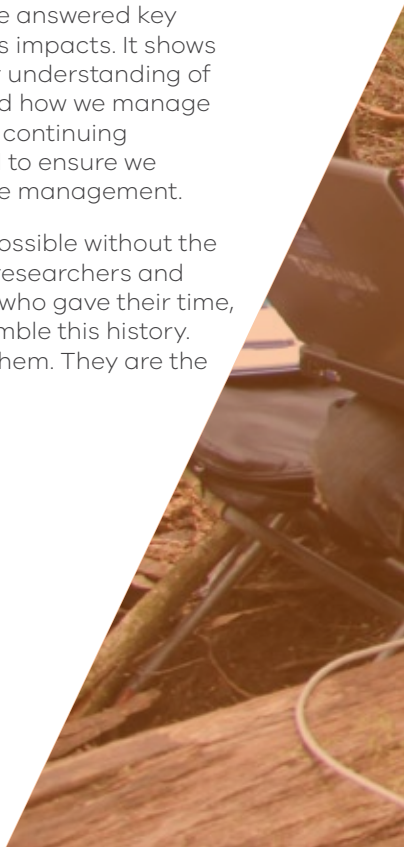

Figure 1: Field research. Source: Pat Lane.

Introduction

Bushfire Policy and Science

Science underpins all our work, holds us to account, and enables us to connect, involve and inform the community in evidence-based decision making to deliver improved outcomes for all Victorians (DELWP Science Strategy 2017).

DELWP has a long history of science investment and its use is now deeply entrenched in every aspect of DELWP's bushfire management activities - from policy directions and management, to field operations and training. In turn, the learning this inspires identifies new avenues of research and scientific endeavour. This adaptive management loop underpins the knowledge base of bushfire science. This strong commitment to knowledge and learning ensures DELWP continues to improve its capacity to deliver critical government policy directions such as *Safer Together (2015)* and the *Code of Practice for Bushfire Management on Public Land (2012) (the Code)*. The DELWP Bushfire Science Strategy 2013-2017 describes this relationship perfectly "DELWP is a science-dependant organisation: good science provides good evidence, which in turn informs good policy".

Interestingly, DELWP's application of scientific discovery to better bushfire management is rarely the result of an outcome from a single research project- more often, science outputs interlink and build upon each other towards a critical outcome or a breakthrough improvement. Bushfire management decisions and new policy are rarely the results of a single research project, but more an accumulation of scientific evidence, often over time. For example, DELWP's planned burning program is informed by decades of research into the effects of bushfire on the environment, and the Review of the *Overall Fuel Hazard Guide (unpublished 2013)* looks back at the original science behind what is now an accepted way of looking at fuel hazard and demonstrates how the research developed over two decades.

Similarly, new research projects draw on knowledge gained through previous research, and practical experience, to fill newly recognised or previously unfillable knowledge gaps.

This is supported by the Research Monitoring, Evaluation and Reporting Framework developed specifically for DELWP's Forests, Fire and Regions Group by RMIT which clearly showed that establishing a causal link between research and a specific policy or operations outcome an "impact " or "direct attribution" is both rarely possible and significantly under-recognises the value of research evidence in DELWP. Instead we need to focus on research 'contributions' across time bringing a broader focus which acknowledges the value of research contributions as powerful and long-lived.

The value of long-term research should never be underestimated. The ability to revisit past research and try new research ideas based on previous findings is invaluable, more so when existing background data is comprehensive. The Wombat Fire Effects Study Areas (FESA) research has been collecting and analysing data about the impact of repeated planned burning for over 30 years. This

work has informed planned burning practices, and the development of successive iterations of the *Code*. One of the most significant messages flowing from these studies is that short-term fire effects can be misleading, given the longevity of forest ecosystems (DSE, 1995). It took until 2005 for the Council of Australian Governments (COAG) to identify that the demonstrated value of long-term research be a priority focus as a nationally significant research gap.

Importantly, not only bushfire science informs DELWP's policy and operations. Ecological research examining flora and faunal species distributions, and habitat requirement has enabled the selection of key bushfire response species, even though this was not the original driver for the research. Similarly, past work on nutrient cycling in forests is informing the impact of bushfire in carbon accounting. This flow of non-fire research into evidence that supports bushfire management includes research from areas as diverse as catchment hydrology, to meteorology and silviculture.

DELWP has been increasingly explicit that research investment is driven by its potential to improve policy and operational performance. In fact, *Safer Together (2015)* highlighted the need for ongoing, applied and pure research. This contrasts with previous investment where research was often funded as a direct result of inquiries into individual fire events. While this research has been and continues to be used proactively (for example, research into the effects of bushfire on catchments after the 2003 Alpine Bushfires, where post-fire erosion was significant, informed the development of catchment management and recovery planning, and the Bushfire Rapid Risk Assessment Team program and training) the impetus for ongoing targeted research remains.

DELWP's research investments operate within a community of bushfire researchers, policy makers and operational management, both within Australia and internationally. This collaboration and information exchange enables our bushfire science to be effective and far-reaching. As early as 1928, fire research was shared at the Empire Forestry Conference between Australia and New Zealand, again in 1968 at the Ninth Commonwealth Forestry Conference in India, and still later in 1972 at the Seventh World Forestry Congress in Buenos Aires. Today, Victorian fire researchers continually exchange ideas and information with colleagues to ensure DELWP science is international best practice- supported by strong networks between individual researchers, research organisations, land managers and policy makers at all levels.

Figure 2: Roadside trees near Healesville, January 1939. Source: DELWP.

The Beginnings of Fire Research in Victoria

Aboriginal people were the first fire managers in Victoria. Their highly skilled use of fire enabled them to control vegetation, attract game, produce food, warmth, shelter and communicate. Fire also had a deeply spiritual value (Hateley, 2010). A range of contrasting views on Aboriginal use of fire and the influence of early colonisation on bushfire frequency can be found in King (1963). It could be argued this debate is a result of the loss of knowledge about bushfire behaviour and ecology gained by the Aboriginal people over the centuries (State Government of Victoria, 2003) leading us to the first and critical question for bushfire managers:

- What has been the cost, to humanity and our environment, of not holding knowledge, and thereby learning and adapting to bushfire in Victoria?

Some of this question is beginning to be answered as DELWP enabled traditional burning to make a return to country in 2017.

Post-colonisation, systematic records of destructive bushfires in Victoria began in the 1850s, collected by the then Department of State Forests (Gill, 1981). Significant bushfires occurred in 1851, 1889, 1905/06, 1912, 1914, and 1919, after which the creation of the Forests Commission led to the collection of more reliable statistics. These simple records were the first attempt at creating systematic knowledge about bushfire in Victoria.

Fire research came next, albeit with a strong timber harvesting focus, as studies on the recovery of native timber trees commenced (FCV, 1928). At the same time a handful of lookout towers monitored fire activity and collected weather information for the Commonwealth Weather Bureau. This was the start of bushfire protection.

However, at this stage bushfire management, and the understanding required to adequately respond to bushfires, had not been considered at a state level.

One calamitous event changed that. In 1939, the Black Friday bushfires made it clear a whole-of-state approach to fire was needed in Victoria.

Black Friday 1939

Considered among the world's worst bushfires, the Black Friday Bushfires were an unprecedented event that impacted three-quarters of Victoria. By the time rain fell two days later, almost two million hectares had been burned, 71 people had lost their lives, and five townships, 1000 homes and 69 sawmills had been destroyed. Smoke and ash from the fires was reported as far away as New Zealand.

The bushfires followed a long drought and a hot, dry summer. Friday January 13th brought record high temperatures and strong winds that fanned several existing fires into a vast fire front stretching from the Yarra Ranges to the Upper Murray. Other bushfires ravaged coastal areas in the southwest, the Otway Ranges and the Grampians.

Three weeks later, the Victorian Government convened a Royal Commission led by Judge Leonard E.B. Stretton, who reported "On that day it appeared that the whole State was alight."

Environmental damage from the bushfires was profound and dead trees can still be seen in some forest areas today. Habitat destruction was extensive and in the worst affected places, soil took decades to recover and water catchments were contaminated for years due to fire debris and soil erosion.

Judge Stretton found the bushfires were the result of carelessly lit smaller fires, including burning off, campfires, sawmill operations and domestic fires. Some of these fires had been burning since December. Blaming ignorance and apathy among land users and forestry workers alike, he wrote: 'it will appear that no one cause may properly be said to have been the sole cause', but it was clear 'these fires were lit by the hand of man'.

The 1939 Royal Commission was to have far-reaching impact on Victoria's fire and forest management, shaping its direction for decades to come and establishing the foundations for contemporary fire practice, including the forests service, Victorian fire services, early monitoring, fire prevention strategies, record keeping and fire data collection.

Judge Stretton's recommendations achieved clearer separation of bushfire and forest management, better cooperation between competing government departments, and more flexible and comprehensible laws of fire protection and prevention. He also made the first recorded recommendation for planned burning as official bushfire management practice in Victoria.

An early initiative from the Royal Commission was the *Forests Act 1939* which enabled the then-named Forests Commission (now DELWP) to control fire management on public land. However, it was not until further severe bushfires in 1944, and Judge Stretton calling for all the recommendations from 1939 to be carried out, that the Country Fire Authority (CFA) was formed to manage fire on private land outside greater Melbourne. There were now three separate firefighting agencies in Victoria – the Forests Commission (now DELWP), the CFA and the Metropolitan Fire Brigade (protecting inner Melbourne)

Figure 3: Front cover of Bushfire Relief publication 1939.

The 1940s to 1970s: Australia grapples with predicting fire spread and impact

The need to better understand and predict bushfire behaviour led to early work on fire danger ratings in the 1940s. Tables indicating fire hazard in grassland were imported from Canada and adapted for local use (Gill, 1981). Despite this increasing recognition of the gravity and impact of bushfires, fire research in Australia remained largely uncoordinated throughout the 1940s and '50s.

It was the 1960s before the Forest Research and Education Branch of the Forest Commission conducted the first planned bushfire management experiments in Victoria. In 1964 fire researcher Athol Hodgson oversaw (unsuccessful) trials of aerial fire suppression at the Ballarat airport (Youl *et al*, 2010). This was followed by more successful experimental fires in the Fire Research Forest near Barkstead in the Wombat State Forest.

By 1969, research in Victoria had expanded from investigations into the impact of bushfire on merchantable timber to the ecological effects of bushfire. By the 1970s, research into the effect of season and repeated fires, including manipulative experiments on the wiregrass habitat of Lyrebirds, was underway. Summarised by Hodgson and Arnis Heislers, this work was presented to the Seventh World Forestry Congress in Buenos Aires in 1972.

At a national level, Alan McArthur at the Commonwealth Forestry and Timber Bureau in Canberra (and later at the CSIRO) began researching fire behaviour, the influence of weather and fuel conditions and control burning in eucalypt forest in the early 1960s. His work on fire danger measurement was ground breaking and led to the development of a predictive tool, the Forest Fire Danger Index and the McArthur Meter, still in use today.

Figure 4: Early aerial firefighting experiments. Source: DELWP.

By the mid-1970s research was starting to really focus on understanding fire behaviour in plantations and native forests with a strong emphasis on the timber industry, regeneration of timber stands, and firefighting equipment. Fuel evaluation, management and moisture content were studied in the Grampians.

Researchers, such as David Ashton in the Mountain Ash forests, began investigating ecological fire effects. By 1977 the Interim Reference Areas Advisory Committee had enough evidence to produce the report 'Estimates of the time required for recovery of Victorian plant communities from ground and crown fires'. The report included a table that approximated the fire frequency required to naturally maintain floristic diversity and structure of classified plant communities.

Finally, also in 1977, Richard Rawson took the initiative and commenced the DELWP *Fire Research Report* series that continues to the present day as the *Fire and Adaptive Management Research Report* series- the name change reflecting the shifting focus to research application. Now numbered at over 100 these reports encapsulate DELWP's commitment to science and learning to better manage bushfire. A list of these reports can be found in Appendix 1: Fire and Adaptive Management Research Reports 1977-2017.

The McArthur Forest Fire Danger Meter (FFDM)

The Forest Fire Danger Index and the McArthur Meter first appeared in operational use in 1967 as the Mk 4 FFDM. The Index brought together results from more than 800 experimental fires and wildfire observations into a single system for general forecasting in Australia's eucalypt forests. A comprehensive summary of this work was presented in 'Fire Behaviour in Eucalypt Forests' (McArthur 1967).

McArthur tested his meter using low-intensity fires on Black Mountain near Canberra with the most extreme conditions when forest fire danger index (FFDI) was in the 20s. Conditions from the Black Friday Bushfires were used as an example of a 100 index.

McArthur's ideas on protection burning were hugely influential, adopted first in WA and then Victoria (Youl *et al*, 2010). He was involved in a joint report by CSIRO and the CFA on bushfires in Victoria's western district in February 1977 including the Glengower-Creswick Fire where the first reported targeted suppression of the north-eastern flank prevented major fire spread with the south westerly wind change.

The FFDI on both Ash Wednesday (1983) and Black Saturday (2009) reached much higher than 100 and, after Black Saturday, the FFDI was revised. A distinction was made between forest and grassland fuels, a FFDI over 75 considered 'extreme' and over 100 'catastrophic' or 'Code Red' (Victoria) to identify situations where forest fires present a critical threat to life and safety.

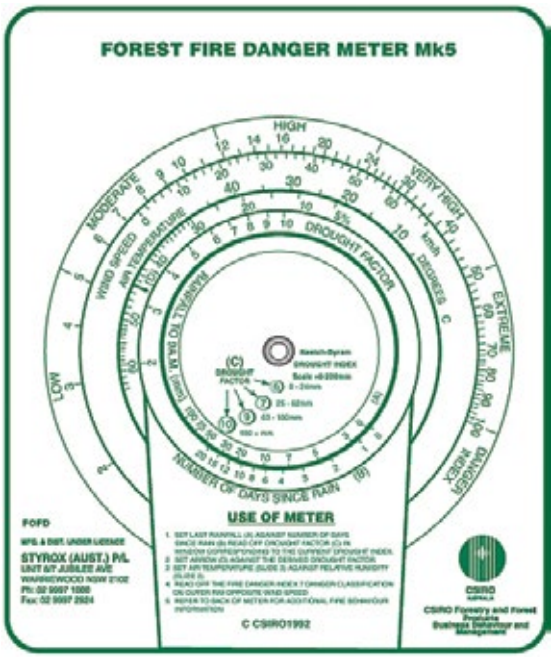

Figure 5: Forest Fire Danger Meter Mk5. Source DELWP.

Figure 6: Firefighters resting Ash Wednesday.

The 1980s: Fire ecology not just fire behaviour

In the early part of the 1980s, research continued to build on what had gone before, including a range of reports with a strong silvicultural and plantation management flavour. Case studies of individual wildfires were conducted opportunistically, and included two reviews looking at the effectiveness of fuel reduction burning.

However, bushfire research underwent a fundamental shift during the 1980s.

In 1981 *Fire and the Australian Biota* (Gill *et al*. 1981) introduced the idea that the ecological ramifications of bushfires was as 'recurrent disturbances', not just 'events', and that the cumulative impact and characteristics of fires play a vital role in determining the response and persistence of species.

Based on contributions to a national conference in 1978, this seminal text gathered together threads of research to create the first complete picture of the state of knowledge in Australia. It looked in detail at bushfire history, physical factors affecting fire behaviour, the responses of individual organisms and ecosystems to fire, and the role of bushfire in ecosystem management. These concepts coincided with an era of intense re-evaluation of the nature of ecological community dynamics in response to disturbance, leading to an invigoration in the field of bushfire ecology, and stimulating research interest in the explanatory power of life-history, species dynamics, and common patterns of response among species in bushfire-prone ecosystems.

At the same time research that used the vital attributes of plants to predict successional changes in disturbed plant communities began to be delivered Noble and Slatyer (1980).

Just as fire ecology was starting to strengthen as a research discipline, the 1983 Ash Wednesday Bushfires provided a devastating reminder that despite substantial gains in knowledge and understanding of bushfire behaviour, there was much to learn.

Ash Wednesday

For a new generation of Victorians Ash Wednesday was the first experience of severe bushfire. The bushfires claimed the lives of 75 people and burned more than half a million hectares across two states.

At the time, Victoria was in the grip of a ten-month drought. The earliest total fire ban day in the state's history had been declared on 24 November 1982, and the following February was one of the hottest and driest on record.

On February 16 1983 more than 100 fires, some deliberately lit, some sparked by power lines, tore across Victoria and South Australia. Northerly winds pushed the fires into long columns with spot fires jumping well ahead, increasing the extent of the columns further. The common early evening wind change turned these narrow columns into one massive fire front. Within an hour of the wind change the greatest loss of life and property occurred.

In Victoria 47 people died, 2080 homes and 210,000 hectares were destroyed. Public land affected included the Dandenong Ranges National Park, the Wombat State Forest and the Otway forests.

The Bushfire CRC (Morgan, 2008) summarised the impact of Ash Wednesday in this way:

The 1983 Ash Wednesday bushfires provided a range of experiences to build upon but they also revealed how much we still had to learn. The suddenness, the velocity and the deadliness of those fires added considerable urgency as far as our need to know more about a range of variables such as fire behaviour and fire weather. We needed better guidelines on how to manage the land for both bushfire protection and for its conservation values – were those values competing or complementary? What was the long-term impact of a bushfire on different types of vegetation? How do you get a community 'fire ready' when the residents have grown up in urban areas, and when fire occurrence appears to be so ad-hoc?

A rigorous dose of further scientific research was going to be the only way we could tackle these questions in a way appropriate to the late twentieth century.

It was after Ash Wednesday, in 1983, that the fourth in a series of Fire Ecology Symposia was held at Monash University. Involving the Forest Commission and the Conservation Council of Victoria these symposia, held in 1969, 1970, 1974 and 1983, highlighted the need for an experimental approach to bushfire research. Much of the work conducted to this point had been opportunistic sampling after unplanned fires, or case studies of individual fuel reduction burns and individual wildfires. These studies were not answering the questions fire managers had about managing broad scale fuel reduction programs. The final symposium, preceded as it was by the Ash Wednesday fires, reinforced the need for better understanding and knowledge to underpin bushfire management. New and emerging issue rose at the symposium- such as the effects of bushfire on fauna, catchment hydrology and the problems of bushfire management on the urban interface. Some of these are still being grappled with today. Tim Ealey, Director of the Graduate School of Environmental Science at Monash University, summed it up best in his closing address: *"More of this sort of thing should be done: actually collecting real data and seeing what's happening"* (Ealey (ed), 1994).

At this point DELWP researchers established Australia's first, long term research into the effects of repeated planned burning.

The Wombat Fire Effects Study was a critical piece of foundation work for DELWP. Its success was in large part due to its inception by a young team of researchers that included foresters and forestry staff. Led by Dr Kevin Tolhurst (later Assoc. Professor), the researchers were first employed by the department and then by the University of Melbourne's Forest Science Centre in Creswick. They remained with the project for decades, building a unique and valuable collective knowledge and understanding of Victorian bushfire behaviour.

The Wombat Fire Effects Study

In 1984 the Wombat Fire Effects Study Areas (FESA) were established. This longitudinal project is widely regarded as the beginning of DELWP's ongoing commitment to research into bushfire behaviour and ecological impact. Operational in scale, scientific in design and multi-disciplinary in scope, the project examined the impact of fuel reduction burning from repeated low-intensity fire, in both autumn and spring, in mixed eucalypt foothill forest. Implementing prescribed burning at a range of time intervals on the same permanent plots, researchers measured ecological impacts on understorey flora, invertebrates, birds, bats, reptiles, terrestrial mammals, soil chemistry and the growth, bark thickness and defect development in trees. Local climate and weather, fuel dynamics and fire behaviour were vital inputs, along with their interactions.

The Wombat FESA had a profound impact on bushfire science. DELWP bushfire research became more experimental and far reaching, involving studies on fuel, fire behaviour, ecologically based fire regimes, smoke emissions, water quality and more recently, carbon. These knowledge gains have informed policy, operations and thinking about scientific learning and fire management and that influence remains embedded in today's practices.

The Wombat FESA also informed decision-making and policy development around fuel management zones and regimes in the original *Code of Practice for Fire Management on Public Land* (1995). This was Victoria's first documented framework for the integrated management of fire and fire related activities on public land in Victoria, and, in turn, this informed the revised Codes in 2006 and 2012.

But there was more to learn. To fulfil an undertaking made in the 1982-83 Bushfires Report, commissioned by the Victorian Government after Ash Wednesday, the Standing Committee on Forestry produced a report in 1987 for the Australian Forestry Council. This review, *'Australian Bushfire Research – Background, Guidelines and Directory'* was a comprehensive list of what was known about bushfire management and research, guidelines for research, issues requiring further research, and a directory of scientists involved in fire research across the nation. Nearly half the recommendations from the 1982-83 Bushfires report had research implications so it was not surprising there were six pages covering issues that required further research.

During the 1980s the DELWP fire research group began developing a new fire reporting system, and from 1989 they worked with the central information systems branch to create state-wide computing systems. These managed functions such as fire reporting, resources and planned burning and even included the first screen-based map of current fires. This DELWP team installed their own local area network and provided the fire management officers in each region with their first personal computer.

A decade later, with the arrival of the World Wide Web, Fireweb was born.

Highly innovative in design, Fireweb stored data as one of four things: event, resource, place or thing, rather than locking the software onto specific ideas like people, aircraft or radios. This focus on resources resulted in a highly flexible and easily maintained system. Once again, the department's in-house knowledge and scientific capacity had combined to transform the way it managed fire.

The 1990s: Fuel load, fire ecology and biodiversity

Insights gained from the Wombat FESA into fuel hazard and overall fuel loads provided the momentum for further research in the late 1980s and '90s. In 1992 DELWP decided it needed to improve the classification and assessment of fuel hazard and build this new information into management planning. The result was the first *Overall Fuel Hazard Guide* in 1999 (McCarthy *et al*) that consolidated previous research into a single guide.

For decades, fuel was quantified in terms of its load in tonnes per acre, then tonnes per hectare. But this predictive tool ignored other variables, such as fuel elevation, structure, weather and fire controls that also impact bushfire behaviour. Researchers then devised a method of quantifying bark relative to the McArthur Forest Fire Danger Index, producing an easy to use and visual guide accessible to both field practitioners and researchers. The same approach was applied to elevated fuels that then became the basis for the Overall Fuel Hazard Guide. Implicit is a shift in terminology. Fuel load referred only to fuel weight per unit area while fuel level was more generic. The Overall Field Hazard Guide and the science behind it have had significant national influence, including the CSIRO's fire behaviour research, *Project Vesta: Fire in Dry Eucalypt Forest Fuel Structure, Fuel Dynamics and Fire Behaviour* (Gould *et al* 2008).

Significant other research initiatives occurred during this period, including development of the Tolhurst-Hood Fine Fuel Moisture Meter to improve fuel moisture measurement and thereby the accuracy of fire behaviour and fuel reduction predictions, and research into the effectiveness of first attack in light of the new understanding of fuels, and use of fire prediction tools such as the McArthur Forest and Grassland Fire Danger Meters. DELWP was actively testing its bushfire management decisions and tools for application and improvement.

By 1992 a major review of the Wombat FESA was published and a series of workshops were held to share the findings. Emerging research began to strengthen the focus on the ecological basis of fuel reduction burning rather than just fire protection, with several case studies demonstrating the value of building ecologically based fire regimes into bushfire planning for the Grampians, Mt Cole, the Mallee, and in east Gippsland's heathlands. Finally, a report on the techniques and philosophy of monitoring vegetation for fire effects was produced at by Mike Wouters.

From the mid 1990s the development of a science-based framework for managing bushfire for the conservation of biodiversity was evolving within DELWP (Lewis and Friend, 2010) - articulated in policy documents such as the Fire Ecology Working Group *Guidelines and Procedures for Ecological Burning on Public Land in Victoria (2004)* (Department of Sustainability and Environment: East Melbourne, Victoria).

Concurrently, the Arthur Rylah Institute (ARI), began focusing on the importance of habitat elements such as old or hollow trees and their importance to both birds and arboreal mammals. The recognition that such habitat elements can be strongly influenced by bushfire meant that this research from further afield began to influence bushfire management to incorporate the needs of these species.

At a national level, Project Vesta, which involved researchers from states and territories across Australia, examined the behaviour and spread of high intensity bushfires in dry eucalypt forests in southern Australia with different fuel ages and under-storey vegetation structures. Designed to quantify age-related changes in fuel attributes and fire behaviour, this work contributed to a deepening understanding of the Victorian picture.

As the 1990's drew to a close, Kevin Tolhurst and Nick Cheney then produced the *Synopsis of the knowledge used in prescribed burning in Victoria* (1999) that concisely described the science behind current prescribed burning practices. It drew on a wide range of historical research and included chapters on fire behaviour, fuels, bushfire weather, and prescribed burning techniques. In one seemingly simple document, the rich experience and knowledge gained from research became easily accessible and available to bushfire managers and a new era of investing in bushfire behaviour research and modelling began.

Figure 7: DELWP field measurements. Source: Salahuddin Ahmad.

From 2000: Adaptation and improvement

During the summer of 2002/03, Victoria was again in the grip of one of its worst bushfire seasons. On January 7, 2003, lightning ignited 87 fires across the North East and East Gippsland. Eight could not be contained and eventually combined to form the largest bushfire in Victoria since Black Friday 1939.

The Alpine bushfires burnt almost 1.3 million hectares over nearly 60 days. Most of the area burnt was public land – 1.19 million hectares of parks and forests, including 60% of the Alpine National Park and 81% of the Mt Buffalo National Park.

The environmental impact was extensive, including significant impact on water quality and quantity across multiple catchments, loss of vegetation and habitats for flora and fauna, loss of commercial timber and extensive damage to recreation and tourism infrastructure assets, cultural sites and farms adjacent to public land.

The fires led to a number of inquiries in Victoria and interstate.

In Victoria these included the State Government's 'Esplin Report', an internal DELWP Review (Wareing and Flinn, 2003), and the Report of the House of Representatives Select Committee into the recent bushfires (2003). A review of these and the interstate and Commonwealth inquiries by Kanowski *et al* (2005) highlighted common principles for bushfire management- such as the integration of learning and knowledge, and the importance of monitoring performance.

Significantly, hydrology emerged as a research focus in post bushfire recovery. Measurement of changes in discharge, sediment and nutrients began, as well as modelling of long-term flows in large catchments and water quality analysis, modelling and nutrient fluxes in burnt catchments. Other research focused on the impact of prescribed burning (now planned burning) on surface run-off and erosion. This lead to specific water management provisions included in the DELWP *Guidelines for prescribed burning*.

Nationally, 2003 also saw the initial Commonwealth Government grant for the establishment of the Bushfire Cooperative Research Centre (CRC). Partner organisations including fire and land management agencies in Australia, such as DELWP, New Zealand, the Bureau of Meteorology and CSIRO, established the CRC as the first collaboratively resourced organisation specifically tasked with bushfire research across Australia. This initiated a range of new research in Victoria and the focus shifted to fire behaviour modelling. The Fire Management Business Model was developed to calculate the probability of ignition and spread of fires across a landscape. In the process, the model produced a fuel characterisation tool that included the fire-spread simulator Phoenix. Research had finally delivered a way to reliably predict the spread of bushfire and support decision-making in real time.

Figure 8: Post fire hydrological measurements. Source: Pat Lane.

Phoenix Rapid-fire

Historically, fire behaviour and risk assessments were manual calculations involving some degree of expert assessment. The Phoenix RapidFire (Phoenix) project wanted to improve the speed and efficiency of these assessments and develop the capacity to dynamically simulate fire behaviour. To this end, a range of projects was funded by DELWP and through the Bushfire CRC program.

Initially, the aim was to develop a fire risk model but this required an ability to simulate fire behaviour, including its spread and reactions to various landscape and weather factors. International models were not suitable for Australian eucalypt-dominated landscapes so the research team developed software informed by previous research in eucalypt-dominated landscapes.

The dynamic simulation capabilities of Phoenix enable land managers to explore potential fire spread under different conditions including weather, terrain and vegetation type. It provides detailed characterizations of a bushfire's strength and intensity, and generates visual representations of its movement across a landscape - taking into account land forms, vegetation types, roads and bushfire history. The software still relies on a fire behaviour analyst reviewing and, if necessary, adjusting outputs but the model has dramatically improved the speed of analysis and fire agencies ability to predict bushfire behaviour and provide advice to communities.

Phoenix has transformed bushfire management decision-making in Victoria. The dynamic simulator makes a direct and ongoing contribution to bushfire management policy and operations, including community warnings and engagement, resource allocation and planning both before and during bushfires. It enables strategic planning through strategic bushfire management plans for each of Victoria's seven bushfire risk landscapes (geographic areas grouped together because bushfires tend to behave in similar ways in those locations). Its ability to simulate and map the potential progress of bushfire can also be used to explore bushfire risks for land use development proposals throughout the state.

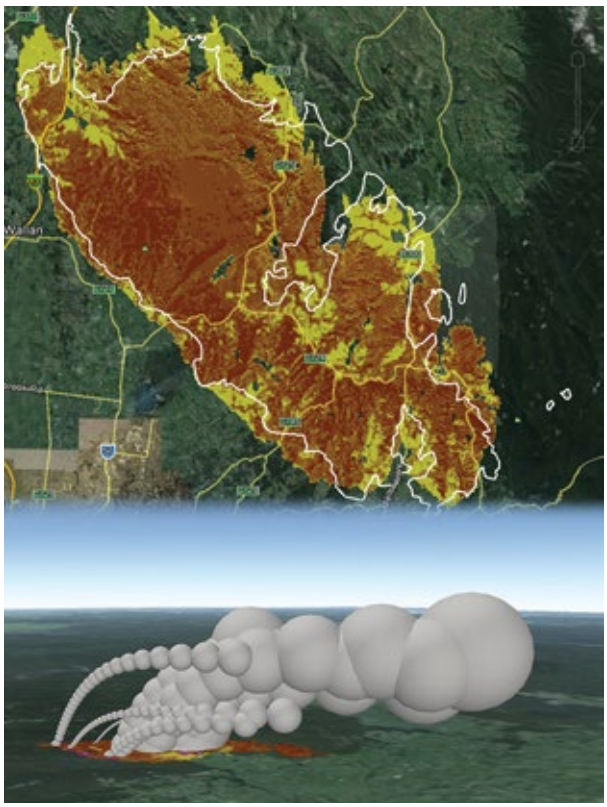

Figure 9: Ensemble forecasting of bushfires across Victoria using Phoenix Rapid-fire. Source: Derek Chong.

Phoenix can be used during a bushfire to enable community warnings and the most efficient deployment of operational resources. It can also demonstrate the fuel reduction outcomes of planned burning by simulating the impact of a fuel-reduced zone on the progress of a potential wildfire. Victoria began using the software operationally during the 2010-11 bushfire season and over subsequent years its use has grown to include a range of strategic planning and community engagement activities across Victoria, NSW, Queensland, South Australia and Tasmania, and internationally. Hundreds of 'fire analysts' have been trained in the use of the model.

In 2003, the Wombat FESA project re-examined the research plots and produced a suite of reports on the ecological impact of repeated fuel reduction burning. The Fire Ecology Working Group produced a *Practitioner's Manual for the Development of an Ecological Burning Strategy,* followed by *Guidelines and Procedures for Ecological Burning on Public Land in Victoria (2004)* and the *Revised Framework for Ecological Burning* (Fire Ecology Workshop draft proceedings) (2005). Fire ecology consolidated as a significant management concern for DELWP as ten Fire Ecology Program Officers (FEPOs) were appointed around the state to ensure ecological considerations were better incorporated into bushfire management planning and DELWP's bushfire research investments began to strengthen their focus on fire ecology and behaviour.

Figure 10: DELWP planned burn. Source: Nick Bauer.

Finally, in 2004, DELWP formalised the move of its in-house research team, the Forest Research Group, to the University of Melbourne and the newly created School of Forest and Ecosystem Science. The previously informal research alliance between the two organisations became a focussed nine-year research agreement with funding and research programs coming with increased requirements for peer-reviewed papers as an indicator of scientific rigor.

Soon after this, DELWP revised the *Code of Practice for Bushfire Management on Public Land* (2006) and reinforced the need for sound scientific information on which to base policy. As with the original Code in 1995, the revised Code articulated the importance of incorporating the best available research into management practices as soon as possible, explicitly acknowledging the ongoing contribution of research to underpin policy.

The gradual accumulation of research evidence about fire ecology finally influenced establishment of the DELWP Fire Ecology Program in 2008. Designed to ensure a sound ecological basis for bushfire management in Victoria, the program cemented the partnership approach between DELWP, Parks Victoria and the CFA, and enabled projects to operate across multiple research institutions including the University of Melbourne, ARI and Deakin University.

For the first time, a series of strategic and interconnected ecological research projects were established. These included floral vital attribute surveys across the Grampians, Mallee, Box Ironbark, Alpine National Park and Wilson Promontory, the *Mallee Fire and Biodiversity Project and Determining Appropriate Ecological Fire Regimes in the Heathy Woodlands of the Southwest*.

Early learning from the Fire Ecology Program produced *Living with Fire: Victoria's Bushfire Strategy* in 2008. The strategy outlined an expanded planned burning program, including the use of the Landscape Mosaic Burn as well as improved ecological research and monitoring.

Living with Fire also encouraged new research directions. By articulating the need for fire managers to improve the community's understanding of fire and the shared responsibility for risk, DELWP began to look at different ways to consult with the community. The department also started a conversation about air quality, recognising communities needed to better understand smoke impacts and how to mitigate the effects from planned burning and bushfires.

Projects driven by the Fire Ecology Program deliberatively challenged the assumptions that underpinned the Landscape Mosaic Burning program

Figure 11: Firefighter, Jane, at planned burn . Source DELWP

through research into the biodiversity impacts of baseline landscape burning in the 2009 bushfire areas, experimentally examining mosaics created by the burning program, and a retrospective study to identify the biodiversity values of different mosaics.

Also in 2008, Malcolm Gill also produced the report *Underpinnings of Fire Management for Biodiversity Conservation in Reserves* that brought together the broad range of fire science available to fire managers in a considered and comprehensive way.

As DELWP recognised the need for more effective community engagement, it began its first forays into social research, adopting the Learning Network approach or 'strategic conversation'. The Learning Network uses some of the practices of community capacity development through a continual series of conversations in local communities. These conversations recognise the strengths and resources within communities and the value of open conversations in which everyone participates on equal terms, including departmental staff. While the approach is challenging, it has started to build into the cultures of the department and the community a revised way of thinking and sharing information that stands to bring significant benefits over the long term.

In spite of these improvements in bushfire science and management, a decade long drought brought heightened risk of bushfire. During December 2005 and January 2006, bushfires raged throughout the northern Grampians, at Anakie near Geelong and the Pyrenees, burning more than 150 000 hectares.

The following summer, on December 1 2006, lightning strikes lit 70 fires in the Victorian Alps. Many of these fires would eventually merge to become the Great Divide Fire Complex. The bushfires burned for 69 days, the longest in the state's history, impacting more than 1 million hectares.

Still, nothing, though, could prepare Victoria for Black Saturday 2009.

Black Saturday 2009

The Black Saturday Bushfires of February 7 2009 were Australia's most devastating bushfires and Victoria's worst natural disaster. Like Ash Wednesday, the drought stricken state was tinder dry as 400 individual fires burned across the state, fanned by northerly winds that became gale force when the wind changed to southwesterly that evening. But 26 years after Ash Wednesday, the state's population growth and expanding urbanisation placed more people at risk than ever before.

More than 78 communities were directly affected by the bushfires and 173 people lost their lives, including 119 people in a single fire at Kilmore East-Kinglake, sparked by an ageing power line. The scale of destruction left the nation shocked and in mourning. The townships of Kinglake, Marysville, Narbethong, Strathewen and Flowerdale were destroyed and more than 5,500 houses and other structures were lost. The total area burnt was half a million km^2, the size of a small country.

In the wake of the fires, policies for dealing with bushfires and management practices were reviewed. Black Saturday led to another Royal Commission that closely examined 15 of the fires burning that day. Among 67 recommendations the Royal Commission advised the following:

Land and fuel management

Recommendation 58 - The Department of Sustainability and Environment significantly upgrade its program of long-term data collection to monitor and model the effects of its prescribed burning programs and of bushfires on biodiversity in Victoria.

Research and evaluation

Recommendation 65 - The Commonwealth establish a national centre for bushfire research in collaboration with other Australian jurisdictions to support pure, applied and long-term research in the physical, biological and social sciences relevant to bushfires and to promote continuing research and scholarship in related disciplines.

These recommendations would form the basis of future research investment in Victoria including refocusing research efforts on the impact of increased fuel reduction burning on biodiversity and other forest values.

Figure 12: Dr Gary Sheridan stands on a post Black Saturday debris flow. Source Pat Lane.

From 2010: Cross-sector collaboration and policy imperatives

After Black Saturday there was significant knowledge transfer and engagement by researchers, particularly from the University of Melbourne, to both land managers and the public on water quality and erosion issues associated with the bushfires. This was the dissemination of years of research started earlier in the decade on bushfire effects on streams and catchments. Information gained from past research on bushfire behaviour and fire ecology was also available to help the public make sense of the disaster and look forward to recovery.

Prompted by recommendations from both the Inquiry into the *Impact of Public Land Management Practices on Bushfires in Victoria* (Parliament of Victoria 2008) and the recommendations of the Victorian Bushfire Royal Commission 2009, the current decade began with strong commitment to, and reliance on, research to deliver better outcomes for Victorian communities.

Again, scientific evidence was used in a revised *Code of Practice for Bushfire Management on Public Land (2012)*. Influenced by the 2009 Royal Commission, it takes a strong risk-based approach to fire management, with two primary objectives (mentioned earlier) that are specifically enabled by the incorporation of the advances in bushfire behaviour science, research into fire ecology, and social research that enables DELWP to work more effectively with the community.

The foresight of the Fire Ecology Program work in the 1990s continued to deliver evidence that enabled DELWP to improve decision making with David Cheals 2010 report, *Growth Stages and Tolerable Fire Intervals for Victoria's Native Vegetation Sets*. The culmination of years of research, this work built on previous fire ecology guidelines to summarise the tolerable fire intervals for Victorian vegetation communities (ecological vegetation divisions) and descriptions of post fire growth stages. This detailed information helped fire management planners develop ecologically appropriate fire regimes. It also catalysed thinking about what else DELWP needed to know to adapt and improve ecological practices.

The landscape scale approach to bushfire management established through the Fire Ecology Program guided much of the continued research project it initiated such as the *Otways Landscape Mosaic Burning* project and the *Fire Ecology Retrospective* study. These were complemented by the Hawkeye fire monitoring program, a direct output from the Victorian Bushfire Royal Commission recommendations which supported placed based monitoring projects.

The rich history of Victoria's fire ecology research and how it has influenced bushfire policy and management has recently been summarised by York and Friend (2016).

Again, the Wombat FESA project was revisited, with data collection taken after 25 years of fire treatments. Thanks to support from fire management and local crews most burning treatments had continued since the projects inception and this remeasure was able to look at 25 years of impacts of repeated planned burning on vegetation, fuels, tree growth, birds, reptiles and soils. It also included new measurements for invertebrates and mammals, and the effects of fuel reduction burning on carbon stocks, a recognition of the growing understanding of fire as part of a system.

The current decade has also seen DELWP consolidate its commitment to science based research to inform and enable management decisions with the release of the *Bushfire Science Strategy 2013-17*. Its objectives are:

1. Policy driven investment- well managed research, based on clearly identified knowledge gaps, that provides evidence for policy and operational management decisions
2. Portfolio structure and responsiveness- world class research, aligned to international best practice, that can adapt to changing management needs, and
3. Knowledge translation- that research is delivered and shared in a context that transitions it from 'information' into understanding that supports management decision making.

The Strategy recognises that past science has been rigorous and reliable and has provided a wealth of supporting knowledge to assist bushfire policy, and the relationship between policy and science has transitioned from being implicit to explicit.

This strategy is underpinned by two innovative major research contracts that improve DELWP's capacity to invest in world-class research across a suite of policy and operational needs.

The Integrated Forest Ecosystem Research (IFER) Agreement was signed in 2012 with the University of Melbourne (UM). Unlike previous research agreements 'the success of the program will be determined in relation to the advancement of land management policy, management action planning and performance measurement (including monitoring) for public land'. This new evergreen agreement overcame the limitations of short-term funding and established a means to carry out both medium term and cumulative research works.

IFER reflects a synergistic relationship in which research to meet DELWP's policy and operational needs targets a range of pertinent and overarching core themes at the landscape scale where management regimes are applied. The themes include forest biodiversity, carbon, socio-economics, water, hazards, vulnerability and health. Research from 2010 to 2016 has helped to shape a range of DELWP polices and management practises. DELWP is now better informed about the design of planned burning regimes to benefit biodiversity and minimise carbon loss; it has improved the predictability of bushfire behaviour so that suppression is better targeted to minimise environmental and social and economic damage; and the development of risk assessment tools has enabled better prediction of post-fire water hazards like contamination, debris flows and flooding.

IFER's development of robust science and datasets now provides a unique opportunity for UM and DELWP to bring together the advances in knowledge about the landscape into an integrative approach to land management decision making. In 2017 DELWP and UM have initiated a significant piece of research that intends to develop a robust knowledge and decision support system and tools that enable land managers and communities to interactively explore the multiple forest value changes posed by policy interventions and key external drivers. This work will enable DELWP to recognise and understand the drivers of change in a Victorian forested landscape, bring together world class robust science and data sets, use this science to develop scenario modelling capacity to better understand the impacts of various interventions in the landscape, and to use this knowledge and decision support system and tools in determining the best policy interventions to achieve the preferred outcome in that landscape.

The second major contract was established with the Bushfire CRC, and subsequently transferred to the Bushfire and Natural Hazards CRC. The Bushfire Risk Management Research Projects (2012) program has delivered cost-effective, collaborative fire science research framed to answer DELWP's specific policy needs, including smoke emissions and transportation modelling, social values research, and improvements in data and modelling for Phoenix RapidFire.

It is clear that research based evidence, and knowledge gained from the previous decade continues to impact DELWP's policy and operational management, with 18 Fire and Adaptive Management Research Reports being published and many more on their way.

Figure 13: Post fire regeneration in the Wombat State Forest. Source: Nick Bauer.

Safer Together

In February 2015, the Victorian Government asked the Inspector-General for Emergency Management to compare the existing hectare target approach to bushfire fuel management with an alternative risk reduction target. This analysis was only made possible because of the development of evidence and tools, through research, to support this approach.

The Inspector-General recommended a risk-reduction target as the most effective way to protect life and property and guide investments in fuel reduction burning. He also recommended improving predictive tools for the smoke effects of planned burning consistent with the State Smoke Plan and adopting performance measures to monitor the quality and effectiveness of community engagement activities.

These recommendations were accepted and delivered as a new policy document for Victoria, Safer Together: a new approach to reducing the bushfire risk in Victoria.

The key aims of Safer Together include better assessment of where and when to use fuel management and other risk reduction activities, avoiding unacceptable impacts on the environment and communities, better integration across public and private land, collaboration between land and fire managers and communities to plan and deliver integrated bushfire management, involving local communities in decision making, drawing on local values and insights to promote resilience and using world-leading science to manage fire and ecosystems. It draws on the decades of research, learning and adaptation that have given DELWP its most comprehensive picture of Victoria's current and future bushfire climates.

DELWP can now better describe and measure bushfire behaviour, the risk of bushfire and the impact of smoke, and knowledge gains have improved bushfire management and informed decision-making and strategic planning in key landscape areas. Significantly, DELWP has the confidence to share this information with Victorian communities in conversations about the risk that communities are prepared to accept and what can be done, individually and collectively, about managing that risk.

Strategic bushfire management of the future has a strong platform of past research and monitoring to build on and will be enhanced as further evidence from fire and ecological science emerges. Who knows what scientific knowledge will influence research in the future from the research of today

Figure 14: Dr Leon Bren inspecting a catchment hydrology research site. Source: Pat Lane.

Section 2: The Forest, Fire and Regions Group Science Catalogue 2018-19

Integrating science with policy and operations

The Integrated Forest Ecosystem Research (IFER) Agreement is a long-term research agreement between DELWP and the University of Melbourne (UM) specifically targeted at research to meet policy and operational knowledge requirements. Since 2010 this collaboration of world class scientists and DELWP has made a significant contribution of evidence to shape a range of contemporary DELWP polices and management practices.

DELWP is now better informed about the design of planned burning regimes to benefit biodiversity and minimise carbon loss; it has improved the predictability of bushfire behaviour, so that suppression is better targeted to minimise environmental, and social and economic damage; and the development of risk assessment tools has enabled better prediction of post-fire water hazards, like contamination, debris flows and flooding. IFER's development of robust science and datasets now provides a unique opportunity for UM and DELWP to bring together the advances in knowledge about forest landscapes into an integrative approach to land-management decision making.

Project title	Description	Management outcome
Integrated landscape decision support system THE UNIVERSITY OF MELBOURNE	This research will develop a Decision Support System (DSS) that enables land managers and communities to interactively explore potential changes, from both policy interventions and key external divers, on multiple forest values. These interventions may include the use of fire, extraction of forest products, management of pests and weeds, habitat maintenance and restoration, or other land-use practices. Engagement with communities also represents an intervention- enabling interactions then encourages understanding of respective interests and values. Initially, the DSS model and tools will be developed and tested in the Victorian Central Highlands landscape, with the scope to identify and develop knowledge and data required for improvement and its geographic extension.	Using the DSS, land managers will be able to: 1. explore a range of policy and operational scenarios and how these alternative approaches influence ecological, social, cultural, and economic values in the initial target landscape 2. engage and communicate with Victorian communities more effectively in decision making processes- as tools that enable a greater understanding of land management decisions that may impact communities are used 3. has the structure to enable state-wide use in the future. *Completion date: June 2019*

Working in partnership with communities

In the last five years DELWP, both independently and in collaboration with Victorian emergency sector partners, has invested in research with the University of Melbourne, LaTrobe University and Risk Frontiers, to better understand Victorian communities' values, perceptions or risk, and tools for improving interactions. Together these projects have helped DELWP understand and improve how the sector interacts with communities. One group of projects conducted by the University of Melbourne have built on each other to develop concepts and approaches for measuring values in different contexts, and to develop strategies and guidance for incorporating knowledge of these values in decision making. This program of research is now at a stage where DELWP and researchers are seeking ways to practically apply understanding of values to decision making, and to evaluate how this might support elements such as objective-setting, analysis of impacts, community engagement and moving towards decisions.

Project title	Description	Management outcome
Incorporating values in bushfire risk decision making: further development of tools and strategies THE UNIVERSITY OF MELBOURNE	Together, researchers and DELWP staff identified opportunities, tools and strategies to incorporate knowledge of values of the Victorian public into bushfire decision making. In this project the researchers will work with DELWP staff on three case studies that will allow early development and evaluation of a small selection of tools and strategies for use in professional practice by DELWP.	The project will improve the capacity of DELWP staff to incorporate values of the Victorian public in bushfire risk decision making by: 1. providing new tools and strategies for incorporating values of the Victorian public in bushfire risk decision making 2. enhancing staff skills in planning, designing and evaluating the tools and strategies developed 3. systematically capturing learning of DELWP staff through development of tools and strategies in ways that will inform future learning. *Completion date: August 2019*
Incorporating values of the public data (community values) into Regional Forest Agreement (RFA) assessments THE UNIVERSITY OF MELBOURNE	This project will consolidate findings from relevant existing research, about the values of the Victorian public, to provide information about the social values of forests for a RFA assessment report. The outputs of this research will enable further investigation of social values through community engagement workshops. The workshop results will support future forest and fire management within Victoria.	With its outputs incorporated into RFA assessments and future forest and fire planning and decision-making, this project will enable DELWP to make effective use of existing social values research in modernising RFAs. *Completion date: June 2019*

Project title	Description	Management outcome
Application of self-evacuation archetypes (ERP 11)  	Individuals and households respond to bushfire in diverse and complex ways according to their circumstances and characteristics. Recent research into protective action decision making identified seven human behaviour 'archetypes' of self-evacuation in bushfire. These archetypes provide insights into the diverse factors shaping people's response to bushfire threat. This project will explore how archetypes research can be applied to bushfire risk reduction strategies by testing their application in a range of Safer Together bushfire risk reduction strategies.	This research will support best practice community engagement approaches, enhance bushfire modelling by including a human behaviour component, and support the measurement of the effectiveness of bushfire risk reduction strategies and impact on communities. The research evidence will have a direct impact on practice and extend the existing research on archetypes in a bushfire context. *Completion date: June 2019* *This project is funded under Safer Together, supported by DELWP and led by the CFA.*
Behavioural insights into fire danger ratings and warnings   Metrix	This research will investigate community perspectives and behaviours associated with the current and proposed fire danger rating systems. It will consider community needs regarding warnings, appropriateness of fire danger ratings signage in communicating risk, and whether ratings categories result in communities taking appropriate actions. This co-investment is part of the National fire danger rating system project.	Improved understanding of community perspectives and behaviours associated with fire danger ratings which will allow fire management agencies to better communicate warnings to potentially impacted communities. *Completion date: February 2019* *This project is supported under Safer Together, with Victoria's contribution managed by the CFA and the project delivered by AFAC.*

Smoke modelling

The smoke emissions and transportation model, previously developed by CSIRO, the Bureau of Meteorology and other institutions, in partnership with DELWP, has enabled emergency sector partners to better manage smoke impact on communities and industries. Building on this work, new innovative and contemporary research projects will work on strategies to validate and calibrate the models and improve DELWP's understanding of the community health impacts and thresholds for smoke.

Project title	Description	Management outcome
Dynamic smoke intelligence using remote sensing and fixed sensors (ERP 4)	This research will build on the existing smoke intelligence system (model), integrated with the smoke modelling (prediction) system, to collate and analyse sources of social media, remote, and field sensing data, to calibrate and validate smoke predictions.	The intelligence system will improve assessments about the nature and extent of smoke from planned and unplanned fires and its impacts on communities, industry and infrastructure - enabling better management decisions and communication. *Completion date: June 2019*
Community impacts of smoke (ERP 5)	This project will develop method to estimate and monitor the impacts of smoke on the health of communities from bushfires and planned burns. Data will be sourced both from health care sources (e.g. Nurse online, health clinics), and social media (e.g. locations of imagery, descriptions of smoke).	By refining thresholds of smoke impacts on community health, including, irritated eyes, nasal and respiratory passage, asthma, and coronary events, DELWP can optimise opportunities to achieve planned burning, while minimising the impact of smoke on the community. *Completion date: June 2019*

Project title	Description	Management outcome
Smouldering: Improved quantification of emissions and plume rise to improve the forecasting of smoke levels and better provide health protection messaging (ERP 20)	This project will improve the Air Quality Forecasting System (AFQx) (smoke emission and transport model) by improving planned burn emissions and plume rise data inputs during the smouldering phase. This will result in more robust and accurate smoke forecasting and aid in health protection messaging.	Reducing the risk of bushfires planned burns may have a negative impact through smoke emissions on communities. The improvement to the model will help support decisions on whether and where to conduct planned burns. *Completion date: December 2020*
ARGOS plume model review of South West fires (ERP 21)	AFQx is a decision-making tool designed to forecast the transport and chemical reaction of emissions from vegetative smoke. This project will reconstruct the emissions and downwind concentrations of PM2.5 from the March 2018 Cobden peat fires to determine the level of accuracy from the plume modelling and air quality forecasting systems during the incident. The reconstruction will identify areas of improvement for algorithm and input data in the models.	Identify areas of improvement of the Air Quality Forecasting System following the Peat fires at Cobden, Victoria in 2018. *Completion date: December 2019*

Bushfire Prediction Research

Phoenix RapidFire fire behaviour and simulation model has transformed bushfire management decision-making in Victoria. It makes a direct and ongoing contribution to bushfire management policy and operations, including community warnings and engagement, resource allocation and planning both before and during bushfires. The dynamic simulation capabilities of Phoenix enable land managers to explore potential fire spread under different conditions including weather, terrain and vegetation type. The software still relies on a fire behaviour analyst reviewing and, if necessary, adjusting outputs but the model has dramatically improved the speed of analysis and fire agencies ability to predict bushfire behaviour and provide advice to communities. Areas of improvement have been identified in the science underlying some key Phoenix modules and increasing their accuracy will improve predictions of individual fires and have flow on effects in improved operations, including community warnings.

Currently, many tools that use Phoenix fire modelling as inputs are being used for both operational bushfire prediction and the evaluation of landscape risk through time. Both improvement to Phoenix and the development of new and innovative modelling capacity guides DELWP's research investment in bushfire prediction modelling.

Project title	Description	Management outcome
Improving the representation of bushfire risk THE UNIVERSITY OF MELBOURNE	Building on previous work, this improvement of Phoenix predictive performance will focus on better defining fire behaviour/fuel/disturbance relationships. This project will deliver improved Phoenix performance through: 1. new curves or relationships used to determine fire behaviour for use in Phoenix 2. enhancements to fire simulation systems to support the representation of uncertainty 3. a system or systems for incorporating a range of values and hazards in landscape risk modelling procedures 4. the development of scientific frameworks underpinning risk assessments so that robust decision making can occur in a defensible and objective manner.	For DELWP this means: 1. improved science on the changes in landscape flammability post disturbance 2. a foundation for improving the robustness of fire simulation predictions, namely by more accurate inputs and better ways to quantify uncertainty to operators 3. an improved ability to represent the impacts of natural hazards on multiple values, including biodiversity, carbon, water and society 4. the development and testing of tools for allowing management alternatives to be considered in terms of their impacts on multiple values. *Completion date: June 2019*

Project title	Description	Management outcome
Quantifying the risk reduction from roadside fire management strategies 	This project will: 1. examine the capacity of Phoenix Rapidfire to incorporate roadside fuel treatment actions to derive estimates of risk reduction 2. develop a methodology that will enable roadside fuel treatments to be assessed and quantified 3. examine methods that may have the capacity to consider trade-offs between management actions such as roadside fuel management, prescribed burning etc.	Having accurate and spatially explicit data on fuel is one of the most important underlying factors for fire behaviour models- understanding how fuel accumulates after disturbance improves the accuracy of fire prediction models and the outputs that form the basis for emergency response decision making and to aid forward strategic bushfire management planning. This project starts a process to better enable non-burning fuel treatments to be incorporated into modelled landscape risk evaluations. *Completion date: June 2019*
Landscape fuel moisture forecasting for bushfire risk assessment (ERP 3)  	To improve the quality (precision and currency) of landscape-level fuel moisture information in Australia and deliver near real-time and forecasted landscape fuel moisture maps and information products, this project will link satellite imagery estimates of forest fuel moisture with field-based intelligence to provide more dynamic, up-to-date and precise estimates of actual and predicted moisture conditions to support bushfire management decision making.	This project will develop and implement a system for generating current and future landscape fuel moisture condition information, in the form of digital maps and data, for application in strategic planning and operational bushfire management across Victoria. This will directly improve Victoria's capacity to manage bushfire risk across the range of prevention, preparedness and response activities. *Completion date: March 2019*
Identifying planned burn windows (ERP 9)   	Planned-burning, as one mechanism for fuel management on public and private land, is an important way Victorian communities and natural environments are protected from the negative impacts of bushfire. To optimise the planning and delivery of the planned burning program this project will analyse data collected since 1972, to provide a greater understanding of planned burning windows available on a daily and seasonal basis.	Evidence to enhance delivery and broader seasonal planning of planned burn operations, through greater understanding of trends and variability in burn window availability, interactions with planned burn prescriptions and evidence for seasonal planning. *Completion date: September 2019* *This project is funded under Safer Together, supported by DELWP and led by the both DELWP and the CFA.*

Project title	Description	Management outcome
Effectiveness of resources to suppress bushfire: Aerial and ground based (ERP 12)	This project will evaluate the effectiveness of a wide suite of fire suppression techniques and practices including, but not limited to, aerial and ground-based techniques. This will include identifying the knowledge, methods and data requirements currently used, or under consideration, internationally, nationally, and within Victorian fire agencies, to assess the effectiveness of fire suppression techniques, the development of a conceptual suppression effectiveness management tool, including recommending data requirements to ensure this tool is statistically robust, and testing and evaluation of that tool over a fire season.	Improved evidence and understanding of how effective fire management agencies are at suppressing fire, will enable more effective fire management responses and reduce the impact of fire on communities and the environment. By exploring the effectiveness of resources to suppress bushfires from both the air and the ground, Victorian bushfire management agencies will be able to identify potential inefficiencies and make recommendations to improve efficiencies. *Completion date: December 2020* *This project is funded under Safer Together, supported by DELWP and led by both the CFA and DELWP.*
Development of seasonal fire prediction tools (ERP 14)	The tools currently used to produce the seasonal fire forecast "Southern Australia Seasonal Bushfire Outlook", limit its ability to be readily updated and verified through the fire season and meet fire agencies' or community decision making needs. This project will review, and clearly define, the needs of fire agencies in Victoria for the development of new seasonal fire forecasting products used for a variety of strategic decision making and risk assessment functions.	A clearly defined needs analysis that enables Victoria to direction set the development of seasonal fire forecast products, so they can answer key questions on the frequency, visualisation and acceptable levels of uncertainty of the seasonal fire forecasts. *Completion date: October 2020* *This project is funded under Safer Together, supported by DELWP and led by both the CFA and DELWP.*
Cropland fire behaviour (ERP 15)	Crop fires cause significant losses each year and yet their spread is not clearly understood as current fire modelling tools are not accurate in predicting crop fire behaviour. This project will conduct experimental burns to develop a baseline for measuring fire spread on cropland. It will consider a variety of factors, including whether harvesting has occurred, and crop row orientation in relation to the wind.	Through the development of a cropland fire behaviour model, the project will provide improvements in predicting and modelling cropland fire behaviour which will provide a basis for improved community risk communication and cropland fire response by agencies. *Completion date: June 2020* *This project is funded under Safer Together, supported by DELWP and led by both the CFA and DELWP.*

Associated fire management, predictive, and behavioural research		
Project title	Description	Management outcome
Improving fire fighter safety with RADAR based warnings 	This research will identify patterns indicating micro to lower mesoscale atmospheric perturbations, such as, storm cell development or other forms of convective winds. These patterns can be a precursor to escalating fire behaviour or result in a change in the safety conditions for on ground firefighters.	A prototype system to identify potential changes in weather patterns, that may pose risks to the safety of on-ground fire fighters will be developed for DELWP, so that fire managers can improve warnings to fire responders. *Completion date: July 2019*
Planned burn mapping in Victoria using remote sensing (Sch 22)  	To identify and develop future management options and technologies for planned burn mapping- which capture changes in time and space, including horizontal and vertical changes in vegetation structure, using remote sensing technologies- delivering known cost and accuracy.	The severity mapping will improve DELWP's capability to repeatedly and reliably map and report on planned burning outcomes, and as a critical input into a risk-based approach to strategic bushfire management planning. *Completion date: June 2019*
User interface-platform for the Victoria historical fire weather gridded dataset (ERP 10)   	This project will develop a user interface to facilitate access to the historic fire weather gridded dataset developed through a collaboration between DRI and Monash University, and funded by DELWP. This dataset has many applications and is currently located on a database with limited capacity to service the wide range of end-users seeking access- including regional and district risk analysts from all agencies. The project will design and test a user-friendly data platform for the interface and develop online training for the wider user base.	The development of an easily accessible user interface platform for the Victorian historical fire weather gridded dataset will inform risk tools for strategic, tactical and community engagement purposes, to be used by Victorian bushfire management agencies. *Completion date: December 2019* *This project is funded under Safer Together, supported by DELWP and led by both DELWP and the CFA.*

Project title	Description	Management outcome
Creation of a Grass Fire Danger Index (GFDI) dataset (ERP 13)   	The existing fire weather gridded dataset for Victoria includes multiple weather variables and Forest Fire Danger Index (FFDI) outputs, however, it does not provide outputs for grass fire danger. This project will develop a historical GFDI dataset to complement FFDI and to improve understanding of the entire Fire Danger Rating system. This will be achieved through combining a curing dataset, derived from archived satellite data, and with the Victorian historical fire weather data. This will complete the fire weather gridded dataset, to allow for analysis of historic bushfire risk.	By creating a GFDI dataset, fire agencies will better understand grassland fire danger, improve their understanding of the fire danger rating system. This will complete the fire weather gridded dataset and provide fire managers with a useful resource for research, planning and preparedness. *Completion date: March 2019* *This project is funded under Safer Together, supported by DELWP and led by both the CFA and DELWP.*
Improving understanding of fuel properties and potential fire behaviour after mechanical treatment  	DELWP plans and delivers extensive areas of non-burn fuel treatments annually. Although the Department captures and reports on this treatment spatially, it has no way of incorporating it into risk analysis methodology, which creates difficulties in assessing the effectiveness of its fuel management program at reducing bushfire risk. This project will: 1. quantify differences in fuel structure, microclimate and vegetation composition between mechanically treated and untreated fuels 2. estimate how flammability may differ between treated and untreated fuels 3. make recommendations for integrating mechanical treatments into landscape risk evaluation processes.	The project will improve DELWP's understanding of how mechanical fuel treatments alter fuel properties and potential fire behaviour and provide guidance about how mechanical fuel treatments could be incorporated into risk planning processes. *Completion date: June 2019*

Project title	Description	Management outcome
Relationship between soil and fuel drying - flammability switch in ash forests and damper foothill forests THE UNIVERSITY OF MELBOURNE	Even though most of the time Victoria's Ash and damper foothill fires are too wet to sustain fire many of Victoria's worst bushfires have occurred in them. While they transition from a wet to a drier state, after prolonged periods of hot and dry weather, and can sustain large-scale severe fires there is little scientific understanding of how much drying is needed for these forests to switch from a 'dormant' state to one that promotes freely spreading fire. This research will develop a model to help predict the likelihood of a fire occurring and spreading in Victoria's ash and damper foothill forest, with a focus on factors that transition forest fuels into a flammable state.	A conceptual model of flammability in ash and damper foothill forests and an evaluation of the ability of moisture metrics to predict fire occurrence will enable fire management agencies to better prepare for and mange bushfires in ash and damper foothill forests. The project outcomes can also be incorporated into fire danger ratings which will improve readiness levels and the communication of fire danger to communities. *Completion date: June 2021* *This project is funded under Safer Together, supported by DELWP and led by both the CFA and DELWP.*
Testing and improving mapping produced by Google Earth Engine (GEE) fire severity map tools Arthur Rylah Institute for environmental research	This project aims to improve the quality of fire severity mapping and the capacity of DELWP staff to map fire severity through: 1. testing and training the current GEE Fire Severity Maps tool for mapping of low severity prescribed burns 2. identifying new mapping approaches that overcome data gaps in severity mapping due to cloud affected imagery 3. capacity building within DELWP to facilitate ongoing use and future refinement of the Fire Severity Maps tool.	This project will enable DELWP to understand, make management decisions, and report on planned-burning with a more robust evidence base. *Completion date: February 2020*

Ecosystem modelling and resilience

Recognising the important role that fire plays in our ecosystems, ecological research evidence informs strategic fire management planning in Victoria. Recent research about fire and its relationship to ecosystem resilience, disturbance regimes and landscape heterogeneity, have been used in the development of DELWP policy on defining, measuring and reporting on ecosystem resilience. This work underpins the Monitoring, Evaluation and Reporting (MER) Framework for Bushfire Management on Public Land. The Tolerable Fire Interval (TFI) is the current but coarse metric for the resilience of plants in a given ecosystem, with research effort being more focused towards the use of Geometric Mean Abundance (GMA) as a measure of resilience of plants and animal communities, and vegetation growth stage structure, on the premise that a mix can optimise biodiversity and therefore ecosystem resilience. Refinement of these resilience metrics remains a key focus for DELWP in the development and testing of new ecological resilience models.

Project title	Description	Management outcome
Framework for using and updating ecological models to inform bushfire management planning (ERP 1) Arthur Rylah Institute for environmental research The University of Melbourne bushfire&natural HAZARDS CRC La Trobe University	This project will consolidate DELWP's use of models, for the three metrics of ecosystem resilience, into a framework that defines the criteria for how the models should be curated, used to inform decision making, and updated with new monitoring and research data. It will: 1. describe the decision-making framework for use of ecological management models to inform fire planning decisions within DELWP's bushfire management planning framework 2. describe the process required to consistently implement the decision-making framework 3. bring together the ecological models into one system (with supporting code and documentation) so they can inform management decision-making, and monitoring and research investment 4. describe and put into practice the processes to manage and update the ecological framework and models reflecting new user requirements and monitoring and research data.	Describing a decision-making framework for the use of ecological models in informing DELWP's bushfire management planning will enable ecological evidence to better inform decisions in strategic bushfire management planning. DELWP will be better able to determine the effectiveness of different management strategies on ecosystem resilience and better identify and assess bushfire risk to ecological values. This framework will enable DELWP to have knowledgeable discussions about the ecological outcomes of different fuel management options with the community, and to make informed decisions about bushfire management. *Completion date: June 2019*

Project title	Description	Management outcome
Ecosystem resilience-collection and analyses for first two of 11 priority ecological fire groups (EFG's) (ERP 2)	This project will research the effects of fire, including both bushfire and planned-burning, on ecosystem resilience by assessing ecosystem resilience metrics across four ecosystems, measure their effectiveness for guiding fire management, and provide data for models and tools used for decision making in relation to bushfire management across the state; specifically, ERP1.	This project will provide knowledge and evidence to support decision making for strategic bushfire management, accountability and reporting against key policy objectives for ecosystem resilience and have knowledgeable conversations with communities about ecological outcomes. *Completion date: June 2021*
Ecosystem Resilience - Technological advances to increase efficiency of ecosystem resilience monitoring (ERP 22)	This research focusses on developing technology to support the monitoring being undertaken in the ERP 2 project and as an input to ERP 1. It will increase the efficiency of future monitoring through development of improved field data capture, camera technology, and automated image analysis and classification.	The outputs of this research will be used to improve the current monitoring methodology, update the standard operating procedures (SOPs), and provide better data to support evidence-based decision making for bushfire management in Victoria. *Completion date: June 2020*
Ecosystem Resilience Data (ERP 6)	This project will analyse state-wide and regional monitoring data to answer improvement and impact key evaluation questions (KEQs). Consolidation of this data will be used to determine the effectiveness of key evaluation questions and then to develop analysis protocols to answer KEQs. The project will make recommendations on necessary adjustments to the monitoring program to ensure the data are adequate to answer the KEQs.	This project enables DELWP to critically assess and adapt its ecological monitoring KEQ's. *Completion date: November 2019*

Project title	Description	Management outcome
Interactions between fire, landscape pattern, and biodiversity (IFER Core Project)	There are significant knowledge gaps around how alternative fire regimes can alter the risk to biodiversity and other values in forested landscapes. This project will improve data for a range of flora and fauna- through systematic collection at established study sites, over time, within an area designated for mosaic burning in the Otway Ranges, effectively sampling a range of vegetation types and growth stages. Using these data, the project will develop models that investigate relationships between: 1. habitat (in space and time) 2. disturbance processes – specifically planned burns and bushfire, but also potentially including other processes such as predation, herbivory, pollination and decomposition 3. plant and animal abundance, diversity and behaviour.	This project will support decision making about fire regimes through evidence about the impact of alternative fire regimes on biodiversity values and ecosystem resilience. It will increase DELWP's capacity to include biodiversity considerations in land management planning based on best science. *Completion date: June 2019*
Using fire to manage biodiversity in fragmented landscapes	DELWP has adopted three broad indicators of ecosystem resilience, but as these were developed in large continuous forests, applicability to fragmented landscapes is not known. As some areas of Victoria contain highly fragmented landscapes, this project aims to assess the effect of fire management on ecosystem resilience, and to build quantitative links between fire management strategies and biodiversity conservation in these environments.	These improved ecosystem resilience metrics will lead to more efficient and effective bushfire management across the diverse and fragmented Victorian landscape and improve the capacity of DELWP to quantify the effect of fire management (both planned-burning and bushfires) on ecosystem resilience in fragmented landscapes. *Completion date: September 2020*
Spatially explicit solutions for managing fire and biodiversity	Fire is a major driver of the structure and function of the high conservation value and vulnerable Mallee and foothills ecosystems, and the strong history of fire research in each provides a wealth of data on its plants, birds, reptiles and mammals. This project will develop a suite of spatially explicit models and tools that enhance the capacity to design and evaluate alternative fire management strategies for biodiversity in these ecosystems.	The project will develop a framework for determining optimal fire regimes for biodiversity conservation in Mallee woodlands/shrublands and foothills forests, enabling better fire management decisions. *Completion date: 2019*

Project title	Description	Management outcome
Strategic Bushfire Management Strategy Fauna Assessment Tool 	This project will look at how the relative abundance of species' changes in relation to planned-burning- reflected in post-burn vegetation growth stages and a map of the species footprint. Vegetation growth stages change through the application of planned-burning and bushfire and can have both positive or negative outcomes for fauna abundance. Vegetation growth stages are related to time since fire, with the abundance of a species related to how the species responds to fire. This project will estimate past, current, and future relative abundance through growth stage distributions- derived by overlaying spatial data for vegetation onto fire history maps and linking this with the predicted relative abundance of fauna in each vegetation growth stage.	Calculating changes in relative abundance from different configurations and frequencies of planned burning provides an opportunity for evaluating different strategies and tracking changes in abundance over time. The information obtained from this project can provide an important insight into how strategic bushfire management strategies will influence single species into the future. *Completion date: June 2019*
Fire severity pilot trial for recruitment of Key Fire Response Species (Banksia spinulosa) 	This research project will investigate the influence of fire severity on recruitment of a sensitive key fire response species (Banksia spinulosa) in the tall mixed forest of Eastern Victoria. The project will provide DELWP with: 1. testing of the practicality of manipulating fire severity for a specific species and documenting its application to burn planning 2. data collected and analysed that shows the relationship between seedling recruitment of B. spinulosa and fire severity, seed source and rainfall.	The project will address objectives in local as well as state-wide monitoring, evaluation and reporting frameworks. The results will contribute to strategic and operational fire planning, by providing a case study of how to account for fire severity as well as fire intervals in maintaining biodiversity. *Completion date: June 2019*
Investigating the short-term impact of planned-burning and the effectiveness of mitigation measures for Greater Gliders in the Hume Region – Data Analysis and Report writing 	This project will investigate the short-term impact of planned-burning and the effectiveness of mitigation measures for Greater Gliders in DELWP's Hume Region. The project will: 1. determine the immediate, short-term impact of planned-burning on Greater Gliders 2. determine the immediate, short-term impact of planned-burning on hollow-bearing trees (critical habitat attribute for Greater Gliders) 3. evaluate the effectiveness of 'mitigation measures' recommended to mitigate the impact of planned-burning on Greater Glider habitat.	This regional component project addresses assessment of the more immediate effects of planned-burning on biota and allows for the monitoring of species and ecological values of regional importance. It contributes to addressing two impact KEQs, derived from a scientifically-based monitoring project within the Victorian Bushfire Monitoring Program. *Completion date: June 2019*

Project title	Description	Management outcome
TechEcology: Evaluating the contribution of new technology and citizen science to achieving Victoria's biodiversity strategy goals 	This project will deploy video traps that constantly monitor reptiles and other small vertebrates. The cameras will provide a trial methodology that can be used more broadly to monitor the effects of fire management on reptiles. The study sites will be located within DELWP's Victorian Bushfire Monitoring Program in grassy-heathy dry forest which has been identified as a priority Ecological Fire Group.	This project aims to support integrated forest and fire management by testing viability of technology, improved understanding of wildlife response variables, and exploring the changes resulting from citizen science. *Completion date: June 2019*
Fire and biodiversity - impacts, recovery and future planning: vegetation responses to planned fire    	This research project will address knowledge gaps relating to the relationships between fire and sensitive environments. It will improve our understanding of vegetation responses to planned fire, of fauna responses in fire-prone environments and of vulnerability of fire sensitive environments to bushfire. These insights will reduce the uncertainty of the impacts of bushfire and planned-burning on biodiversity and ecosystem resilience and improve the application of planned fire to enhance fire-dependent ecosystems and habitats. It will improve ecosystem resilience models and metrics, including tolerable fire intervals, vital attribute databases, species responses and vegetation growth stage models.	The outputs of this research will reduce the uncertainty of the impacts of bushfire and planned-burning on biodiversity and ecosystem resilience and improve the application of planned fire to enhance fire-dependent ecosystems and habitats. It will improve land and fire management and community understanding and confidence in bushfire management planning, delivery and recovery. *Completion date: October 2019* *This project is funded under Safer Together and is led by Parks Victoria.*

Modernising Regional Forests Agreement's

DELWP's commitment to the modernisation of the Victoria Regional Forest Agreement's (RFA's) is underpinned by the need for evidence to inform and support outcomes. The suite of research FFRG is undertaking will deliver for both the broader RFA assessment, and pre-harvest survey programs, delivering sustainable and accountable forest management.

Project title	Description	Management outcome
Mapping high conservation value forests in Eastern Victoria 	By identifying areas of forests that are likely to contain high conservation values at a landscape-scale, this project will generate datasets that will provide the ecological basis for: 1. estimating the area of habitat of forest-dependant fauna 2. mapping of key growth stages and ecosystems for biodiversity management and conservation 3. estimates of forest biomass that can be used to predict forest carbon pools and fuel loads 4. predictions of forest density and diameter distributions that can inform timber harvest planning and sapwood area for water yields.	This project will provide important information for supporting decision-making during the current Regional Forest Agreement planning process. *Completion date: March 2020*
Environmental scan of models and tools to support integrated forest management 	The Integrated Forest and Fire Planning (IFFP) framework and amended Regional Forest Agreements (RFAs) are being developed over the next 12-18 months. This project will evaluate the risk assessment tools and provide recommendations to support improved accuracy and transparency in decision making for both IFFP and RFA assessments. It will: 1. identify the potential suite of forest values for risk assessment (focusing on ecosystem services and other environmental values) 2. identify existing and emerging risk assessment tools for and the management of forest values (focusing on ecosystem services and other environmental values) 3. evaluate the feasibility of existing risk assessment tools in IFFM 4. provide recommendations on risk assessment tools which are available to be applied in the short and medium term (focusing on ecosystem services and other environmental values).	This research project will support the development of the IFFP and RFA process through a review of potential analysis tools for assessment of ecosystem services and values (including old growth, wilderness, and endangered species) as part of measuring the impacts of forest and fire fuel management strategies on Victoria's environment. *Completion date: June 2019*

Project title	Description	Management outcome
Pre-harvest Fauna and Floristic Surveys: 2018-2019 	This project will contribute to the planning, prioritisation and conduct of the pre-harvest flora and fauna surveys, including terrestrial and aquatic fauna, in priority coupes between July 2018 and June 2019, by: 1. developing a tool to prioritise which species to survey at coupes, and using this tool to provide a list of species to survey in 80% of coupes planned for harvest 2. contributing to the development of survey guidelines for the key survey types to be used in the pre-harvest surveys, and provide taxon expertise, including providing training and quality control where required. 3. undertaking targeted plant surveys in priority coupes 4. undertaking Spotted-tailed Quoll surveys 5. undertaking surveys for Leadbeater's Possum and provide specialist support to contractors undertaking other Leadbeater's Possum surveys 6. undertaking surveys for aquatic fauna in priority coupes, including fish, and burrowing and spiny crayfish 7. providing timely species occurrence/abundance data and spatial data in an agreed format to DELWP 8. ensuring all flora and fauna data are entered in the Victorian Biodiversity Atlas.	This project supports the pre-harvest survey program. *Completion date: June 2019*
RFA - Rainforest Value Datasets – state-wide satellite-based classification 	This project will model the current extent of the five primary rainforest types across Victoria to produce revised data products. The project will make use of learning algorithms along with a suite of freely available earth-observation data as cool temperate and warm-temperate rainforest types (i.e. the predominant types of rainforest in Victoria), have distinctive signatures within both the environmental and remote-sensing space.	This project will contribute to the broader RFA assessment and Forest Protection Survey Programs ensuring that the modernised RFA's will be based on the best available information. *Completion date: March 2019*

Project title	Description	Management outcome
RFA: Development of an improved forest stem age dataset for East Gippsland 	This project will develop a deterministic rules-based model of stem-age, built using the best available estimates of mature stem-age for East Gippsland at various historic junctures, disturbance histories and tree species distribution models. This dataset could then be classified to generate an improved, transparent and reproducible representation of forest stems at selected ages and provide an interim forest age dataset prior to LiDAR capture or other intensive programs being completed. It is assumed that stem age, within an environmental context or ecosystem type, will be related to the prevalence and development of tree hollows.	This project will contribute to the broader RFA assessment and pre-harvest survey programs ensuring that the modernised RFA's will be based on the best available information. *Completion date: March 2019*
RFA: Updated habitat distribution models for key forest species 	Habitat distribution models (HDMs) are spatially explicit models of a habitat suitability index that can be expressed individually for each species. HDMs interpolate (i.e. model the gaps) between known observations of species. The purpose of HDMs is to provide a higher level of information content to inform management than from individual observations. The development of revised HDMs for forest-dependent taxa can provide the basis for development of integrated data tools and frame works that consider species' distribution, forest resources, access, etc. This project will develop a series of HDMs that better reflect the current distribution of the selected forest dependent taxa, particularly with respect to an increasing interest in 'landscape scale' threatened species management.	This project will contribute to the broader RFA assessment and Forest Protection Survey Programs ensuring that the modernised RFA's will be based on the best available information. *Completion date: June 2020*
RFA: Landscape Scale Surveys 	This project will conduct landscape scale surveys to collect new field data to improve understanding of the distribution of high priority, forest-dependent threatened species by updating their HDMs. The project will select sites based on sampling areas that will provide the greatest information gain to the models, within eastern Victoria, and be tenure blind- they may include areas outside the current known distribution of the species or in marginal habitats.	This project will contribute to the broader RFA assessment and Forest Protection Survey Programs ensuring that the modernised RFA's will be based on the best available information. *Completion date: June 2020*

Building our understanding of bushfire, climate and risk		
Project title	Description	Management outcome
Climate and fire regime: feedbacks, ecohydrology and water resources (IFER Core Project) THE UNIVERSITY OF MELBOURNE	This project will build on existing knowledge and models to further develop modelling capability that enables the prediction of the combined impacts of fire and climate on forest hydrology. Both current and previous research has yielded a good understanding of the many principal "levers" on individual system components response to disturbance, recovery and climate forcing's. There are however two areas of significant uncertainty: 1. the changes in rainfall-runoff relationships during the Millennium drought that have been identified in recent analyses 2. it may be that the feedbacks between the system components are as critical, or even more critical than the individual component responses, acting to amplify (or mitigate) biophysical and consequent hydrologic outcomes. This project will synthesise our data and other knowledge of system response to climate and fire, develop a conceptual model, translate the conceptual model into an implementable model, parameterise the model/s, use the model to guide our experimental program, and test the model.	This work will consolidate several experimental projects, resulting in improved and integrated understanding and models of fire severity impacts on yield and quality, and the climate drivers that force the magnitude and frequency of responses. It delivers a model that can be used to evaluate management options such as planned-burning and inform water supply planning and catchment management in the context of future hydrologic outputs. *Completion date: June 2019*

Project title	Description	Management outcome
Landscape vulnerability and health (IFER Core Project)  	Recognising the need for improved understanding of the interactions between bushfire, land management practices, and changing climate on plant communities this project will aim to understand impacts on the distribution of forest species, and changes in the composition and structure of forest communities. The sampling of forest types along the climatic gradient from warm and dry, to cold and wet will serve as a proxy for understanding the role of changing climate on plant communities. These field site data will feed into the calibration and validation of models that predict the impact of climate, bushfire and land management practices on species composition in forests, including identifying: 1. tipping points that may result in irreversible change in forest structure and composition and the associated ecosystem services they provide 2. information that allows land managers to analyse the potential effects of bushfire, land management practices, and changing climate on the resilience of Victoria's public forests 3. land management practices that maintain and enhance ecosystem services in space and time 4. scientific models that can be used to assess the vulnerability of Victoria's forests to changing climate and land management practices now and into the future.	The results from this study will be critical for evaluating the impacts of altered fire regimes, changing climate and land management practices on Victoria's forests and the ecosystem services they provide. *Completion date: June 2019*

Project title	Description	Management outcome
Understanding and managing Victoria's forest carbon  	Forest carbon is the net result of forest productivity, which underpins most ecosystem services, and therefore an integrated value. Therefore, maintaining and enhancing forest carbon is central to sustaining healthy and productive forests in accordance with sustainable forest management objectives. Temperate forests like those in Victoria are an important component of the global forest carbon sink and Australia has made international commitments to report changes in that sink in line with efforts to mitigate climate change, so it is important that we understand the size of our forest carbon assets (i.e. how much carbon is stored), how resilient those assets are to emerging fire and climate regimes, and how risks to carbon assets can best be identified and managed. This project will address key knowledge gaps relevant to: 1. the estimation of the largest carbon assets (live trees and soil) 2. the resilience of those assets to changing climate and fire regimes. These data and relationships will be integrated into a carbon-modelling framework, which will be used to identify risks and opportunities in forest carbon management. Conceptual developments will include an evaluation of the way risks to carbon assets, and management opportunities to mitigate and adapt to those risks, can be expressed and communicated to diverse audiences. Risks and opportunities in forest carbon management will be examined using scenario-based modelling, with scenarios defined in an iterative manner in consultation with DELWP to ensure relevance to emerging management questions.	This project will enable DELWP to make better management decisions based on a stronger: 1. understanding of the management options for, and the drivers of, maintained or enhanced forest productivity and health (represented by forest carbon as an integrated biophysical value) 2. basis for reporting carbon store changes to be best placed for future carbon market opportunities (through improved quantification of forest carbon estimates, including in the largest stores) 3. basis for quantifying, representing and communicating risks posed by different drivers (e.g. climate, fire) to forest carbon and underlying productivity and resilience (through identification and quantification of potential 'tipping points' in the largest stores) 4. basis for quantifying, representing and communicating effectiveness of mitigation and adaptation policies and practices to reduce risks to forest carbon and underlying productivity and resilience. *Completion date: June 2019*

Project title	Description	Management outcome
Predicting the impact of climate change on fire weather variables (revised environmental scan only) (ERP 8)	Australia has been described as one of the developed countries most vulnerable to climate change, and already experiences a significant climate variability including exposure to extremes in rainfall, winds and drought. This research will bring together current knowledge and data about how climate change impacts on fire weather variables, such as temperature, precipitation, wind speed and relative humidity and identify what further data is required to help us predict the likelihood and severity of bushfires with more confidence. This will enable the identification of climate change induced alterations to planned burn windows, season length, extreme events and fire behaviour.	By reviewing the impacts of climate change on fire weather variables in Victoria, bushfire management agencies will understand how this knowledge informs risk decision making, and have an evidence base for the longer-term objective- the preparation of a series of datasets that enable exploration of fire weather under different climate change scenarios. *Completion date: June 2019* *This project is funded under Safer Together, supported and led by DELWP.*
Using below canopy Unmanned Aerial Vehicles (UAVs) for surveying hazardous forest environments subject to planned and unplanned fire	The use of Unmanned Arial Vehicles (UAV's) or drones within DELWP is currently utilised across a range of land management and mapping/ monitoring applications. Due to a reduction in cost of this technology, the opportunity for DELWP to further expand the use of UAV's to incorporate operational needs has become feasible. This project will investigate the use of UAV's in forested environments to undertake sub-canopy surveying in potentially dangerous and challenging environments, while reducing human exposure to risk. The research will also explore mounting sensors on the UAV's to enable high resolution measurement and modelling of hazards such as fuel structure, moisture dynamics, real-time impact of fire on vegetation and fire behaviour.	The outcomes of this project will significantly improve DELWP's operational use of UAV's to: 1. remotely survey areas of forest to assess hazardous trees risk 2. rapidly identify safe and effective dozer control line routes during bushfire response 3. survey risks in forest environments immediately after a bushfire or other hazard 4. undertake search and rescue In addition, the project will improve DELWP's operational planning capacity through enhanced forest access which will assist with lighting decisions on days of planned-burning as well as the prediction of burn behaviour and firefighter safety. *Please note the completion of this project is dependent upon successful additional funding bids.*

Environmental compliance

Environmental compliance is a dynamic field requiring up to date information to meet regulatory responsibilities. Accurate and timely information to educate and enforce legislation is imperative in ensuring DELWP respond to public information, initiate targeted operations, conduct investigations and prosecute through the courts efficiently and effectively. Current research is focusing on utilising improved technologies to strengthen datasets, enhancing guidelines for protecting and managing wildlife, developing metrics to measure the effectiveness of compliance activities on reducing environmental crime, and understanding whether compliance objectives align with community expectations.

Project title	Description	Management outcome
Developing strategic intelligence for the environmental compliance regulator (ERP 7) *Research organisation to be confirmed.*	Strategic intelligence can help to better recognise and understand priority risks and harms in the operating environment, including new and emerging risks. It can enable a more confident determination as to where and how to target policies, regulatory tools and compliance efforts for the best outcomes, gauge the impacts of efforts, and adjust approaches accordingly. This project will develop capabilities (systems, tools and capacity) for DELWP to capture, analyse and use data in more dynamic ways, to assess the performance and functioning of its regulatory systems, and better identify emerging or intensifying issues.	Generation of strategic intelligence from existing and under-utilised data as well as new and emerging technologies and datasets, will improve DELWP's ability to undertake strategic assessments and thinking across the environmental regulatory framework in the context of social, political and economic operating environments. *Completion date: to be confirmed*
Use of emerging technologies for native wildlife population assessment and management (ERP 16) *Research organisation to be confirmed.*	Accurate and timely assessments of native wildlife are needed for many purposes such as monitoring the effectiveness of management strategies, management of wildlife taken as game or reported to be damaging crops and pastures, and to rapidly identify and manage threats to wildlife such as disease and natural hazards. This project will collect, identify and analyse species imagery and habitat condition data to develop algorithms and systems that will enable managers to interpret population and habitat/impact data.	The development of survey standards, systems and methods for DELWP to undertake ecologically sound, repeatable and reliable assessments of wildlife populations and habitat conditions. *Completion date: to be confirmed*

Project title	Description	Management outcome
National Guidelines for the seizure and holding of wildlife (ERP 17) *Research organisation to be confirmed.*	DELWP and other agencies that have wildlife management and compliance responsibilities, have insufficient and poorly defined standards to manage the requirements and risks associated with the seizing and holding of wildlife. This project will develop guidelines for wildlife management and compliance agencies that outline the requirements for housing, feeding, transporting and disposing of the most commonly held and traded classes and orders of native and invasive wildlife. In addition, the project will outline the design and layout requirements for wildlife enclosures and the competencies and training curriculum for staff.	Guidelines for the seizure and holding of wildlife, including how animals are housed, fed and handled as well as infrastructure design, the development of wildlife facilities and the appropriate training for staff. The guidelines will assist DELWP and other agencies with wildlife management and compliance responsibilities to ensure facilities, capabilities and standards are enough in relation to the seizing and holding of wildlife. *Completion date: to be confirmed*
Making a difference - conceptual framework to show benefits of compliance (ERP 18) *Research organisation to be confirmed.*	As part of DELWP's draft Environmental Compliance Policy, there is a commitment to use a risk-based approach to resource allocation which will address actions that are causing the most harm to the environment, the biggest impact on fair and legal access to public land and access to natural resources. To achieve this, DELWP requires metrics to estimate and, over time, measure the loss that was avoided due to compliance actions. This project will develop metrics for environmental and social 'uplift' resulting from compliance actions.	This project will enable DELWP to meet its Environmental Compliance Policy objectives to reduce harms to our natural and heritage values, and the environment and to reduce illegal, inequitable and unsafe access to public land and use of natural resources. *Completion date: to be confirmed*
The human dimension of environmental crime (ERP 19) *Research organisation to be confirmed.*	As part of DEWLP's draft Environmental Compliance Policy, the community is placed at the centre. This project aims to consider compliance issues relating to social, environmental and economic values in the areas of native wildlife, trafficking of exotic species, licensing of the sale of native flora and fauna, rubbish dumping, recreational values and fire prevention on public land, as well as unauthorised occupation of crown land and adherence to license, permit and lease conditions. The project will investigate and analyse community perceptions of policy options and provide training to staff on how to obtain relevant information from communities.	A better understanding of community expectations of environmental compliance values and objectives will enable DELWP to ensure compliance program priorities align with community priorities. A better understanding of motivations behind non-compliance to enable DELWP to target compliance actions more effectively. A better understanding of community perceptions of wildlife management to enable DELWP to develop new wildlife population management solutions that are acceptable to the community. *Completion date: to be confirmed*

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Appendix 1: Fire and adaptive management research reports

For copies please go to: **https://www.ffm.vic.gov.au/research-and-publications/fire-research-and-adaptive-management-publications**

1. 1977. A study of the distribution of aerially applied fire retardant in softwood plantations. R. Rawson.
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3. 1978. Fuel properties before and after thinning in young Radiata Pine plantations. D.F. Williams.
4. 1979. Using fire to reduce fuel accumulations after first thinning in Radiata Pine plantations. P.R. Billing.
5. 1979. Some of the effects of low-intensity burning on Radiata Pine. P.R. Billing.
6. 1980. A low-intensity prescribed burning operation in a thinned Radiata Pine plantation. P.R. Billing.
7. 1980. Some aspects of the behaviour of the Caroline Fire of February 1979. P.R. Billing.
8. 1981. Changes in understory vegetation in Sherbrooke Forest following burning or slashing. R. Rawson and B. Rees.
9. 1981. Hazard-reduction burning in the Big Desert. P.R. Billing.
10. 1981. The effectiveness of fuel-reduction burning: five case histories. P. Billing.
11. 1982. A fire tornado in the Sunset Country January 1981. P. Billing and R. Rawson.
12. 1982. A summary of forest fire statistics, 1972-73 to 1980-81. R. Rawson and B. Rees.
13. 1982. Fuel moisture changes under Radiata Pine. M. Woodman.
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20. 1983. Otways Fire No. 22 – 1982/83: aspects of fire behaviour. P. Billing.
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22. 1984. Forest fire statistics, 1974-75 to 1983-84. B. Rees.
23. 1985 The Avoca Fire, 14 January 1985. P. Billing.
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25. 1985. Effectiveness of fuel-reduction burning: 10 case studies. R. Rawson, P. Billing and B. Rees.
26. 1986. Operational aspects of the Infra-Red Line Scanner. P. Billing.
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28. 1987. Monitoring the ecological effects of fire. F. Hamilton (ed.)
29. 1990. Fire behaviour and fuel-reduction burning – Bemm River. A.J. Buckley.
30. 1991. Fire hazard and prescribed burning of thinning slash in eucalypt regrowth forest. A.J. Buckley and N. Corkish.
31. 1992. Assessing fire hazard on public land in Victoria: fire management needs and practical research objectives. A.A.G. Wilson.
32. 1992. Eucalypt bark hazard guide. A.A.G. Wilson.
33. 1992. Fuel reducing a stand of eucalypt regrowth in East Gippsland: a case study. A.J. Buckley.
34. 1992. Monitoring vegetation for fire effects. M.A. Wouters.

35. 1993. Elevated fuel guide. A.A.G. Wilson.
36. 1993. Wildfire behaviour in heath and other elevated fuels: a case study of the 1991 Heywood fire. M.A. Wouters.
37. 1993. The accumulation and structural development of the wiregrass (Tetrarrhenajuncea) fuel type in East Gippsland. L.G. Fogarty.
38. 1993. A case study of wildfire management in the Byadlbo and Tingaringy Wilderness Areas. A.G. Bartlett.
39. 1993. Developing fire management planning in Victoria: a case study from the Grampians. M.A. Wouters.
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43. 1996. Fuel hazard levels in relation to site characteristics and fire history: Chiltern Regional Park case study. K. Chatto.
44. 1998. Effectiveness of fire-fighting first attack operations by the Department of Natural Resources and Environment from 1991/92-1994/95. G.J. McCarthy and K.G. Tolhurst.
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46. 1997. Analysis of fire causes on or threatening public land in Victoria 1976/77 – 1995/96. C. Davies.
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53. 2003. Determination of sustainable fire regimes in the Victorian Alps using plant vital attributes. G.J. McCarthy, K. Tolhurst and K. Chatto.
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55. 2003. Ecological effects of repeated low-intensity fire in a mixed eucalypt foothill forest in south-eastern Australia. Summary report (1994-99).
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61. 2003. Effects of repeated low-intensity fire on terrestrial mammal populations of a mixed eucalypt foothill forest in south-eastern Australia. M. Irvin, M. Westbrooke and M. Gibson.
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