



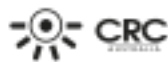
# RESEARCH FORUM 2014: PROCEEDINGS OF THE RESEARCH FORUM AT THE BUSHFIRE AND NATURAL HAZARDS CRC & AFAC CONFERENCE

Wellington, New Zealand, 2 September 2014





Version	Release history	Date
1.0	Initial release of document	1/3//2015
1.1	Missing paper, Fawcett et al added	11/9/2015



© Bushfire and Natural Hazards CRC 2015

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form without the prior written permission from the copyright owner, except under the conditions permitted under the Australian Copyright Act 1968 and subsequent amendments.

**Disclaimer:**

The Bushfire and Natural Hazards CRC advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, the Bushfire and Natural Hazards CRC (including its employees and consultants) exclude all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

**Publisher:**

Bushfire and Natural Hazards CRC

ISBN: 978-0-9941696-3-1

February 2015

**Citation:**

M. Rumsewicz (Ed) 2015, 'Research forum 2014: Proceedings of the research forum at the Bushfire and Natural Hazards CRC & AFAC conference' 2 September 2014, Wellington New Zealand, Bushfire and Natural Hazards CRC, ISBN: 978-0-9941696-3-1

**Cover:**

A keynote talk at the sold out 2014 Research Forum.



## TABLE OF CONTENTS

### MANAGING SEVERE WEATHER – PROGRESS AND OPPORTUNITIES

*J.D. KEPERT, M. NAUGHTON AND J. BALLY* ..... 1

### BUILDING COMMUNITY RESILIENCE TO NATURAL HAZARDS IN NORTHERN AUSTRALIA

*J. GOULD, B. SITHOLE, A. CAMPBELL, G. JAMES AND S. SUTTON* ..... 14

### ESTIMATING THE IMPACTS OF NATURAL HAZARDS ON FATALITIES AND BUILDING LOSSES

*R. VAN DEN HONERT, L. COATES, K. HAYNES AND R. CROMPTON* ..... 23

### THE HEATWAVES OF THE 2013/2014 AUSTRALIAN SUMMER

*R.J.B. FAWCETT AND J.R. NAIRN*..... 34

### MITIGATING THE EFFECTS OF SEVERE FIRES, FLOODS AND HEATWAVES THROUGH THE IMPROVEMENTS OF LAND DRYNESS MEASURES AND FORECASTS

*I. DHARSSI, V. KUMAR, C.S. YEO, J. BALLY AND J.D. KEPERT* ..... 46

### DISRUPTION OF CRITICAL INFRASTRUCTURE DURING PROLONGED NATURAL DISASTERS

*E. PHILLIPS, F.D. DE OLIVEIRA, V. KOSCHATZKY AND P. SOMERVILLE* ..... 52

### URBAN SEARCH AND RESCUE OPERATIONS IN TROPICAL CLIMATES

*M. BREARLEY, I. NORTON, M. HUTTON, D. RUSH, S. SMITH AND H. FUENTES* ..... 60

### MANAGING CRITICAL INFRASTRUCTURE IN A CHANGING CLIMATE: RISK, ROLES, RESPONSIBILITIES AND POLITICS

*K. HUSSEY AND S. DOVERS* ..... 71

### THE EFFECTS OF FIRE-PLUME DYNAMICS ON THE LATERAL AND LONGITUDINAL SPREAD OF LONG-RANGE SPOTTING

*W. THURSTON, K.J. TORY, J.D. KEPERT AND R.J.B. FAWCETT* ..... 85

### CHALLENGES OF MEASURING EMERGENCY MANAGEMENT PERFORMANCE UNDER ADVERSITY: THE GOOD THE BAD THE UGLY

*C. OWEN, C.B. BROOKS AND C. BEARMAN* ..... 95

### INTEGRATED DISASTER DECISION SUPPORT SYSTEM INCORPORATING MITIGATION PORTFOLIO OPTIMISATION

*J. NEWMAN, H.R. MAIER, H. VAN DELDEN, A.C. ZECCHIN, G.C. DANDY AND E. PIKUSA* ..... 106

### THRESHOLD BEHAVIOUR IN DYNAMIC FIRE PROPAGATION

*J.J. SHARPLES, C.C. SIMPSON, J.P. EVANS, R.H.D. MCRAE* ..... 116

### A PRE-DISASTER MULTI-HAZARD DAMAGE AND ECONOMIC LOSS ESTIMATION MODEL FOR AUSTRALIA

*A. RAJABIFARD, M. ULUBASOGLU, K.E. POTTS, M.H. RAHMAN, M. KALANTARI AND P. BHATTACHARYA* ..... 127

### DISCOVERING FUTURE DISASTER MANAGEMENT CAPABILITY NEEDS USING SCENARIO PLANNING

*P. BARNES* ..... 134

### PROMOTING CHILD RESILIENCE TO DISASTERS: POLICY, PRACTICE, RESEARCH

*K.R. RONAN, B. TOWERS, K. MCAUSLAN, V. JOHNSON, E. ALISIC, S. DAVIE, J. HANDMER, K. HAYNES, N. IRELAND, M. PETAL, A. AMRI AND D. JOHNSTON* ..... 146

### BUILDING COMMUNITY RESILIENCE THROUGH INFORMAL EMERGENCY VOLUNTEERING

*J. WHITTAKER, J. HANDMER AND B. MCLENNAN* ..... 155

### MANAGING ANIMALS IN DISASTERS (MAID): THE EXPERIENCES OF EMERGENCY SERVICES PERSONNEL IN SUPPORTING ANIMALS AND THEIR OWNERS IN DISASTERS

*M. TAYLOR, G. EUSTACE, B. SMITH, K. THOMPSON, R. WESTCOTT AND P. BURNS* ..... 166



---

<b>SOCIAL MEDIA, CRISIS COMMUNICATION AND COMMUNITY-LED RESPONSE AND RECOVERY: AN AUSTRALIAN CASE STUDY</b>	
<i>M. IRONS, D. PATON, L. LESTER, J. SCOTT AND A. MARTIN</i> .....	180
<b>NSW RFS BUSH FIRE HOUSEHOLD ASSESSMENT TOOL</b>	
<i>M. O'HALLORAN</i> .....	190
<b>LEARNING FROM ADVERSITY: WHAT HAS 75 YEARS OF BUSHFIRE INQUIRES (1939-2013) TAUGHT US?</b>	
<i>M. EBURN, D. HUDSON, I. CHA AND S. DOVERS</i> .....	198
<b>THE EFFECT OF HAZARD REDUCTION BURNING ON THE FUEL ARRAY IN NATURE RESERVES AND URBAN PARKS IN THE ACT</b>	
<i>A. LEAVESLEY, J. MALLELA, J. SEDDON, T. CORRIGAN, N. COOPER AND B. LEVINE</i> .....	213
<b>IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS</b>	
<i>D.J. HENDERSON AND J.D. GINGER</i> .....	232
<b>MODELLING THE FIRE WEATHER OF THE COONABARABRAN FIRE OF 13 JANUARY 2013</b>	
<i>R.J.B. FAWCETT, C. YEO, W. THURSTON, J. D. KEPERT, K. J. TORY</i> .....	241





# MANAGING SEVERE WEATHER - PROGRESS AND OPPORTUNITIES

PROCEEDINGS OF THE RESEARCH FORUM AT THE BUSHFIRE AND  
NATURAL HAZARDS CRC & AFAC CONFERENCE  
WELLINGTON, 2 SEPTEMBER 2014

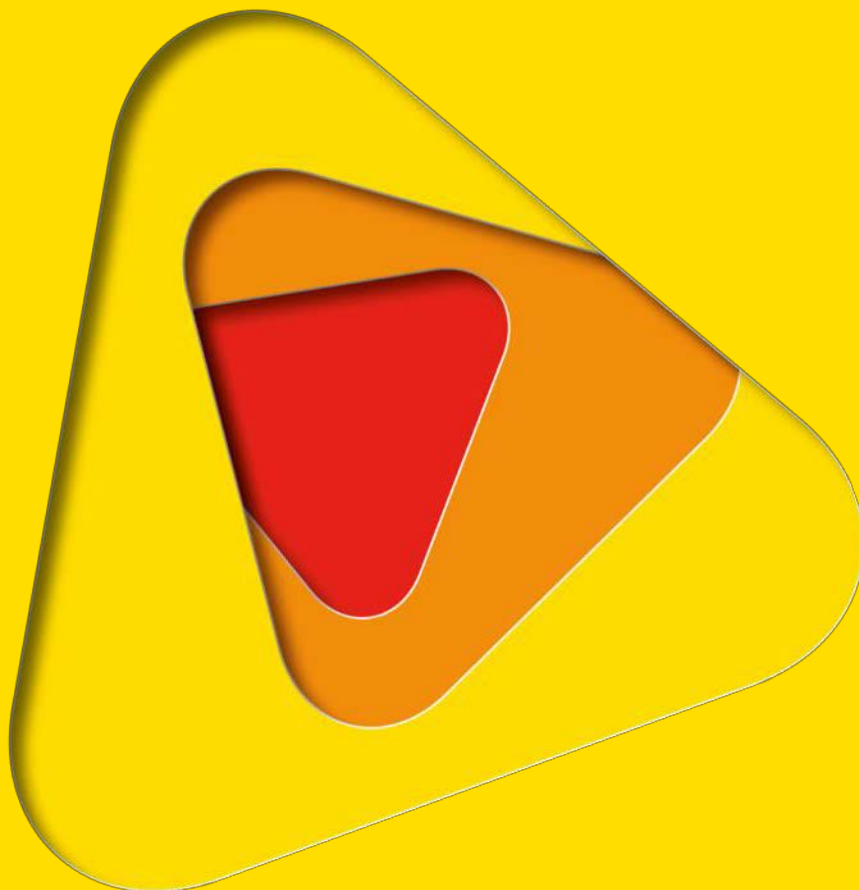
**Jeffrey D. Kepert<sup>1,3</sup>, Michael Naughton<sup>1</sup> and John Bally<sup>2,3</sup>**

<sup>1</sup>Centre for Australian Weather and Climate Research

<sup>2</sup>Tasmanian Regional Office, Bureau of Meteorology

<sup>3</sup>Bushfire and Natural Hazards CRC

Corresponding author: [j.kepert@bom.gov.au](mailto:j.kepert@bom.gov.au)





## INTRODUCTION

Severe weather often becomes "high impact" weather when certain "tipping points" are reached. Rivers burst their banks, houses lose their roofs, and bushfires exceed suppression capacity as thresholds are crossed. The high adverse impact events tend to be rare, because society and the environment naturally tend to adapt to more frequent events of lower impact. They are often small scale, or a relatively small part of a larger system. And they are often subject to considerable forecast uncertainty.

Managing the impacts of severe weather is therefore about managing risk. The results of exceeding one of these thresholds are profoundly different to merely approaching it – our memories of Hurricane Katrina would be very different if the storm surge had not been high enough to overtop and breach the levees protecting New Orleans. Often, the differences in the meteorology between a close call and a disaster will fall within current forecast uncertainty. Balancing the costs of over-preparation and under-preparation in the presence of such uncertainty is a formidable task.

Managing risk when information is uncertain requires that we move from considering a single, "deterministic" forecast that is our best estimate of what will happen, to consideration of a range of possibilities that reliably reflects the forecast uncertainty. It is not enough to just consider the average (mean) forecast, which may not even be a physically plausible event (you can't half-flood New Orleans). Even the most likely scenario (the mode) risks leaving us unprepared in the face of more destructive, if less likely, possibilities.

We therefore need to consider not just multiple scenarios, but also their relative likelihood. This paper discusses some selected examples from around the world into objectively providing such information. Making effective use of this richer but more complex information stream is a challenge, and we will also consider progress in this area.

## FLIP-FLOPS AND FORECAST UNCERTAINTY

Few things annoy a forecast user more than an about-face in forecast policy. Forecast flips, flip-flops and flip-flop-flips<sup>1</sup> – also known as the windscreen wiper effect – make implementing a coherent preparation strategy very difficult. Nor is the problem confined to end-users of forecasts.

Meteorologists also struggle when the model guidance is changing from one run to the next. Does the model really have a handle on the situation when it has flipped, and then flopped back again?

---

<sup>1</sup> A "flip" is where forecast outcome A is replaced by the distinctly different outcome B. A "flip-flop" is where a flip is followed by a return to outcome A. And a "flip-flop-flip" contains one additional alternation. These terms were originally defined by Zsoter et al (2009).



Tropical cyclone recurvature provides a good example of the issues. Western Australian tropical cyclones often begin by running parallel to the Pilbara coast. At some point in their life, they may make a turn to the left (recurve) and impact the coast. The time between recurvature and coastal impact can be well under 24 hours, so predicting recurvature well before it happens is crucial.

Sometimes, the atmospheric conditions that cause recurvature are unequivocal, and the forecaster can confidently predict it. Other times, those conditions are present, but it is unclear whether they will become strong enough to force a direction change. In such cases, the most likely event may be a “straight runner”, but the forecaster maintains a cyclone watch along the coastline as a precaution. In these cases, users may well want to know whether the chance of a landfall is 10%, or 40%.

Suppose that at one forecast time, the probabilities are 60% for straight track, and 40% for recurvature. The most likely scenario is the straight track, so that will be the official forecast, along with a precautionary watch or warning for the coast, and likely some words expressing caution about the possibility of recurvature. If, at the later time, the probabilities reverse to 40:60, so that recurvature becomes the most likely event, then the official forecast will “flip”.

In this hypothetical example, a modest change in probability has led to a dramatic change in the deterministic forecast. Which would be more useful: a series of forecasts “straight”, “straight with some caution”, “landfall”; or instead “the probability of a landfall is 20% ... 40% ... 60%”. Even though some users may prefer the simplicity and perceived certainty of a definitive forecast, there will be many who can make good use of the probabilistic information. Long experience with, and extensive verification of, ensemble prediction systems has shown that they can provide reliable probabilistic information. Not only do probabilities provide a means of avoiding abrupt changes in communicating forecast policy as in this example, but as recently shown by Zsoter et al (2009), ensemble forecasts are also less prone to flips and flip-flops than their deterministic cousins.

Before we leave cyclone recurvature, we should briefly consider Severe Tropical Cyclone George, which impacted the Pilbara coast in 2006 as a category-five storm, causing three deaths. George’s recurvature was not predicted by the deterministic models until quite late, but the European Centre for Medium-Range Weather Forecasting (ECMWF) Ensemble Prediction Scheme (EPS) indicated a significant probability of recurvature approximately three days before landfall. Interestingly, nearly all of the more intense ensemble members recurved, while most of the weaker members ran straight (Fig 1). That is, the EPS not only predicted that there was a significant chance of landfall, but also that, if landfall occurred, then it would very likely be as an intense cyclone.

## **ENSEMBLE FORECASTS OF HURRICANE SANDY**

Hurricane Sandy struck New York on 29 October 2012. Along with the wind and heavy rain, it brought a devastating storm surge which caused extensive flooding and major damage to infrastructure.

Sandy struck a densely populated area with an enormous amount of valuable assets, an area seldom affected by such storms. The impact was huge.

Sandy was also a meteorologically very interesting storm. Most hurricanes, once they move polewards out of the tropics are captured by the mid-latitude westerlies and move rapidly to the east. Sandy began this process, but later swung back to the west and impacted New York.



Ensemble predictions from nine days ahead of impact gave some hint of this unusual track (Fig 2). A few ensemble members show the storm heading across the Atlantic, but some curve it back onto the northern part of the US east coast or onto Canada. A subsequent ensemble run from two days later “tightens up” the ensemble spread and shows a clearer signal of northwestwards movement at the end. Further runs closer to the event narrow down the region of uncertainty and provide greater certainty. If we calculate the probability of strong winds in the vicinity of New York from these ensembles (Fig 3), the first hints of trouble are evident nine days ahead of the event. As time passes, the predicted probability of an impact increases reasonably steadily. This consistent signal, in conjunction with other information, gave forecasters and emergency services personnel steadily growing confidence that action was necessary. Even though the forecast tracks were highly unusual, the confidence provided by a consistent ensemble signal, in conjunction with other information, helped provide a strong emergency response.

## **SOMETIMES THE ATMOSPHERE IS HARD TO PREDICT**

Regular footy tippers know that some games are much easier to pick than others. Similarly, a meteorologist’s confidence in a forecast can vary widely. Sometimes, the atmosphere is just more predictable than at others.

Typhoons Soulik and Fitow provide a nice example of this difference. These two storms occurred a few months apart in 2013, in much the same part of the North West Pacific. Both tracked towards the north of Taiwan and then China, and both were intense storms that produced a significant amount of damage, with Fitow becoming the second most damaging typhoon in monetary terms for China.

Predicted tracks for the two storms from the Japanese Meteorological Agency’s EPS are shown in Fig 4. Obviously, the amount of spread in the forecast tracks varies enormously. Ensemble track diagrams from other major numerical weather prediction (NWP) centres’ EPS systems show a similar result.

Why was Fitow so much less predictable? Assigning cause in these circumstances can be difficult, but one challenge with Fitow’s forecasts was the proximity of Typhoon Danas (Fig 5). Tropical cyclones can, when close enough, interact and affect each other’s tracks. In this case, “close enough” depends not just on the physical distance, but also on the size and strength of the storms. Predicting the occurrence and strength of an interaction is therefore very subject to uncertainty, and may have contributed to the large spread in the forecasts of Fitow.

In the event, both typhoons tracked approximately through the middle of the ensemble “cloud”. But, in real time and without the benefit of hindsight, they should have prompted a very different emergency response, since the threat from Fitow extended from the northern Philippines to southern Japan, a vastly greater area than that from Soulik.

All users know that forecasts are always uncertain, and in the absence of information about that uncertainty, will often add on a bit of a “safety margin” to allow for the forecast being out by a small amount. The contrast between Soulik and Fitow shows peril of this approach, for the safety margin will depend on the situation.



## TROPICAL CYCLONE OSWALD

As a wind-producing system, Oswald was one of the weakest and shortest-lived tropical cyclones in Australia's history. Oswald briefly attained cyclone strength in the Gulf of Carpentaria, before crossing Cape York Peninsula and tracking southwards parallel to Australia's east coast. Along the way, it produced some exceptional rainfall totals and significant flooding (Fig 6).

Consider the five days from when Oswald was a tropical low in the Gulf, to its reaching the Queensland east coast as a major rain system. The main deterministic NWP systems either partially or completely failed to predict this transition. However, the Australian EPS system, currently being run in research mode, had four of 24 members with a low in the right region, indicating a 17% probability. Similarly, the long-established ECMWF EPS suggested a 12% chance, with 6 out of 51 members. In addition, the mean of all **AGREPS** (Australian Community Climate and Earth-System Simulator (**ACCESS**) Global and Regional Ensemble Prediction System) members predicted a low somewhat to the northwest of reality, from five days ahead. In the case of AGREPS, the probability of rainfall exceeding 25 mm exceeded 50% along a significant part of the Queensland coast. Moving closer to the event, the forecast probabilities of 25 mm or more of rain from three days ahead were markedly higher, covered a larger area, and were now accompanied by similar probabilities from the ECMWF EPS (Fig 7). Both EPS systems continued to predict high probabilities of significant rain as ex-Oswald tracked southwards, with the probabilities generally increasing as time progressed.

Oswald was an unusual event. Its failure to weaken and long track southward are both contrary to the normally expected behaviour of tropical cyclones after landfall. Several days before the flooding began, and even before Oswald had become a cyclone, the EPS systems gave a clear indication of the risk, even though the higher-resolution deterministic NWP systems were giving the all-clear for that part of Queensland. Early warning, even at low probability, raises the possibility of better mitigation.

## THE VICTORIAN HEATWAVE OF JANUARY 13-17, 2014


Victoria experienced a marked heatwave during January 13 to 17 of this year, with Melbourne having four consecutive days with a maximum temperature over 41 °C. Ten-day forecasts from the research AGREPS system gave clear indication of this event, a week in advance (Fig 8). The hot spell was followed by a cool change and cooler conditions on the 18<sup>th</sup>. The prediction of this change by AGREPS from eight days ahead is interesting (Fig 9); the maximum temperature shows a very wide range of spread and it is clear that there is a substantial chance of one, and perhaps even two, more days of heat. Looking also at the wind speed probabilities for this period, it is clear that the probability of high winds increases later in the heat-wave period, and that these are therefore the more dangerous days for fire risk.

## WIND CHANGE TIMING ON BLACK SATURDAY

It is well known that the most dangerous time for bushfires is when a wind change strikes. Forecasting the timing of the wind change is therefore of critical importance. Given that the majority of fire deaths occur in conjunction with a wind change, careful risk management of the change is essential. Thus, some idea of the likely error bars on the change timing and position are needed.

Figure 10 shows the strength and location of the wind change, here detected as the line of maximum northwest component of temperature gradient, for a 24-hour forecast from the ECMWF EPS valid at





11 pm on Black Saturday (7 February 2009). The white line shows the change position in the ensemble mean, and the thin grey lines are the position in each member. The black numbers are the standard deviation of the change position in an east-west direction, in degrees of longitude (one degree of longitude is approximately 87 km at these latitudes). Interestingly, the position uncertainty varies along the change.

These data provide quantitative information on the likely progression of the change. They can be used to help answer the question of what is the earliest (or latest) the change can hit a given location. And they add to what was already a very high level of confidence that the change will indeed arrive and not “fizzle out” – every single member had a significant wind change.

## SUMMARY AND DISCUSSION

Ensemble prediction systems have significant advantages over deterministic NWP systems. They:

- can be used to **assess the predictability** of the atmosphere
- give an estimate of the **probability distribution** of the forecast
- are **more valuable** than single forecasts
- are **more consistent** than single forecasts
- provide the tools to properly **manage risk**.

Against this, probabilistic information can be more difficult to interpret than categorical forecasts, and many studies have found that a level of user training is necessary to facilitate proper interpretation. For example, the final report of the FIRE-DST (Fire Impact and Risk Evaluation – Decision Support Tool) project (Cechet et al. 2014) noted that some emergency managers were fixated on yes/no outcomes, and that probabilistic information was “too complicated”.

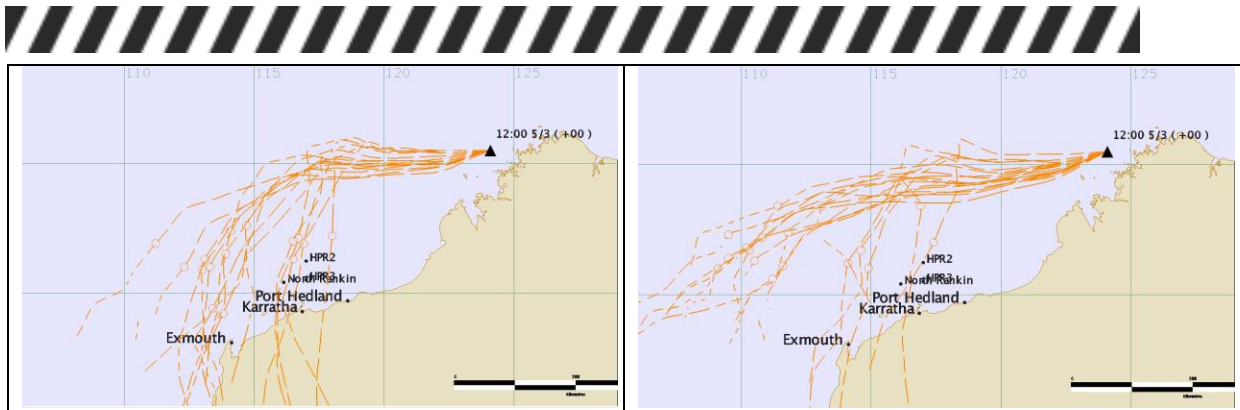
Given the benefits of ensemble forecasting, the challenge then is to gradually move towards making better use of them, with support from the relevant stakeholders. Ensemble forecasting has many well-demonstrated advantages, and is widely regarded as being the future of NWP. Realising those benefits in practice will, however, take time and effort.

## ACKNOWLEDGEMENTS

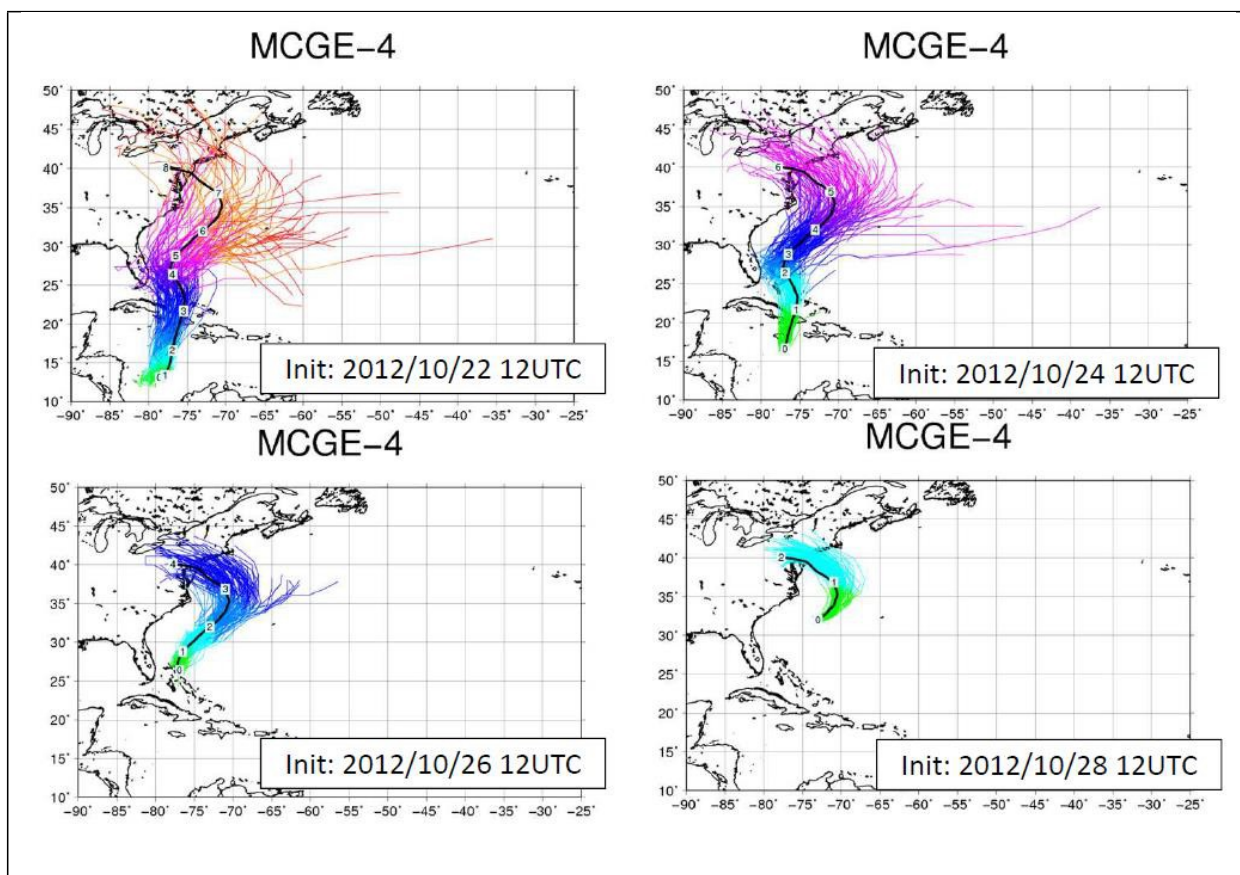
We thank Grant Elliot for the data on TC George, David Smith for his work on AGPREPS, especially the verification, and Munehiko Yamaguchi for the data on Typhoons Fitow and Soulik.

## REFERENCES

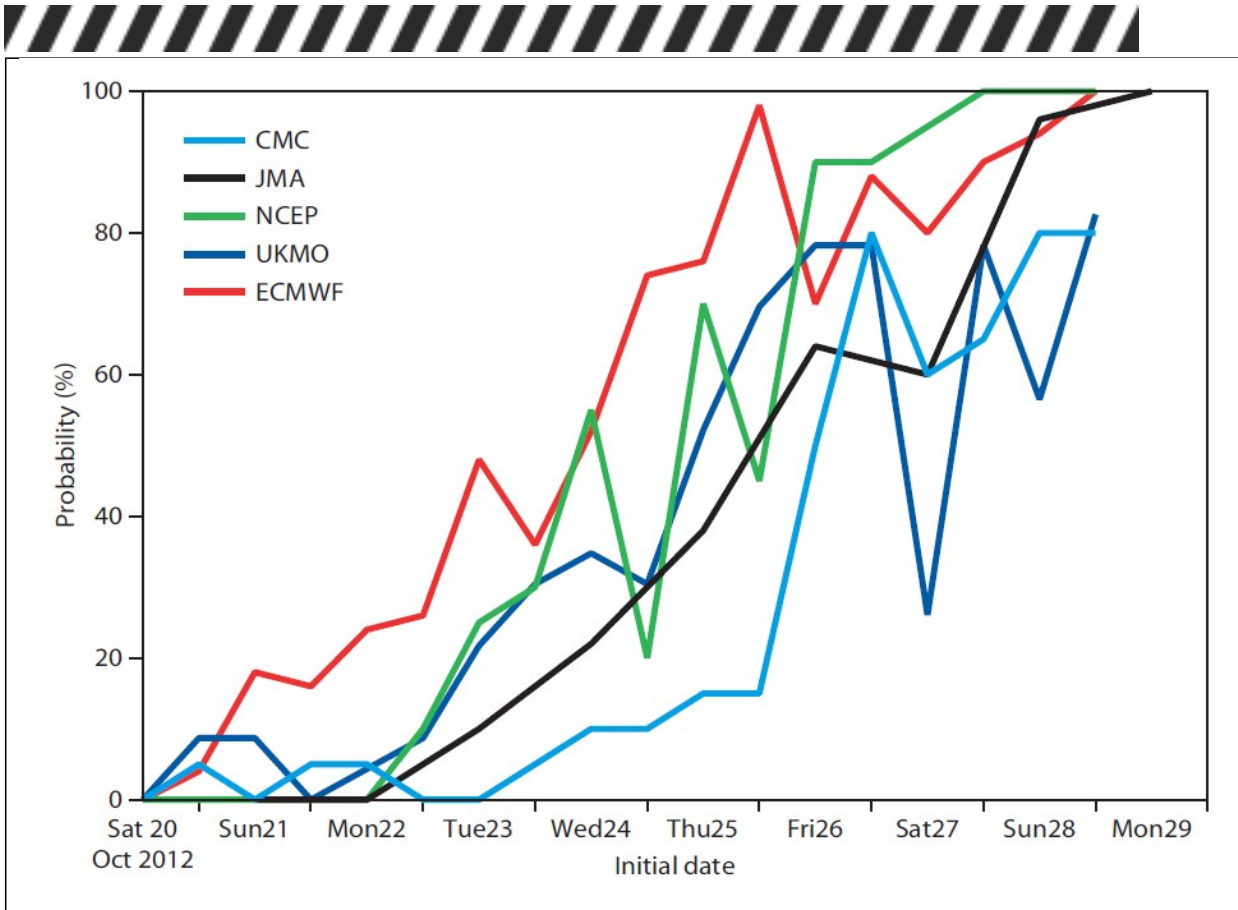
- Cechet R P et al. (2014). Fire Impact and Risk Evaluation Decision Support Tool (FIRE-DST): Final Project Report. Bushfire Cooperative Research Centre, Australia.
- Magnusson, L., J.-R. Bidlot, S.T.K. Lang, A. Thorpe, N. Wedi and M. Yamaguchi (2014). Evaluation of Medium-Range Forecasts for Hurricane Sandy. *Mon. Wea. Rev.*, **142**, 1962 – 1981.
- Zsoter, E., R. Buizza and D. Richardson (2009). “Jumpiness” of the ECMWF and Met Office EPS Control and Ensemble-Mean Forecasts. *Mon. Wea. Rev.*, **137**, 3823 – 3836.



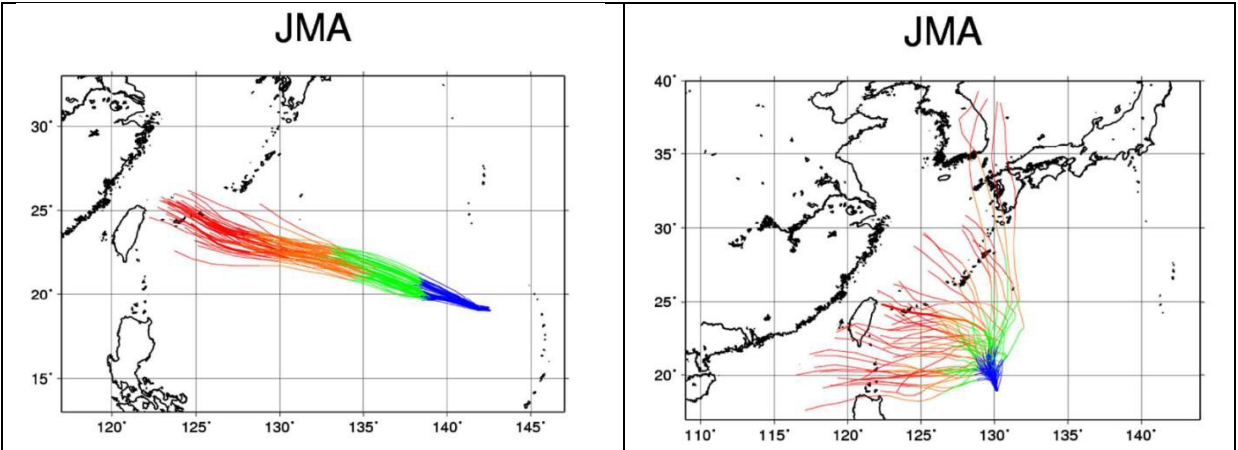
**Figure 1.** Predicted tracks of TC George, from the ECMWF EPS system. The left panel shows those members in which the intensity was greater than 75 kt, and the right panel those in which the intensity was below 65 kt. Figures courtesy of Grant Elliott.



**Figure 2.** Predicted tracks of Hurricane Sandy from a 4-model Multi-Centre Global Ensemble, for four different start times. The colours indicate the forecast day. The observed track is shown in black. Figure courtesy of Munehiko Yamaguchi.

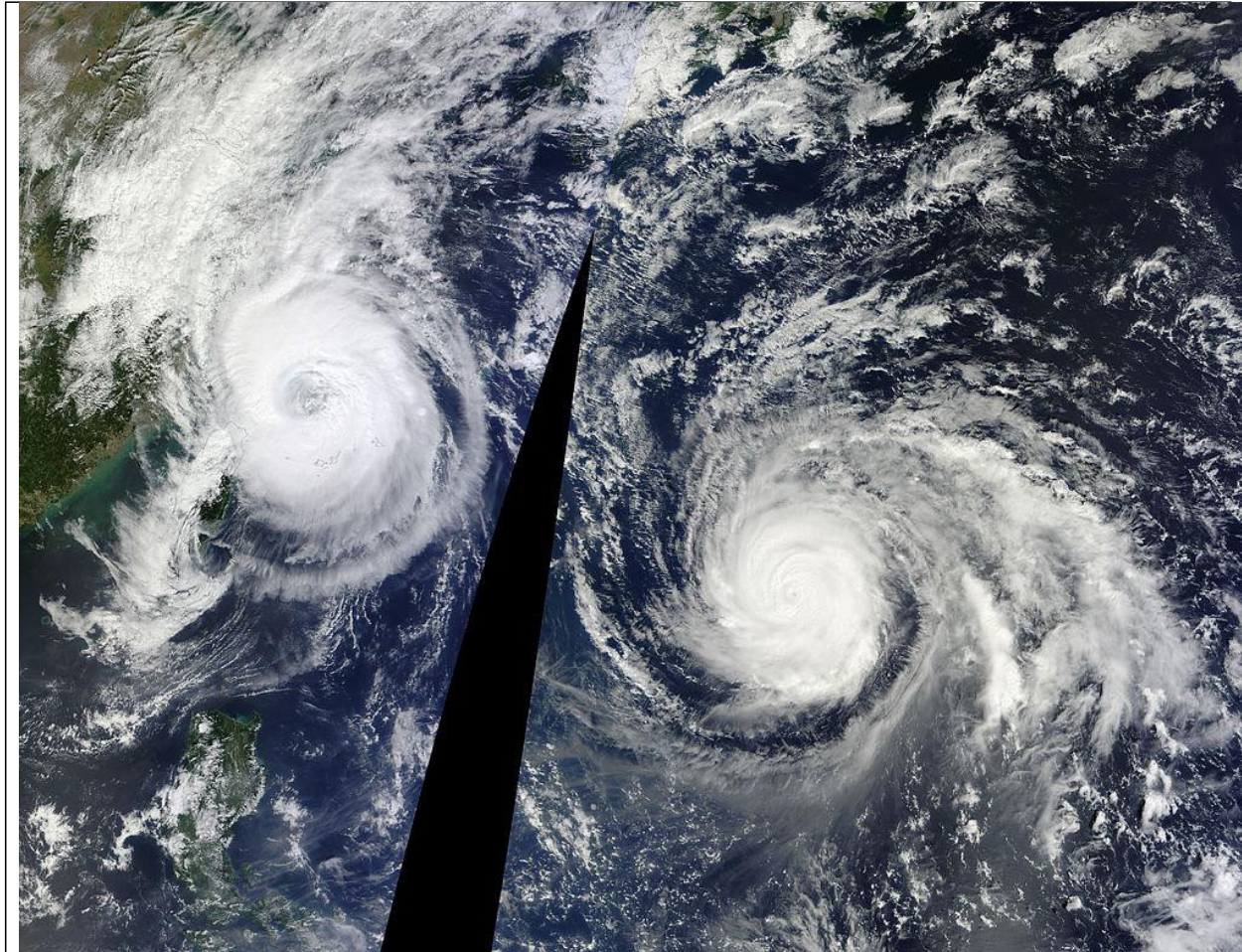


**Figure 3.** Probability of the wind speed at 850 hPa (about 1.5 km above mean sea level) exceeding  $38 \text{ m s}^{-1}$  within 100 km of New York Harbour during the 24 hours commencing 1200 UTC on 29 October 2012, from five different global NWP centres, as a function of forecast issue time. From Magnussen et al. (2014).

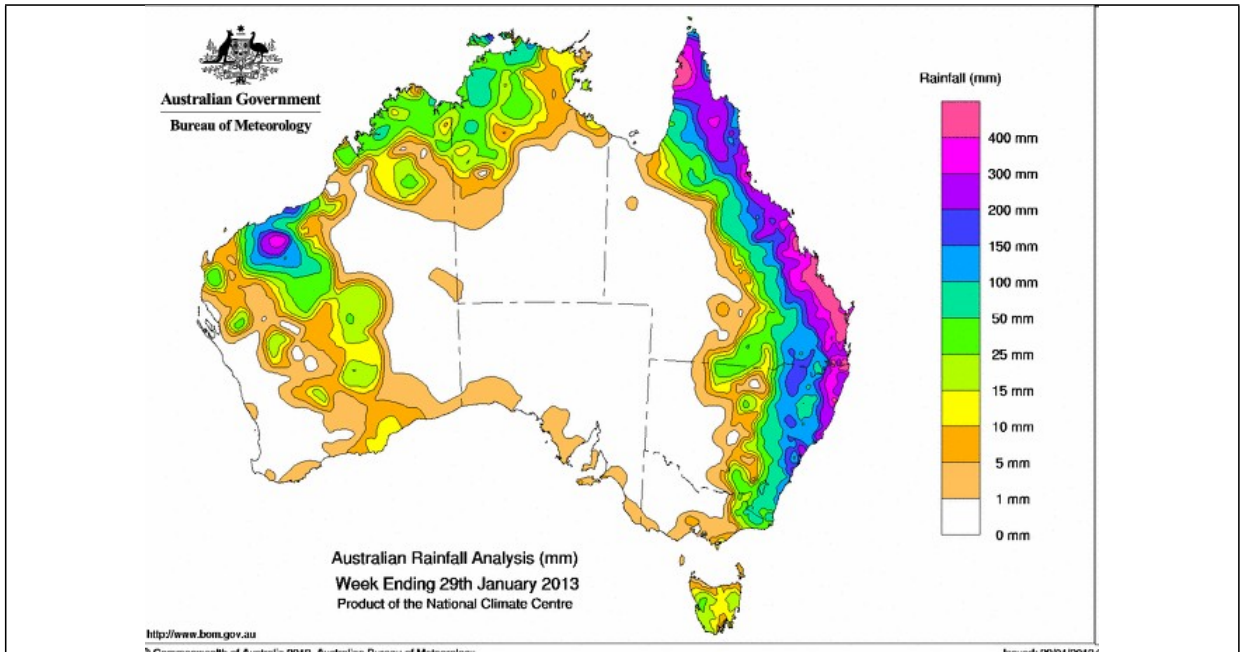


**Figure 4.** Ensemble track predictions for Typhoons Soulik (left) and Fitow (right) from the Japanese Meteorological Agency's EPS. The tracks each extend for four days, with the colour indicating the forecast day. Figure courtesy of Munehiko Yamaguchi.



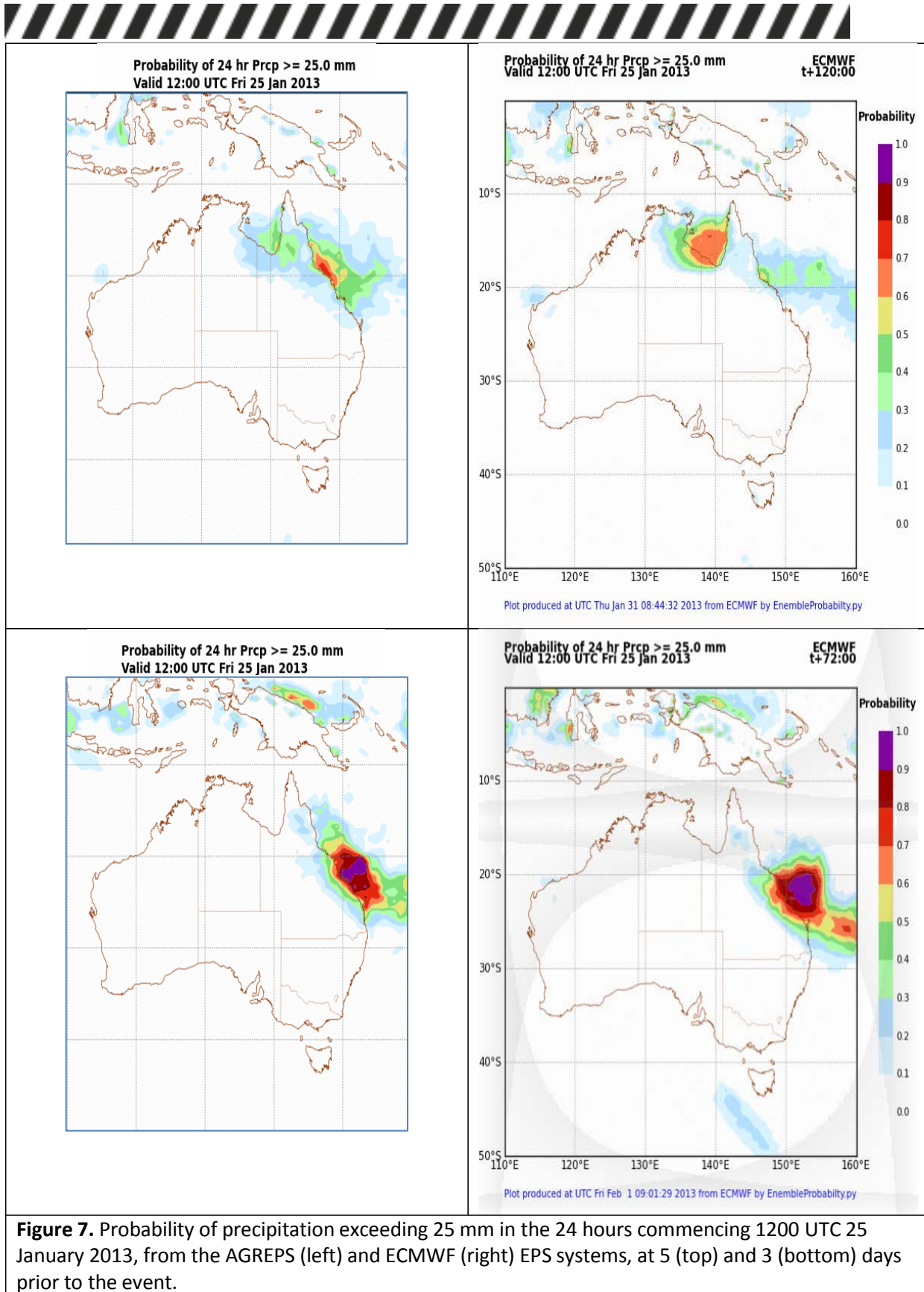


**Fig 5.** MODIS composite satellite image at 0255UTC 6 Oct 2013, showing Typhoons Fitow (left) and Danas (right).



**Figure 6.** Rainfall totals for Australia for the week ending 29 January 2013.



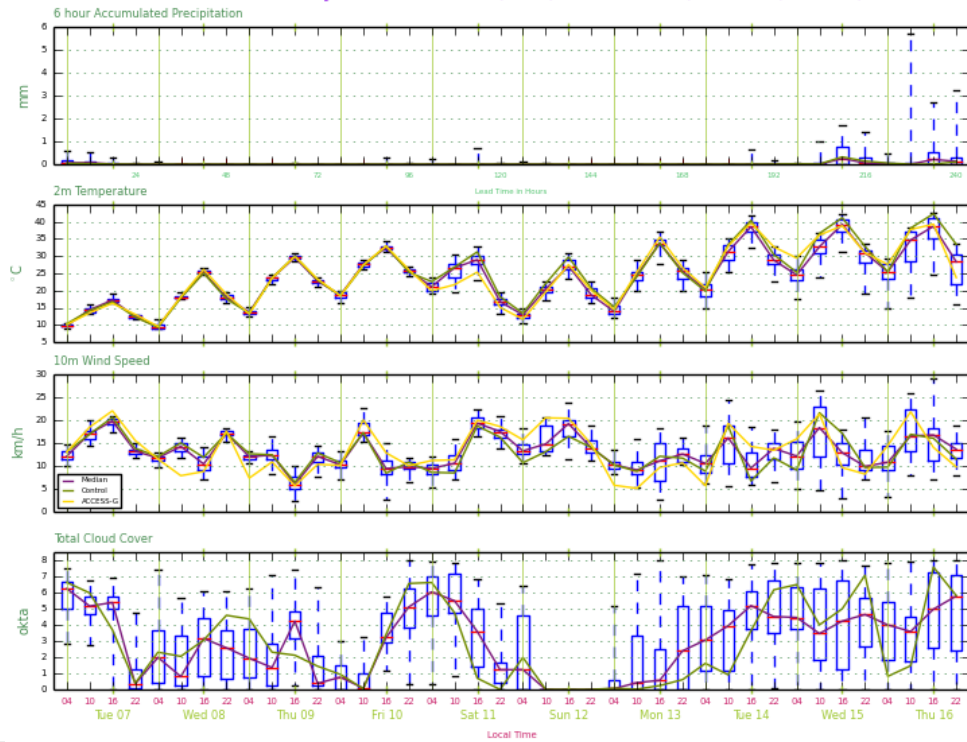


**Figure 7.** Probability of precipitation exceeding 25 mm in the 24 hours commencing 1200 UTC 25 January 2013, from the AGREPS (left) and ECMWF (right) EPS systems, at 5 (top) and 3 (bottom) days prior to the event.





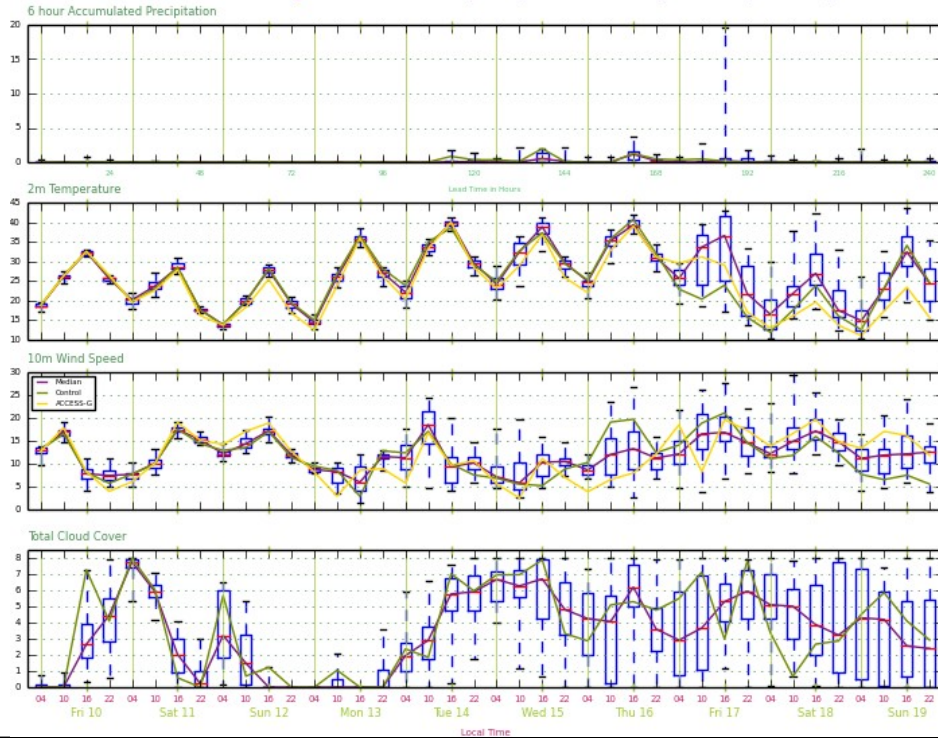
AGREPS-G Start Mon Jan 6 2014 12Z (+10): Melbourne (144.8° E,37.7° S)



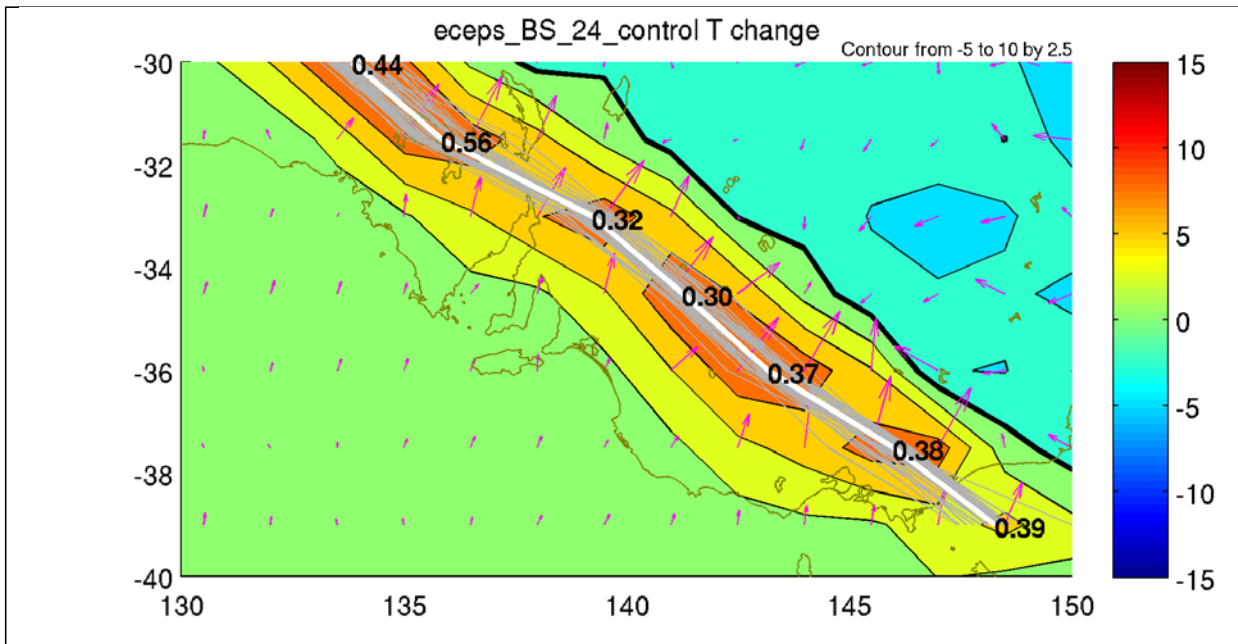
**Figure 8.** Meteograms of precipitation, 2-metre air temperature, wind speed and cloud amount for Melbourne according to the AGREPS ensemble for a 10-day forecast commencing 1200 UTC 6 Jan 2014. Note the heat-wave conditions, with maximum temperatures exceeding 40°C, for the last three days.



AGREPS-G Start Thu Jan 9 2014 12Z (+10): Melbourne (144.8° E,37.7° S)



**Figure 9.** As in Figure 8, except commencing three days later, at 1200 UTC on 9 Jan 2014. Note the continued consistent forecast of the heat wave, and the considerable uncertainty surrounding the eventual cool change on the 17<sup>th</sup>. Note also the strong winds, and consequent extreme fire danger, with the possible hot conditions on the 16<sup>th</sup> and 17<sup>th</sup>.



**Figure 10.** Ensemble prediction of the wind change at 11 pm EDT on Black Saturday, 7 February 2009. The arrows show the magnitude and direction of the surface air temperature gradient, and the colour shading shows its north-west component, in the ensemble mean. The change is diagnosed as the line of strongest north-west temperature gradient, and is shown in the ensemble mean as the white line and in the 51 members as the thin grey lines. The numbers show the standard deviation of the location of the change in degrees longitude.



# **BUILDING COMMUNITY RESILIENCE TO NATURAL HAZARDS IN NORTHERN AUSTRALIA**

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**J. Gould<sup>1,3</sup>, B. Sithole<sup>1,3</sup>, A. Campbell<sup>1,3</sup>, G. James<sup>2,3</sup> and S. Sutton<sup>1,3</sup>**

<sup>1</sup>Charles Darwin University

<sup>2</sup>North Australian Indigenous Land and Sea Management Alliance

<sup>3</sup>Bushfire and Natural Hazards CRC

Corresponding author: [jackie.gould@cdu.edu.au](mailto:jackie.gould@cdu.edu.au)





## ABSTRACT

Sparsely settled regions of northern Australia are extremely vulnerable to a range of annual natural hazard impacts, including those from cyclones, flooding and extensive fires. Outside of large towns, the majority of the population is Indigenous with limited access to infrastructure, or readily available institutional support for dealing with bushfires and natural hazards (BNH). Low population densities and poor communications mean that even relatively large communities have almost no formal emergency management capacity.

Natural hazards are being amplified by climate change, with likely more and bigger fires, on-going sea level rise, potentially fewer but more destructive cyclones, and more days of severe heat stress, with consequent risks to economic productivity, infrastructure and human health and wellbeing. Improving community resilience to bushfire and natural hazards in the north is an evident priority and challenge; approaches that might apply in other regions of Australia are unlikely to work in the unique institutional, infrastructural, demographic, ecological and climatic contexts of the northern third of the continent.

This paper explores potential pathways to improve community preparedness, response and recovery capabilities in remote Indigenous communities, and broader implications for public policy and government agencies in northern Australia, with reference to the research portfolio being developed in the northern hub of the Bushfire and Natural Hazards CRC.

## INTRODUCTION

Over 30% of the north Australian community is Indigenous (Altman et al. 2009). In remote areas, this proportion rises dramatically, with the majority living in communities ill-served by existing emergency services. While these communities have significant Indigenous and local knowledge capacities which afford a degree of resilience in the face of bushfire and natural hazard (BNH) events, poor health, under-investment in infrastructure, restricted communication services and flawed governance models heighten vulnerability to an increasing array of natural hazards extant across the region (Green et al. 2009). There is wide acknowledgement that current government services appear ill-equipped to deal effectively with BNH events in remote areas (COAG 2004, FESA and KLRC 2008, Leonard et al. 2013, Newman and Smith 2004). Further, there is the question of how local needs can be best served within the existing framework of disaster relief, and what expectations Indigenous people have of these. Cost, logistical challenges, and different social, institutional and infrastructural settings mean that urban service models are not suited or perhaps even applicable in remote areas. Consequently, there is a strong push to find service models which are informed by local realities and which respond to the needs and priorities that local Indigenous people identify. The wide variety of situations, needs and circumstances found across the remote north also means that models must be capable of being adjusted and made to suit diverse community settings.

To meet these challenges, the Bushfires and Natural Hazards CRC is supporting a suite of projects under the broad theme, *Building Community Resilience in Northern Australia*. Collectively, these projects provide an opportunity first to map out the current preparedness and capacity of remote communities in northern Australia, and to then assess the steps that need to be taken to develop the infrastructural, institutional and governance capacities of local communities for better dealing with BNH events. An allied aim of the project is to better understand, and engage with, BNH issues in the broader geographical context of northern Australia and its near neighbours, especially Indonesia, Timor Leste and Papua New





Guinea. The full northern Australia resilience research program is due to be rolled out sequentially over the next few years.

The aim of this paper is to briefly introduce the scope, methodology and rationale for two component projects which specifically address gaining a better understanding of how Indigenous community governance institutions interact with wider institutional structures in the context of BNH management and response, and how these interactions could be improved. The first component, *Scoping Remote North Australian Community Resilience*, will engage the Aboriginal Research Practitioners Network (ARPNet) and employ Participatory Action Research (PAR) methodologies to canvass community views, expectations and current response strategies in the context of natural hazards. ARPNet will engage community-based Indigenous research practitioners to explore local views and preferences on current and possible future service models. The second component, *Action Research on Appropriate Governance Models for Building and Maintaining Resilience in Local Communities*, will commence once the *Scoping* subproject is completed at the end of 2015, and aim to design grassroots models of service delivery.

The *Scoping* stage of the project has already commenced, although is in its infant stages. It will involve multiple research institutes, agency stakeholders and northern Australian Indigenous communities. Crucially it will employ Indigenous researchers to engage with community members in the project. The involvement of many stakeholders means that there will be parallel yet interconnected streams of data collection, allowing all stakeholders to participate separately and sometimes collectively in spaces the project creates. This project involves the participation of two key Aboriginal organisations, the North Australian Indigenous Land and Sea Management Alliance (NAILSMA) and ARPNet, in delivering the project, and also is linked to a host of key government agencies including NT Police Fire and Emergency Services, Bushfires NT, and local service agencies such as relevant Shires, land management organisations, medical services and representative bodies. The Research Institute for Environment and Livelihoods (RIEL), at CDU, is the coordinating agency for the project.

The project will initially be implemented in two selected remote Northern Territory communities, although it is anticipated that additional communities in Queensland and Western Australia will be incorporated as the project unfolds. The two initial communities involved are Gunbalanya (located just east of Kakadu National Park in Arnhem Land), and Ngukurr (located west of Katherine, on the Roper River and close to the Gulf of Carpentaria).

The *Building Community Resilience* projects are one of several suites of projects being run through the Northern Hub of the Bushfire and Natural Hazards CRC. This broader suite of projects seek to understand the drivers and constraints to building greater community resilience in the monsoonal north, both in remote communities and in the larger urban centres; and to then work with end users to develop new tools and build new capabilities that improve management of bushfires and natural hazards across northern Australia and the region. In doing so linkages will be built with neighbouring countries who face many of the same hazards (as well as tsunamis, volcanoes and earthquakes) with even fewer resources than are available in a remote north Australian context.



## THE SCOPING RESILIENCE PROJECT

Resilience is broadly seen as a capacity to respond to and ‘bounce back’ from a major natural hazard. But what does this mean in the context of remote Indigenous communities in Australia’s remote north? Remote communities are generally seen as ‘vulnerable’ because of poverty, poor health, low education levels, and the lack of services and infrastructure associated with their isolation from major urban centres (on the complexity of examining ‘vulnerability’ in remote Australian Indigenous communities see Ellemor 2005, Howitt et al. 2012, Leonard et al. 2013, Petheram et al. 2010, Veland et al. 2013). Remoteness, and cultural and linguistic diversity, compound the issue of poor communication between communities and the structures of political representation, resource allocation, and service provision which are centred in the city. These vulnerabilities exacerbate the impacts of natural hazards present across the region such as cyclones, bushfires, and floods. However, it is also important to consider in this context the existing strengths of communities, such as local decision making and authority structures, communication networks and customary/local knowledge which afford a degree of resilience in the face of natural hazards (McLachlan 2003, Veland et al 2010). These ‘resilience factors’ may themselves be vulnerable to external forces such as inconsistent government policy, funding priorities, and the imposition of inappropriate governance structures or ‘over-governance’ of communities.

Current Australian policy positions resilience as “the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals”. It describes “a disaster resilient community” as “one that works together to understand and manage the risks that it confronts” (COAG 2009:iii). In a remote Indigenous setting, the risks which need to be managed are different to those affecting other locales, as are the capacities of local communities. ‘Working together’ in such settings requires different kinds of partnerships and response structures. This unique context underpins the rationale for the *Scoping Resilience* project.

The *Scoping Resilience* project addresses the complexities inherent in identifying and building on the existing scaffold of knowledge and understanding of bushfire and natural hazards in a remote Indigenous Australian context. Its aim is to develop a fine-grained understanding of how local knowledge and other capacity relate to existing risk management and post-event responses, and what changes would be most effective and valued. This project will employ a participatory, applied and action-oriented approach to engage residents of two remote Northern Territory communities along with relevant agency stakeholders.

The key aims of the Scoping phase of the project are to:

- Describe the types of natural hazards and impacts of greatest present concern to Indigenous communities in remote northern Australia;
- Summarise the aspirations of participating communities for social and economic development and meeting cultural obligations, and identify those aspirations that appear most vulnerable to natural hazards;
- Describe present approaches to dealing with natural hazards and outline Indigenous views of their appropriateness and effectiveness, including eliciting suggestions for improvements;
- Describe human capability, including skill sets and experience, formal institutions and social networks, presently available within participating communities.



As noted above, the project is a collaboration between RIEL, ARPNet and NAILSMA. Each of the collaborating research partners will undertake a subset of the research. NAILSMA will conduct an asset mapping exercise, a survey of relevant literature, and an action research component of the project focused on service delivery models. ARPNet will be undertaking research within the two case study communities. RIEL will liaise with key emergency services agencies at the Federal, Territory and community levels.

## **CONCEPTUAL ISSUES AND METHODOLOGICAL CHALLENGES**

Bringing together these three research partners with complementary competencies, the project benefits from ARPNet's experience and tools for working in remote communities, while NAILSMA is able to bring its wealth of experience in delivering culturally appropriate and effective programs based on Indigenous knowledge and contemporary science in the management of land and seas. By drawing in researchers from The Northern Institute and the School of Psychological and Clinical Sciences at Charles Darwin University, RIEL will bring experience in emergency services management, project management, and in working with stakeholders to collect, synthesise and coordinate the different components of the project. The strength of the project lies in recognition of the direct need from the government for data with a strong explanatory value, while acknowledging that communities have a heightened sense of awareness of vulnerabilities and resilience factors, given their history and experience of hazards.

Community resilience among Indigenous communities in remote areas is an interesting but complex concept (Veland et al. 2013). Initial discussions at a focus group meeting to plan for the project elicited responses from remote community residents which showed both the complexity of the concept and the context that defines it. For example, one participant in the focus group said...*'them mob government worrying for natural hazards when being in a community is hazardous itself'*, suggesting the complexities inherent to the notion of community resilience in the context of the 'disaster of colonisation' (Howitt et al. 2012), and the implications for how Indigenous people view natural hazards vis a vis the hazards they face in daily life. This is indicative of the need to read community responses carefully and from within the context of local realities which include many intricacies beyond the basic architecture of emergency service delivery.

An appreciation of the complex nature of Aboriginal circumstance, lifestyle and history is crucial for the project. Current service models pit mainstream ways of reading the environment and notions of community against those employed by Indigenous people. This is perhaps unintended, but a real consequence of a broader historic failure to recognise and explore Indigenous knowledge and experience. This project requires that service providers acknowledge local knowledge systems and forms of social action, and prepare responses which incorporate these (FESA and KLRC 2008, Leonard et al. 2013, McLachlan 2003, Petheram et al. 2010, Veland et al. 2013). Inherent to this challenge is to comprehend and mediate parallel, and at times conflicting, readings of hazards. For example, the notion that hazards may be punishments from ancestors of people because they failed to look after country or are not living on country is strong (Leonard et al. 2013, Veland et al. 2013). The belief that hazards can be minimised, stopped or averted with good natural resource management presents an interesting dimension to this work, and may represent an emerging space for developing mitigation and preparation/response strategies which bring both Indigenous and Western knowledge systems together.



The project underscores the need for building local models suited to the remote indigenous situations and circumstance, and there is an explicit suggestion that government will support or use the results. But Aboriginal people have been promised many things and they have received - in equal measure - expectations of government action which did not materialise. Lack of or inadequate delivery is an everyday occurrence for communities. This project is thus being implemented in a context where promises mean very little. It is not clear how the project will address the scepticism which may prevail in the communities regarding government genuineness to support a grassroots model of service delivery. To a certain degree one sees a level of resilience within communities as they develop strategies to survive the impacts of poor policy, inadequate service provision, short funding cycles, constantly shifting policy regimes and a lack of meaningful engagement from government (cf. Ellemor 2005). A key component of this research is to identify these strategies. A key assumption is that these are the best place to start in building greater resilience. On the one hand, 'top-down' approaches to policy development and service provision will at best suffer from a lack of engagement and at worst undermine existing community capacity. On the other, current policy approaches to hazard preparedness and response focus on the responsibilities of communities - so it is at this level that needs, priorities and modes of action must be clearly understood if existing strengths are to be built upon.

The literature on resilience contains some material on remote Australia. By and large, this literature raises the need to foster greater community engagement, capacity development and empowerment, on better communication strategies, and the need for better education regarding how emergency services are delivered (Attorney General's Department 2007, COAG n.d., FESA and KLRC 2008, Hocke and O'Brien 2003, Leonard et al. 2013). This work however contains few detailed case studies about how such goals can be realised (some of the notable exceptions have been referred to throughout this paper). The involvement of ARPNet will allow fresh insights into notions of community resilience in the remote north. ARPNet will also explore local notions of risk. While service providers traditionally focus on hard assets (such as houses, power supplies, and roads) and notions of personal safety (minimising injuries, deaths and other health impacts) there are likely to be different understandings of these risks, and additional assets which are valued, at the community level (Bird et al. 2013, Veland et al. 2013). These may for example include cultural assets; relationships; particular aspects of country; and livelihood activities vulnerable to BNH events. As noted earlier, these 'community assets' may be regarded not only as vulnerable to natural hazards but also key factors in ensuring the ongoing resilience of communities.

## **POLICY IMPLICATIONS AND LIKELY OUTCOMES**

Key documents such as 'Keeping Our Mob Safe' by the Remote Indigenous Communities Advisory Committee of the AEMC, highlight issues such as the need for better engagement and communication with Indigenous communities (Attorney General's Department 2007). The questions posed by the Scoping Project are not new. However they do represent a chance to apply these concepts in concrete terms within specific community contexts. While much varies from one community to the next, general insights are likely to be made regarding the:

- Key institutional relationships which allow for coordinated responses during a natural hazard, and the day-to-day interactions which determine the strength of these relationships;
- Key areas of divergence in notions of 'hazard' and 'risk' between service providers and remote Indigenous communities, and consequent implications for communication tools, messages and strategies;



- Key opportunities to enhance institutions, resources and human capacity to enhance natural hazard readiness;
- Key aspects of how broader aspects of community resilience interact with natural hazard preparations and responses.

The involvement of a multi-stakeholder group encompassing both community end users and agency service providers provides an opportunity to identify gaps in communication, capacity and understandings of what does (or should) happen during an emergency event. Communities will get to review and put together their plans for response, and the service providers will gain direct insights about the situation and views of the local community. The creation and testing of response models by NAILSMA will create another direct platform for engagement, where results will be applied and hopefully the process validated and legitimised.

While still in their early stages, this and the wider set of Northern Hub projects hope to deliver findings of wider policy import, while making a substantial contribution to building bushfire and natural hazards research and management capacity in northern Australia and the region. Our scope deliberately extends beyond local bushfire and natural hazard events, to encompass the role of Darwin in particular as the base for Australia's response to events in our region, and as a south-east Asian knowledge hub for disaster resilience and emergency management. Charles Darwin University has a newly-developed Masters in Humanitarian and Disaster Management (delivered online and face-to-face) that is building strong links with government agencies, non-government organisations and practitioners working across the region, and is likely to be complemented by short-course intensives over the next couple of years. Research through the Northern Hub and other Bushfire and Natural Hazards CRC projects will feed into this training, providing an excellent outreach vehicle for the CRC into the region.

## **CONCLUSION**

This project has elements which make it a unique and exciting flagship project. It has been developed with the involvement of two key Aboriginal organisations and is connected to a host of stakeholders including service providers and other expertise relevant to the provision of emergency services in a remote northern Australian context. The Indigenous ownership of and participation in the project is crucial for ensuring meaningful engagement and ownership of the PAR process and outcomes of the project. On another level, this project provides an integrated platform for practitioners, experts and policy makers to interact. Maintaining the integrity of the local processes during PAR and the local voice will be the main objective of the research.





## REFERENCES

- Altman JC, Jordan K, Kerins S, Buchanan G, Biddle N, Ens E, May K (2009) Indigenous interests in land and water. In 'Northern Australia Land and Water Science Review 2009 Full Report'. (Ed Stone P) pp. 7.1–7.56. (Department of Infrastructure, Transport, Regional Development and Local Government: Canberra)
- Attorney General's Department (2007) Keeping Our Mob Safe: A National Emergency Management Strategy for Remote Indigenous Communities. Commonwealth of Australia. (Canberra)
- Bird D, Govan J, Murphy H, Harwood S, Haynes K, Carson D, Russell S, King D, Wensing E, Tsaldssiris N, Larldn S. (2013) Future Change in Ancient Worlds: Indigenous adaptation in northern Australia. National Climate Change Adaptation Research Facility. (Gold Coast)
- COAG (2004) Natural Disasters in Australia: Reforming mitigation, relief and recovery arrangements. Commonwealth Department of Transport and Regional Services. (Canberra)
- COAG (2009) National Strategy for Disaster Resilience: Building the resilience of our nation to disasters. Council of Australian Governments. (Canberra)
- COAG (n.d.) COAG Review of Natural Disaster Relief and Mitigation Arrangements - Improving emergency management outcomes for remote Indigenous communities in northern Australia. Council of Australian Governments.
- Ellemor H. (2005) Reconsidering emergency management and indigenous communities in Australia. *Environmental Hazards* **6**, 1-7.
- FESA and KLRC (2008) Indigenous Translation of Western Australian Emergency Management Guidelines and the Emergency Management Arrangements. Fire and Emergency Services Authority of Western Australia and Kimberly Language Resource Centre.
- Green D, Jackson S, Morrison J (2009) Risks from Climate Change to Indigenous Communities in the Tropical North of Australia. Department of Climate Change and Energy Efficiency. (Canberra)
- Hocke I, O'Brien A (2003) Strengthening the capacity of remote Indigenous communities through emergency management. *The Australian Journal of Emergency Management* **18**(2), 62-70.
- Howitt R, Havnen O, Veland S (2012) Natural and Unnatural Disasters: Responding with Respect for Indigenous Rights and Knowledges. *Geographical Research* **50**(1), 47-59.
- Leonard S, Mackenzie J, Kofod F, Parsons M, Langton M, Russ P, Ormond-Parker L, Smith K, Smith M (2013) Indigenous Climate Change Adaptation in the Kimberley Region of North-western Australia - Learning from the past, adapting in the future: Identifying pathways to successful adaptation in Indigenous communities. National Climate Change Adaptation Research Facility. (Gold Coast)



McLachlan E (2003) Seagulls on the airstrip: indigenous perspectives on cyclone vulnerability awareness and mitigation strategies for remote communities in the Gulf of Carpentaria. *Australian Journal of Emergency Management* **18**, 4–12.

Newman M, Smith SA (2004) Integration of Emergency Risk Management into West Australian Indigenous communities. *The Australian Journal of Emergency Management* **19**(1), 10-15.

Petheram, L, Zander KK, Campbell BM, High C, Stacey N (2010) 'Strange changes': Indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia). *Global Environmental Change* **20**(4), 681-692.

Veland S, Howitt R, Dominey-Howes D, Thomalla F, Houston D (2013) Procedural Vulnerability: Understanding environmental change in a remote indigenous community. *Global Environmental Change* **23**(1), 314-326.

Veland S, Howitt R, Dominey-Howes D (2010) Invisible institutions in emergencies: Evacuating the remote Indigenous community of Waruwu, Northern Territory Australia, from Cyclone Monica. *Environmentals Hazards* **9**, 197-214.



# ESTIMATING THE IMPACTS OF NATURAL HAZARDS ON FATALITIES AND BUILDING LOSSES

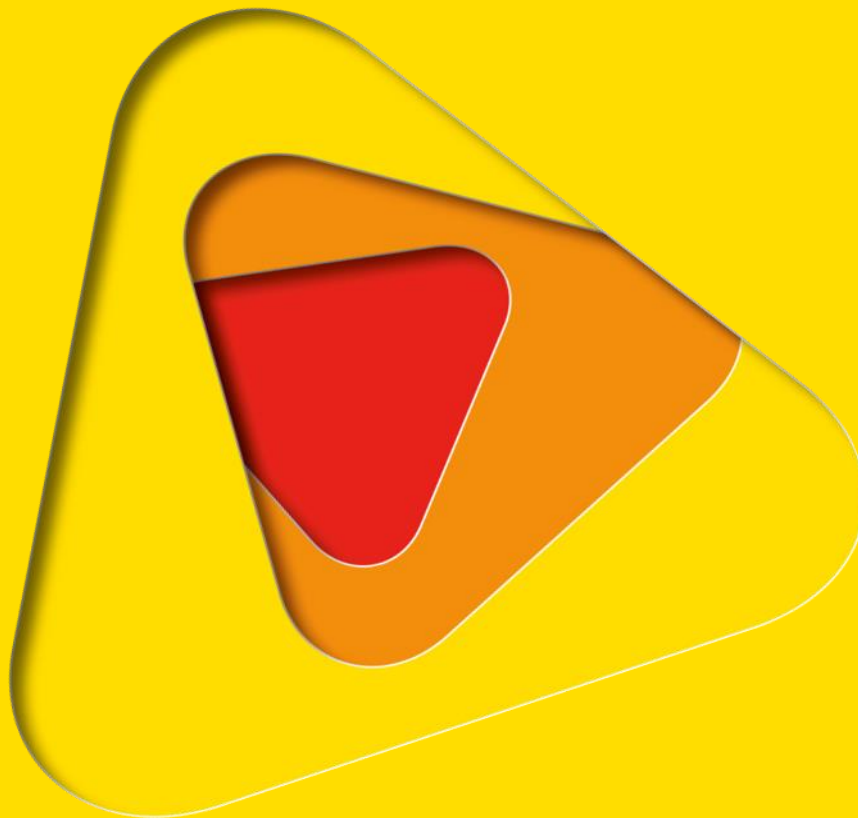
Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**R. van den Honert<sup>1,2</sup>, L. Coates<sup>1,2</sup>, Katharine Haynes<sup>1,2</sup> and R. Crompton<sup>1,2</sup>**

<sup>1</sup>Risk Frontiers, Macquarie University

<sup>2</sup>Bushfire and Natural Hazards CRC

Corresponding author: [rob.vandenhonert@mq.edu.au](mailto:rob.vandenhonert@mq.edu.au)





## ABSTRACT

This paper is a first pass at quantifying the impacts of natural hazards on fatalities and building losses in Australia over the past century. The emphasis is on developing a methodology which allows the effects of societal changes (population and wealth) across time to be taken into consideration. This process, termed normalisation, effectively estimates the building losses or fatalities from an event as if the event were to impact present-day society, thus allowing a comparison of the most damaging natural hazard events, even if they occurred many years apart. *PerilAUS*, a database of natural hazard events in Australia and virtually complete since 1900, is described. Future research into losses from natural hazards in Australia is documented.

## INTRODUCTION

The Bushfire and Natural Hazards Cooperative Research Centre ([www.bnhcrc.com.au](http://www.bnhcrc.com.au)) has been set up to explore the causes, consequences and mitigation of natural disasters. The *Scenarios and Loss Analysis* cluster project entitled “*An analysis of building losses and human fatalities from natural disasters*”<sup>1</sup> aims to measure and understand the impacts of natural hazards in terms of the toll on human life and the built environment. This examination is a fundamental first step to providing an evidence base for future emergency management policy, practice and resource allocation and to enable efficient and strategic risk reduction strategies. The analysis underpinning the project will be based on an examination of the historical record of losses caused by natural hazards in Australia since 1900.

The project has two distinct focuses:

- An analysis of building damage, by hazard, across time and by state/territory due to natural hazards, and
- A longitudinal analysis of the social and environmental circumstances in respect of fatalities, injuries and near-misses. This will include an examination of trends over time in terms of exposure and vulnerability. It is envisaged that these trends will be interpreted in the context of emerging issues (e.g. an ageing population, spatial population shifts, climate change etc) and how these issues might influence vulnerability and exposure trends in the future.

Key to this project will be the collection of set of data relating to losses (human and building) from natural disasters, in particular flood, cyclone, bushfire, severe storm, heatwave and earthquake. Some data exists (see the description of *PerilAUS*, below): the objective is to make this data set as complete as possible, given the resources made available through the BNHCRC project.

This paper will concentrate on the first of these focuses, and will describe and justify the approach to be taken. It will touch on human fatalities from natural hazards, and describe next steps in the project to expand and explore this data. Some very preliminary results are provided.

## BUILDING LOSSES FROM NATURAL DISASTERS

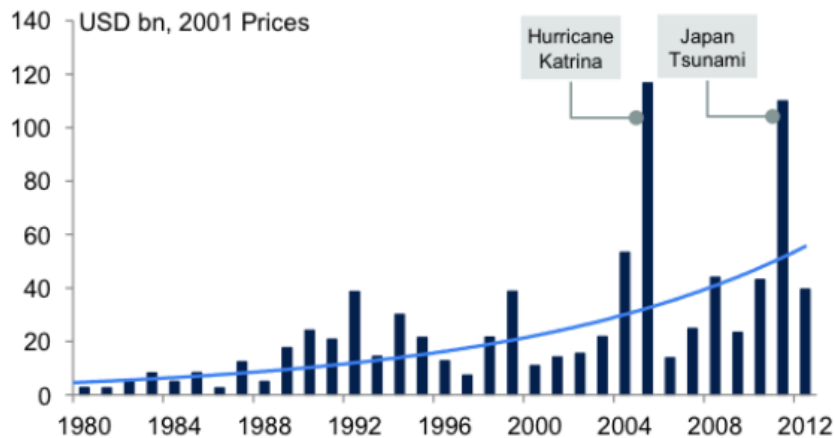
Insured losses caused by natural disaster events have increased rapidly in recent years. Figure 1 shows global insured disaster loss data from Swiss Re, Munich Re and Deutsche Bank Research.

---

<sup>1</sup> <http://www.bnhcrc.com.au/research/economics-policy-and-decision-making/235>



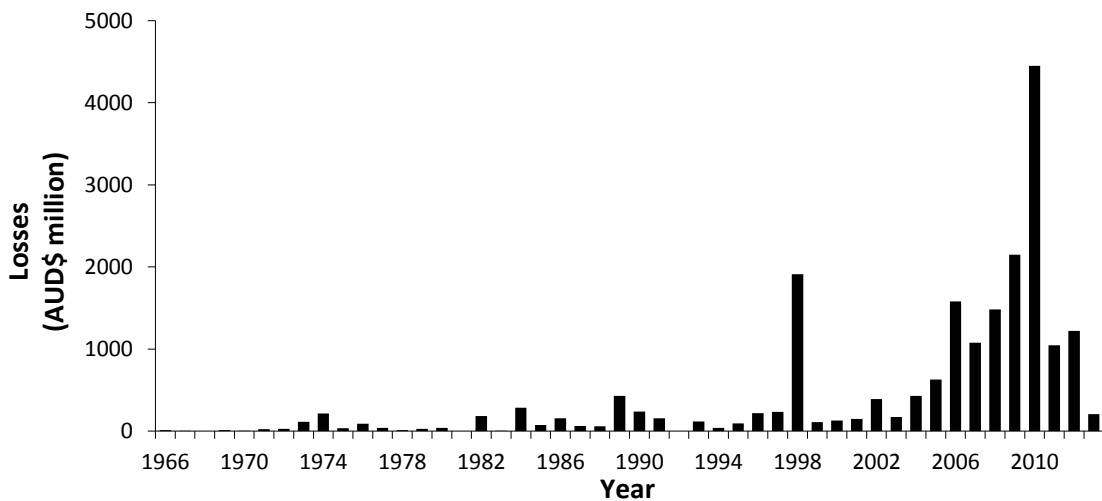
Figure 1. Global natural disaster losses, 1980-2012 (Source: Business Insider Australia, 2012)



Whilst the insured real losses are rising, the losses are seen to fluctuate wildly from year to year.

Although geographically far from other countries, Australia is not immune to these rising costs. Figure 2 displays data from the Insurance Council of Australia's historical Disaster Statistics list (ICA, 2014), composed of insurance industry losses from weather-related natural hazards (e.g. hail, floods, cyclones, etc) in Australia since 1967. This data closely mirrors the trend in Figure 1.

Figure 2. Australian weather-related natural disaster insurance industry losses, 1967-2013 (Data source: ICA, 2014)



A linear regression function of the form losses (in \$) = a + b (year) shows a statistically very significant increasing trend in this data ( $p < 0.0001$ ), implying increasing insured losses across time. The losses are increasing at an annual average rate of \$32 million per year.

What might be causing this increase in losses? Over recent years there have been societal changes: for example significant population growth and movements of some of this population to areas susceptible to natural hazards (such as river floodplains and coastal or bushland fringes). Furthermore, with this increase in population has come an increase in wealth in hazard-prone areas – homes are costing more in dollar terms and are getting bigger. To illustrate, the two photographs



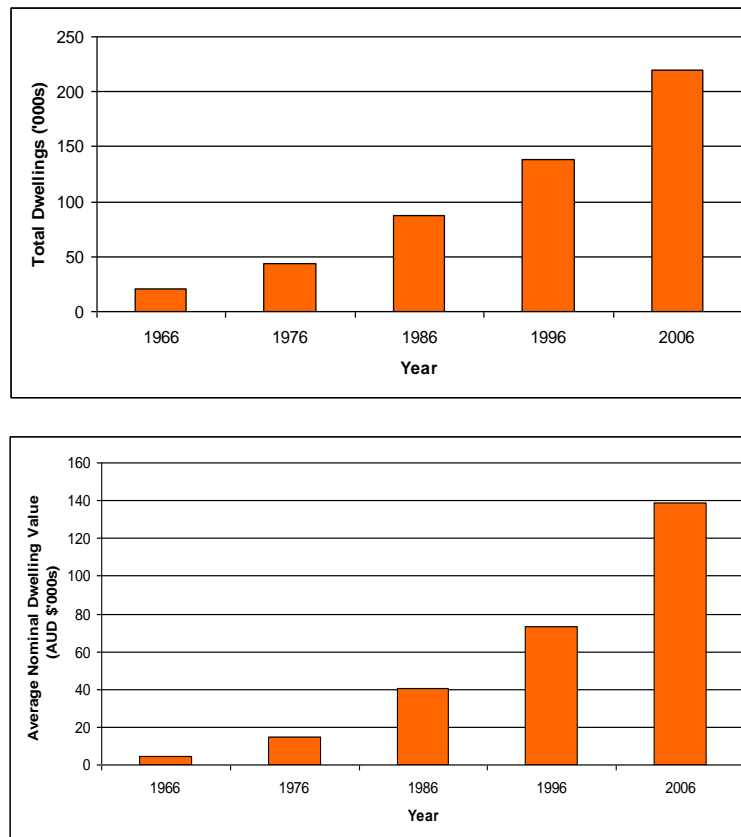
in Figure 3 depict the Gold Coast/Surfers Paradise beachfront area, around 1970 and again in about 2003.

Figure 3. Gold Coast, around 1970 (left) and around 2003 (right). (Source: Local Studies Library, Gold Coast City Council)



Immediately noticeable is the proliferation of high-rise buildings in more recent times – more people and more wealth have become established here. Figure 4 quantifies these increases: an increase in population (proxied by the increase in the total number of dwellings) and an increase in wealth (proxied by the average dwelling value).

Figure 4. Gold Coast/Tweed Heads, 1966-2006. Total number of dwellings (above) and average dwelling value (below). (Source: ABS, 2014)



This is just one example of what has been happening in many places across Australia.

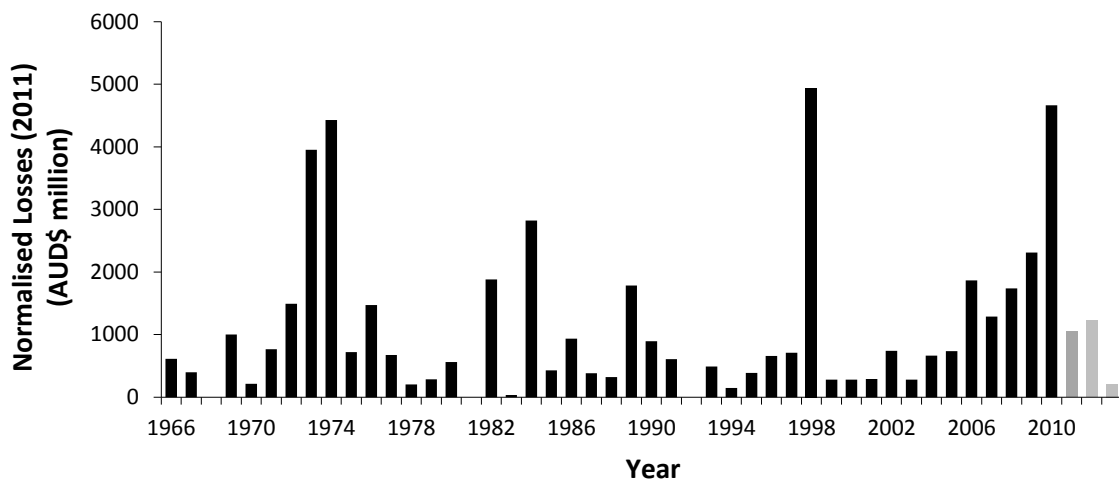




These societal changes offer a clue to the increase in insured losses from natural hazards, as observed in Figures 1 and 2. Normalisation refers to the process of adjusting historical losses for known societal changes (e.g. numbers of homes, the value of these homes and improvements in building codes and construction). Normalised losses effectively estimate the losses as if past events were to impact present-day society (i.e. an ‘apples-versus-apples’ comparison of event losses over time).

After normalisation the loss data shows a different picture (Figure 5). Whilst there is substantial variability across time there is now *no* statistically significant upward trend ( $p > 0.50$ ). This result implies that no signal has yet been detected to indicate that insured losses from causes other than societal changes (such as population changes and wealth growth) are increasing.

Figure 5. Australian weather-related natural disaster losses, 1996-2013, normalised to 2011 dollars. (Data from 2011-2013 have not been normalised.) (Data source: ICA, 2014)



## MAJOR AUSTRALIAN DISASTER LOSSES

Normalisation allows a comparison of the most damaging natural hazard events, even if they occurred many years apart (Table 1).

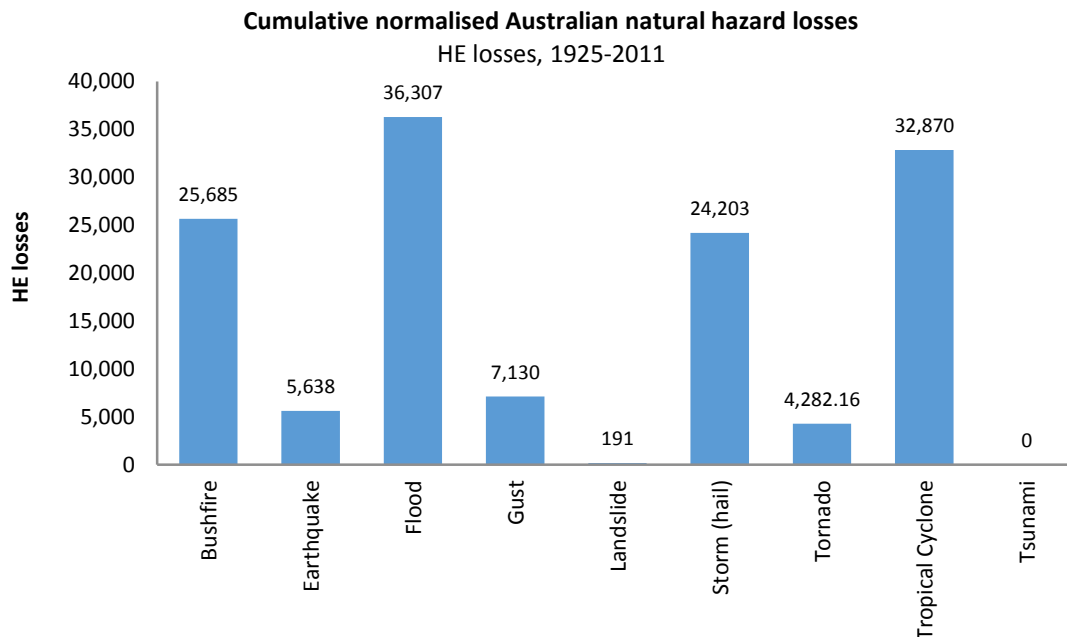
Table 1. The largest Australian natural disasters (in terms of normalised insurance losses) of each peril type, 1967-2013, normalised to 2011 dollars (Source: Crompton, 2011; Data source: ICA, 2014)

Event	Ranking	Year	Normalised cost
Sydney Hailstorm	1	1999	4.3 Billion AU\$
Tropical Cyclone Tracy	2	1974	4.1 Billion AU\$
Newcastle Earthquake	3	1989	3.2 Billion AU\$
QLD Floods	5	2011	2.5 Billion AU\$
Ash Wednesday Bushfires	7	1983	1.8 Billion AU\$



Table 1 shows that, after removal of the impact of population and wealth, no single peril dominates or is responsible for most insured building losses - damaging hailstorms, tropical cyclones, floods, earthquakes and bushfires all feature in the top seven most damaging events in Australia. This means that mitigation against natural hazards cannot be limited to one peril alone. Indeed, Figure 6 shows the cumulative normalised losses from 1925 to 2011 from the natural hazards that have caused most damage, with flooding, tropical cyclone, bushfire and storms (mostly hail) all prominent.

Figure 6. Australian natural losses, 1925-2011, measured in House Equivalent<sup>2</sup> (HE) (Data source: PerilAUS database, Risk Frontiers)



Major earthquakes are arguably the most damaging of all natural hazards. Over the decade 1992-2001 major earthquakes were cumulatively the costliest of all natural disasters (Alexander, 2004). The 1989 Newcastle earthquake remains the third most damaging disaster in Australia in terms of normalised insured losses. Earthquakes are rare in Australia and so, on a cumulative basis, losses from earthquakes have been relatively small.

## FATALITIES FROM NATURAL HAZARDS

A glimpse at human fatalities caused by natural hazards is revealing.

In a similar vein to building loss data, an analysis of the number of human fatalities per year should be normalised to take into account population growth. Figure 7 displays fatalities from bushfires, earthquakes, floods, wind gust, hail, landslides, lightning, rain, tornadoes and tropical cyclones in Australia from 1900 to 2010. A linear regression on the raw data (Figure 7a) shows no significant trend, i.e. the fatality rate has been constant across time, whilst a regression on the normalised data (Figure 7b) shows a highly significant *decreasing* trend, amounting to around 0.7 deaths per year over the last 110 years ( $p < 0.001$ ). This is in line with research on global natural disasters (Alexander, 2004), which indicates that human fatalities are constant or decreasing.

<sup>2</sup> House Equivalents, a measure of building damage, is best described in the section “PerilAUS – a database of natural hazards in Australia”.



Figure 7a. Australian natural disaster fatalities, 1900-2010 – raw data (Data source: PerilAus database, Risk Frontiers)

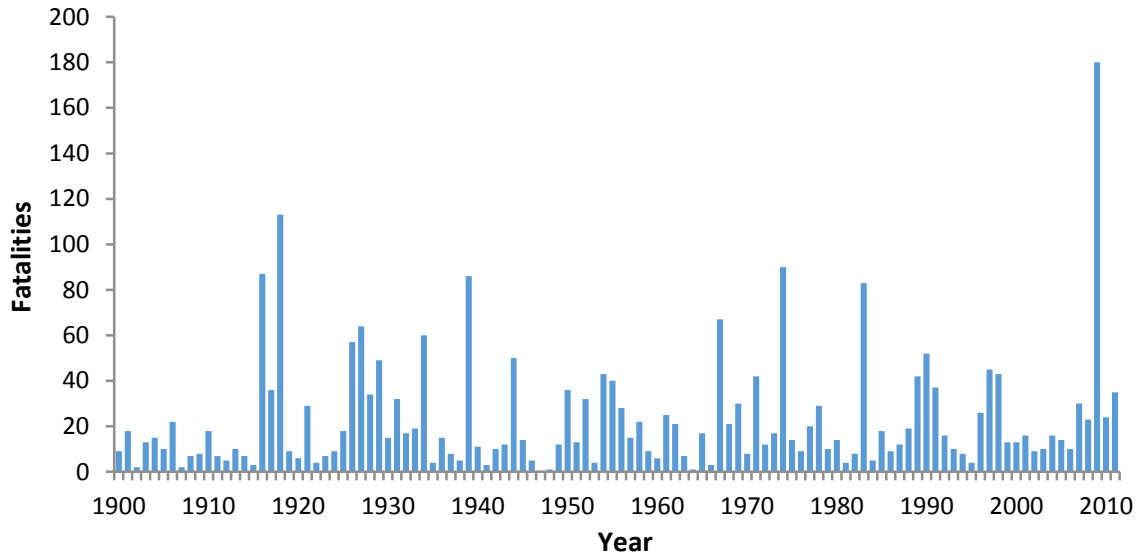
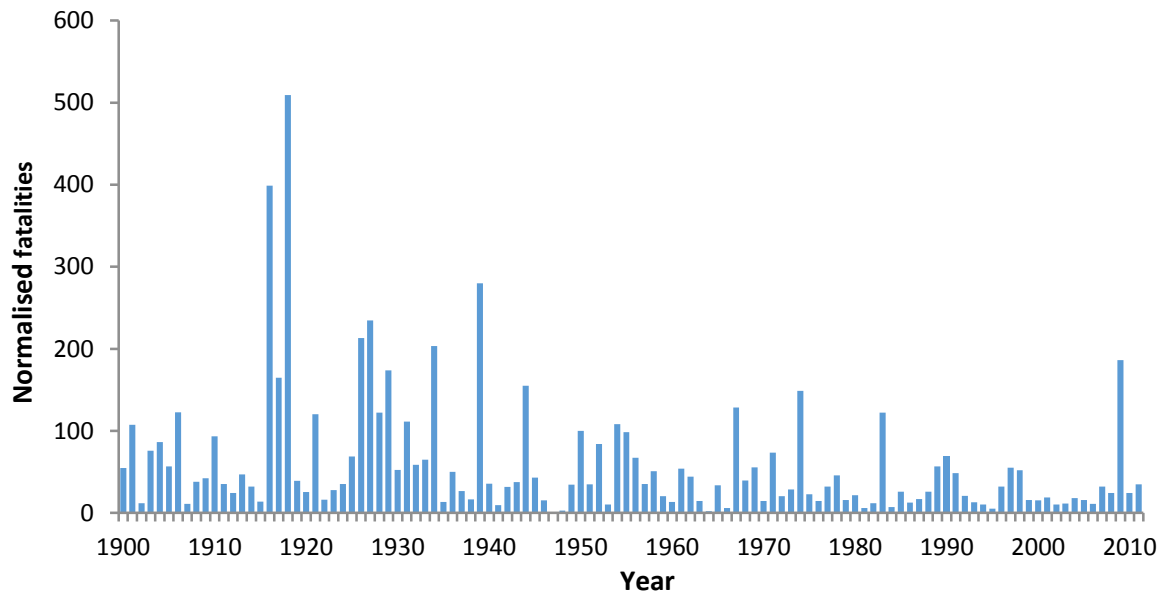


Figure 7b. Australian natural disaster fatalities, 1900-2010 – data normalised to 2010 numbers (Data source: PerilAus database, Risk Frontiers)



Natural hazard fatalities from 1900 to 2011 as recorded in *PerilAus* are displayed Table 2. Coates *et al.* (2014) found that the effects of extreme heat have killed more people in Australia since 1900 than as a result of all other natural hazards combined. Alexander (2004), reporting on a global scale, also concluded that heatwaves (and droughts) were the most lethal of all natural hazards.



Table 2. Natural hazard fatalities in Australia, 1900-2011 (Data source: Coates et al., 2014)

Natural hazard	Deaths 1900-2011	% total natural hazard deaths 1900-2011
Extreme heat	4,555	55.2
Flood	1,221	14.8
Tropical cyclone	1,285	15.6
Bush/grassfire	866	10.5
Lightning	85	1
Landslide	88	1.1
Wind storm	68	0.8
Tornado	42	0.5
Hail storm	16	0.2
Earthquake	16	0.2
Rain storm	14	0.2

## PERIL AUS – A DATABASE OF NATURAL HAZARDS IN AUSTRALIA

The “An analysis of building losses and human fatalities from natural disasters” project will be utilizing a unique database of natural hazard impacts.

Over the last 20 years Risk Frontiers (Macquarie University, NSW) has been compiling a comprehensive database of natural hazard events in Australia from European settlement that have caused fatalities and/or damage to buildings, agriculture, infrastructure and lifelines. Where available, data has also been collected on the economic, social and environmental impacts of the event and on the number of people injured, evacuated and/or rendered homeless. The focus has been on natural hazard incidence, consequences and insurance losses, including event analyses, damage indices, insurable tangible damage and risk assessments.

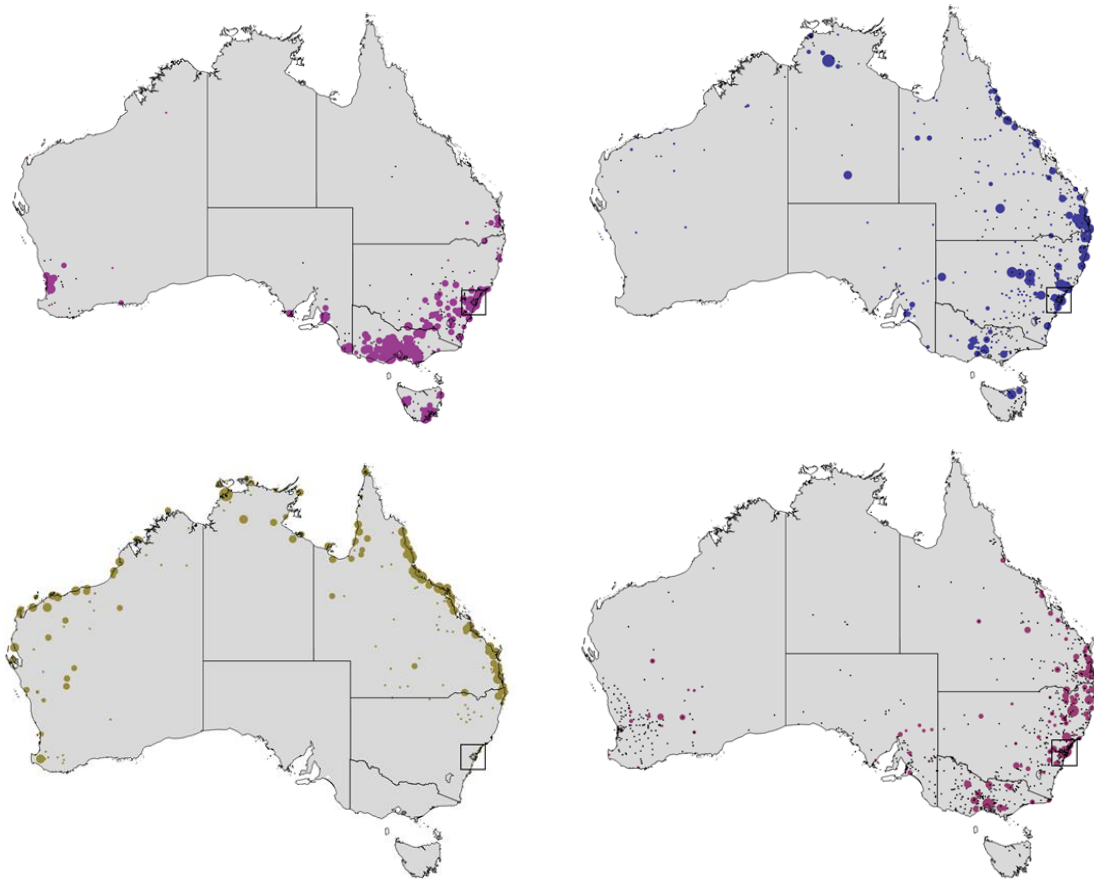
Hazards covered in *PerilAUS* include bushfires, earthquakes, floods, wind storms, hail storms, heatwaves, landslides, lightning strikes, rain events, tornadoes, tropical cyclones and tsunamis. The record is complete for all major events from 1900 to December 2013. *PerilAUS* is distinguished from other such databases by the wealth of descriptive detail concerning the hazard impact and the inclusion of data about any built environment damage and/ or fatalities caused by that hazard. The damage information, especially the unique “housing equivalent” calculator, has been utilized in comparisons of particular hazard types, locations or years of record by a variety of insurance and specialist hazard-related organizations.

Data in *PerilAUS* has been collected from major and local newspapers and government and other official reports (including publications by the Australian Bureau of Statistics, the Bureau of Meteorology, the Registry of Births, Deaths and Marriages, Coroners’ reports and Geoscience Australia).

*PerilAUS* has over 16,000 event reports dating from the European settlement of Australia to the current time. From 1900 there are almost 14,500 event reports. These event reports are supported by over 18,000 references. Figure 8 displays the geographic location of specific bushfire, flooding, tropical cyclone and hail events contained in *PerilAUS*.



Figure 8. Australian natural disasters recorded in Peril AUS, 1926-2013. Bushfires (top left), floods (top right), tropical cyclones (bottom left), and hail (bottom right) (Data source: PerilAUS database, Risk Frontiers)



An important attribute of PerilAUS is its use of House Equivalents (HE) as a means of comparing and/or summing damage caused to buildings by natural hazard events of various types, in various locations and from at times. HE is based on buildings damaged or destroyed, and the unique damage index created from it, are described in detail by Blong (2003). In summary, an average house is assigned a Replacement Ratio (RR) of 1.00. Other building types are assigned ratios of greater (generally) or lesser value depending upon the area, amongst other factors. Replacement Ratios are estimates indicating how the costs of replacing the building in question compare with the cost of replacing a median-sized house. In effect, RR is the multiple required to express the cost of a building as a number of houses. A Central Damage Value (CDV) ranging from 0 to 1.0 (complete destruction) is then assigned and the damage to buildings of a specific type with the same amount of damage is then:

$$\text{Damage [HE]} = \text{RR} \times \text{CDV} \times \text{Number of Buildings}$$

This result is summed for differing building types and damage values to arrive at a total HE for a particular location, which can then be summed for all affected locations to determine the HE of a natural hazard event.



It should be noted that, as Risk Frontiers' House Equivalents considers only building damage with other important forms of damage excluded, a close parallel between HE values and records of insured losses is not expected. For example, in the April 1999 hailstorm in Sydney about 38% of the insured damage bill was for motor vehicles and aviation hulls. Neither of these losses are considered in the calculation of HE.

## **WHAT MORE CAN BE LEARNED ABOUT LOSSES CAUSED BY NATURAL HAZARDS? – FUTURE WORK**

From the building loss perspective, the starting point will be updating and improving existing data contained in *PerilAUS*. Thereafter, temporal and spatial analyses of the data will be undertaken for each hazard, thus providing a natural priority ranking of hazard risks for each state. An analysis of changes to frequency of occurrence of hazards will be undertaken.

From the human fatalities and injuries perspective, updating *PerilAUS* with mortality data (from various coronial archives, the National Coroners' Information System, the Australian Bureau of Statistics and the Bureau of Meteorology) and morbidity data (from health departments (hospital attendance and admission records) and the Australian Institute of Health and Welfare) will be the initial outcome of the project. Further injury, "near miss" and rescue data will be collected from relevant emergency management agencies, where available.

A thorough statistical analysis will then be undertaken on the fatality/injury/rescue data in order to examine the relationship between demographics, social circumstances (warnings received, preparation, reasons behind actions, activities at the time of death etc) and the environmental circumstances at the time of the onset of the disaster (location, weather, hazard details etc). Past vulnerability and exposure trends will be interpreted in the context of emerging issues (e.g. ageing population, population shifts, climate change etc) in order to determine potential future vulnerability and exposure trends.

It is envisaged that a case-control study (details to be decided in collaboration with project end-users) will be conducted involving a survey of people who successfully reduced their risks and received little impact from a hazard event and those who did not reduce their risk and consequently received fatalities or injuries, or required rescues. This will offer insights into resilience in practice.

It is hoped that interviews with key senior emergency management practitioners and government policy makers will be undertaken to identify the policy and procedural changes that have been implemented over the years to reduce risks to people and property. A comparison of this with key trends within the fatality, injury and property loss data will enable an analysis of the impact that various changes to policy and procedures have had.





## REFERENCES

ABS (2014) Census Statistics. Available online at

<http://abs.gov.au/websitedbs/censushome.nsf/home/quickstats?> Accessed 21 August 2014.

Alexander, D E (2004) *Natural Hazards on an Unquiet Earth*. In: Matthews, J A and Herbert, D T (Eds) *Unifying Geography: Common Heritage, Shared Future*. Routledge, London.

Business Insider Australia (2012) *The Exploding Cost Of Natural Disasters*. Available online at <http://www.businessinsider.com.au/chart-natural-disaster-costs-2012-12>. Accessed 21 August 2014.

Blong, R J (2003) A new damage index. *Natural Hazards*, 30, 1-23.

Coates, L, Haynes, K, O'Brien, J, McAneney, K J and Dimer de Oliveira, F (2014) A longitudinal examination of extreme heat events in Australia 1844-2010: exploring 167 years of social vulnerability. *Environmental Science and Policy*, 42, 33-44.

Crompton, RP (2011) *Normalising the Insurance Council of Australia Natural Disaster Event List: 1967-2011*. Report prepared for the Insurance Council of Australia, Risk Frontiers. Available online at <http://www.insurancecouncil.com.au/assets/files/normalising%20the%20insurance%20council%20of%20australia%20natural%20disaster%20event%20list.pdf>. Accessed 21 August 2014.

Gold Coast City Council (2014) Local Studies Library. Available online at

[https://gccc.sdp.sirsidynix.net.au/client/onlinelibrary/rw\\$003d0\\$0026rm\\$003dPICTURE\\$002bGOLD\\$002bc1\\$00257C\\$00257C\\$00257C1\\$00257C\\$00257C\\$00257C0\\$00257C\\$00257C\\$00257Ctrue\\$0026pv\\$003d-1\\$0026ic\\$003dfalse\\$0026dt\\$003dlist\\$0026sm\\$003dfalse\\$0026](https://gccc.sdp.sirsidynix.net.au/client/onlinelibrary/rw$003d0$0026rm$003dPICTURE$002bGOLD$002bc1$00257C$00257C$00257C1$00257C$00257C$00257C0$00257C$00257C$00257Ctrue$0026pv$003d-1$0026ic$003dfalse$0026dt$003dlist$0026sm$003dfalse$0026). Accessed 20 August 2014.

ICA (2014) *Historical Disaster Statistics*. Available online at

<http://www.insurancecouncil.com.au/industry-statistics-data/disaster-statistics/historical-disaster-statistics>. Accessed 21 August 2014.



# THE HEATWAVES OF THE 2013/2014 AUSTRALIAN SUMMER

Proceedings of the Research Forum at the Bushfire and Natural Hazards CRC  
& AFAC conference  
Wellington, 2 September 2014

**Robert J. B. Fawcett<sup>1</sup> and John R. Nairn<sup>2</sup>**

<sup>1</sup>Centre for Australian Weather and Climate Research

<sup>2</sup>Bureau of Meteorology

Corresponding author: [r.fawcett@bom.gov.au](mailto:r.fawcett@bom.gov.au)





## ABSTRACT

Heatwaves represent a significant natural hazard in Australia, arguably more hazardous to life than bushfires, tropical cyclones and floods. In the 2008/2009 summer, for example, many more lives were lost to heatwaves than to that summer's bushfires which were among the worst in the history of the Australian nation. Yet for many years, these other forms of natural disaster have received much greater public attention than heatwaves. This might be changing in Australia however, as health and emergency services increasingly use weather forecast information to become proactive in providing advice to the community on how to mitigate the effects of heatwaves. Significant community engagement took place during the 2013/2014 Australian summer, a summer which generated some significant heatwaves, comparable to those of 2009, 2004, 1939 and 1908.

In January 2014, the Australian Bureau of Meteorology introduced a pilot national heatwave forecasting service, to issue forecasts of forthcoming non-severe, severe and extreme heatwaves. The service is based on the excess heat factor (EHF) or heatwave intensity concept, which quantifies the extent of the temperature elevation during a heatwave in a manner relevant to the expected impact of the heatwave on human health. The forecasting system makes use of both daily maximum and minimum temperatures, the latter providing implicit information about average humidity levels, without humidity being included explicitly in the calculation.

This paper will document the heatwaves of the 2013/2014 Australian summer, in terms of the EHF metric, and will describe how well they were forecast by the new service.

## INTRODUCTION

Heatwaves represent a significant natural hazard in Australia, arguably more hazardous to life than bushfires, tropical cyclones and floods. In the 2008/2009 summer, for example, many more lives were lost to heatwaves (374 excess deaths in Victoria alone, [VDHS 2009](#); an additional 50 to 150 deaths in South Australia have been estimated, [Reeves et al. 2010](#)) than to that summer's bushfires (173 deaths, [VBRC 2010](#)) which were among the worst in the history of the Australian nation. Yet for many years, these other forms of natural disaster have received much greater public attention than heatwaves. This might be changing in Australia however, as health and emergency services increasingly use weather forecast information to become proactive in providing advice to the community on how to mitigate the effects of heatwaves. Significant community engagement took place during the 2013/2014 Australian summer, a summer which generated some significant heatwaves, comparable to those of 2009, 2004, 1939 and 1908.

In January 2014, the Australian Bureau of Meteorology introduced a pilot national heatwave forecasting service, to issue forecasts of forthcoming non-severe, severe and extreme heatwaves. The service is based on the excess heat factor (EHF) or heatwave intensity concept ([Nairn and Fawcett 2013](#)), which quantifies the extent of the temperature elevation during a heatwave in a manner relevant to the expected impact of the heatwave on human health. The forecasting system makes use of both daily maximum and minimum temperatures, the latter providing implicit information about average humidity levels, without humidity being included explicitly in the calculation.

This paper will document the heatwaves of the 2013/2014 Australian summer, in terms of the EHF metric, and will describe how well they were forecast by the new service. We also compare the 2014 Melbourne heatwave with earlier heatwaves in its history.



## METHODOLOGY AND DATA

The EHF is a new measure of heatwave intensity, incorporating two ingredients. The first ingredient is a measure of how hot a three-day period (TDP) is with respect to an annual temperature threshold at the particular location. If the daily mean temperature (DMT) averaged over the TDP is higher than the climatological 95<sup>th</sup> percentile for DMT (denoted  $T_{95}$  in what follows), then the TDP and each day within it are deemed to be in heatwave conditions. [This calculation uses the period 1971-2000.] On average, around 18 days per year will have a DMT exceeding  $T_{95}$ , but it is necessary to have three high DMTs in succession in order to form a heatwave according to this characterisation. The second ingredient is a measure of how hot the TDP is with respect to the recent past (specifically the previous 30 days). This takes into account the idea that people acclimatise (at least to some extent) to their local climate, with respect to the temperature variation across latitude and throughout the year, but may not be prepared for a sudden rise in temperature above that of the recent past.

The heatwave intensity (i.e., the EHF) is a combination of these two ingredients, and larger values of each ingredient result in a larger EHF (see [Nairn and Fawcett 2013](#) for a detailed explanation of the calculation and the climatology periods adopted). The heatwaves across the period 1958-2011 are assessed, and the severity threshold at each location set to be the 85<sup>th</sup> percentile of EHF values. This implies that 15 per cent of the TDPs in heatwave at a particular location will be severe. The extreme heatwave threshold is then set at a multiple (three) of the severity threshold. The units of EHF are  $(^{\circ}\text{C})^2$ , or perhaps more conveniently  $\text{K}^2$ , as the EHF is a modified product of the two ingredients described above.

EHF values may be calculated using site daily temperature data (as in Figure 2 below) or using gridded analyses of daily temperature such as the Bureau of Meteorology's operational analyses ([Jones et al. 2009](#); the choice of 1958 as the start year for the climatology period arises from data availability considerations in these operational analyses). Forecasts of DMT, and subsequently of EHF, have been prepared using the modified Gridded Objective Consensus Forecast (GOCF) system described in [Fawcett and Hume \(2010\)](#). This GOCF system allows forecasts of DMT for seven consecutive days, and consequently forecasts of EHF for five consecutive overlapping TDPs to be made once each day. While these EHF forecasts were only issued to the Australian public from 8 January 2014 onwards, the Bureau of Meteorology was generating these forecasts internally before their public release, and accordingly we present forecast verification results for the period November 2013 to March 2014 inclusive.

The heatwave forecasts issued to the public took the form of maps (an example is shown in [Figure 1](#)) showing areas forecast to be in extreme, severe and non-severe heatwave, or not in heatwave at all, together with supporting commentary. Underlying these maps were gridded forecasts, but these were not made available to the public during the 2013/2014 summer.

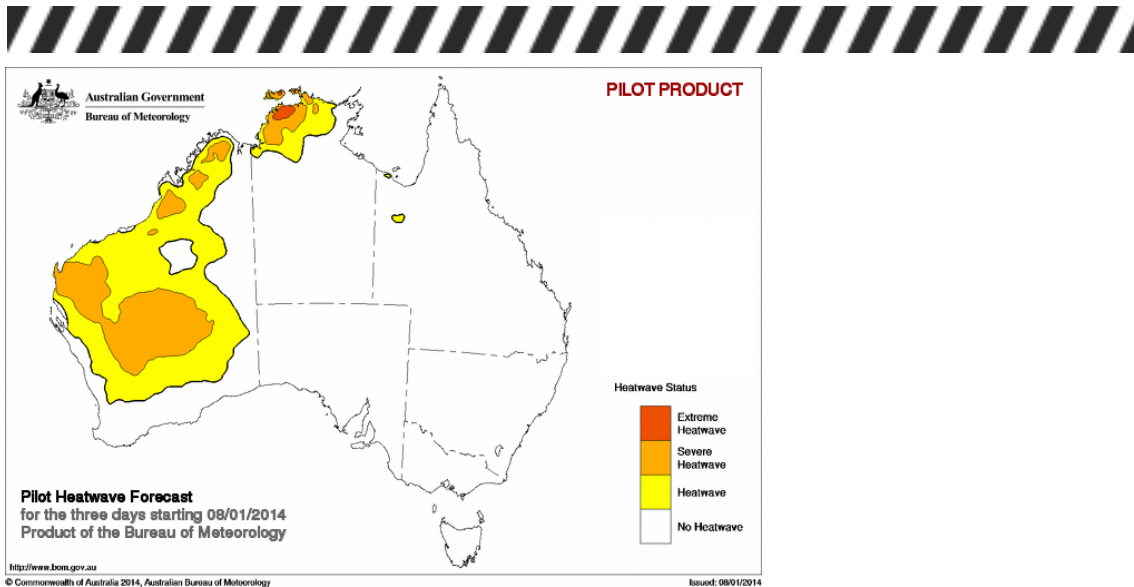


Figure 1: Heatwave forecast map for the TDP 08/10 January 2014, prepared in the morning on 8 January 2014. The coloured shades denote regions with heatwave, severe heatwave and extreme heatwave forecasted.

## RESULTS

Figure 2 compares the heatwaves of 1908, 1939, 2009 and 2014, as they appear in the daily temperature data from the Bureau of Meteorology's Melbourne Regional Office site (Station number 086071), using the base periods described in the previous section. These daily temperature data are quality-controlled, but not homogenised. To put these four years in context, a pre-federation heatwave in mid-January 1875 saw three consecutive days with maximum temperatures above 41°C in Melbourne, with a peak EHF of 140 K<sup>2</sup> (more than five times the severity threshold). The cool temperatures in the weeks preceding this event were a notable contributing factor to the very high EHF. Thirty years later, an event in mid-January 1905 saw three consecutive days above 40°C and a peak EHF of 94 K<sup>2</sup> (more than three times the severity threshold).

The 1908 heatwave (Figure 2a) peaked (at 82 K<sup>2</sup>) just into the extreme range at Melbourne, with the city experiencing five consecutive days with maximum temperatures of 40°C or above, and six consecutive days of 39.9°C or above, setting consecutive-day records which still stand. While the peak intensity of this event was less than that of the 1905 event, the longer duration of the 1908 event made it much more significant in terms of cumulative heat load. 246 fatalities across southern Australia have been reported for this heatwave (Reeves et al. 2010).

The 1939 heatwave (Figure 2b) was weakly represented in the Melbourne data, with its strongest presence in southwest New South Wales. Melbourne experienced some very hot days during the heatwave (43.1°C on the 8<sup>th</sup>, 44.7°C on the 10<sup>th</sup>, 45.6°C on the 13<sup>th</sup> and Melbourne's then hottest day on record broken only in 2009), but they were not consecutive and were interspersed with much cooler days. 438 fatalities have been reported (Reeves et al. 2010), 300 being in country NSW.

The 2009 Melbourne heatwave (Figure 2c) in late January was extreme, with 9 consecutive days of heatwave and six consecutive days of severe heatwave. The peak intensity (132 K<sup>2</sup>) was nearly five times the severity threshold. There were three consecutive days with maximum temperatures above 43°C, a new three-day record. An analogous two-day record was also set during the event: both still stand. A week after the heatwave, on 7 February, a new daily record (46.4°C) was set, breaking the previous 45.6°C record of 13 January 1939, both days of catastrophic bushfires (Pyne 1991; VBRC 2010).



The 2014 Melbourne heatwave (Figure 2d) in mid-January was even more extreme than the 2009 heatwave, with a peak intensity (147 K<sup>2</sup>) more than five times the severity threshold. There were seven consecutive days of heatwave and six consecutive days of severe heatwave. There were four consecutive days with maximum temperatures above 41°C (from the 14<sup>th</sup> to the 17<sup>th</sup>), a new four-day record. In summary, the 2014 heatwave in Melbourne was comparable with the worst previously experienced in the instrumental record (which extends back to 1856).

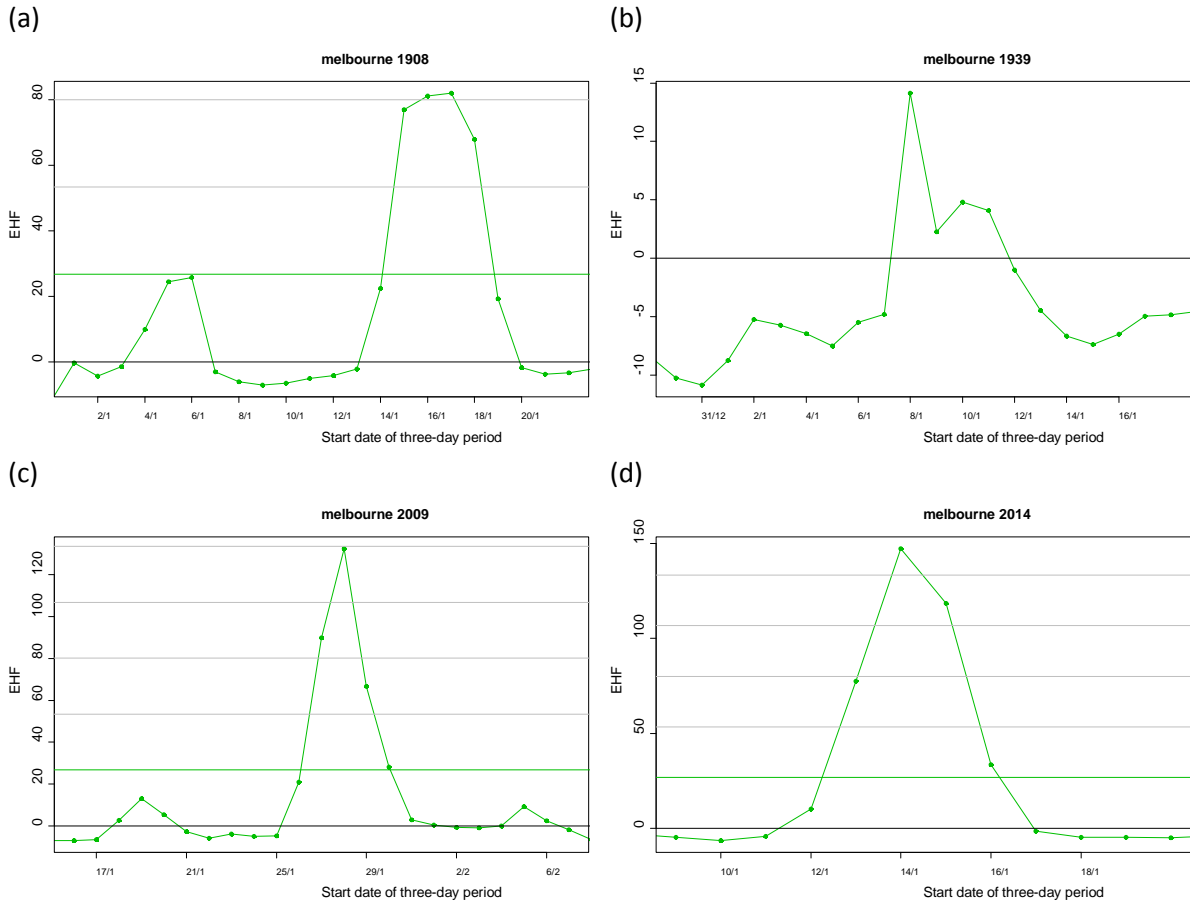


Figure 2: Four heatwaves in Melbourne, Victoria: (a) January 1908, (b) January 1939, (c) January/February 2009, and (d) January 2014. The horizontal green line represents the EHF severity threshold EHF85, with the horizontal grey lines multiples thereof. The calculation based on site data. At this site,  $T_{95}$  is 24.9°C.

Figure 3 shows the percentage area of Australia (as calculated using continental Australia and the main island of Tasmania) in heatwave for each TDP from November 2013 to March 2014, with Figure 4 and Figure 5 showing the analogous results for severe and extreme heatwaves, respectively. At the peak summer extent, more than half the country was simultaneously in heatwave, and more than 30 per cent simultaneously in severe heatwave. At one point (not shown) all of Victoria was in severe heatwave, and most of it actually in extreme heatwave.



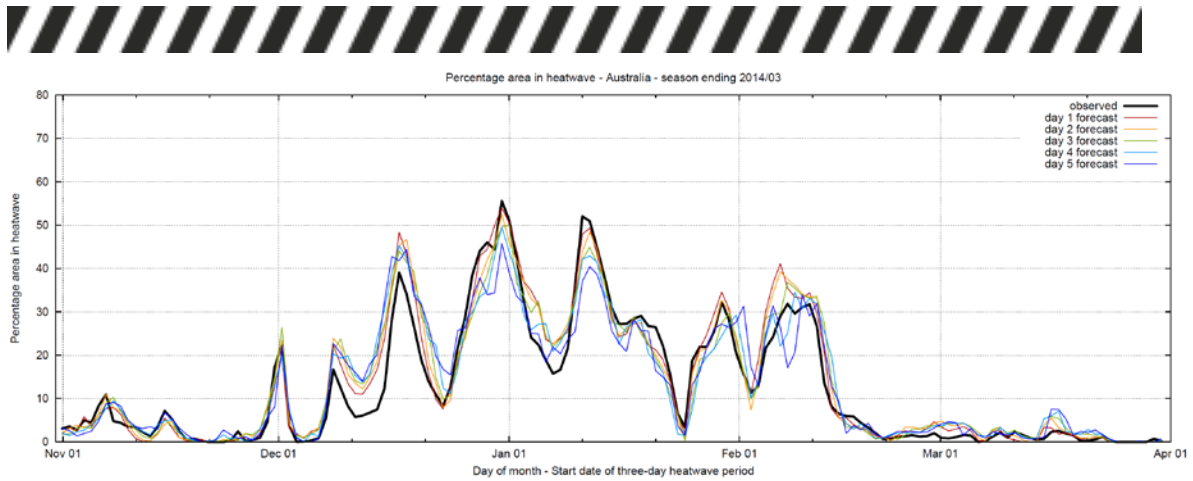


Figure 3: Percentage area of Australia in heatwave (black line) for the period November 2013 to March 2014, together with the percentage area forecast to be in heatwave at short (red, yellow) to long (blue, purple) lead times.

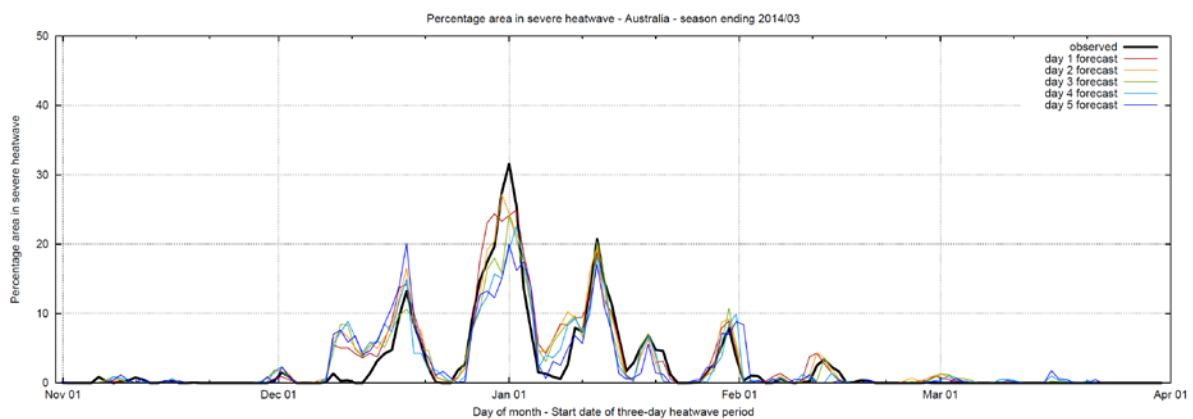


Figure 4: As per Figure 3 but for severe heatwaves.

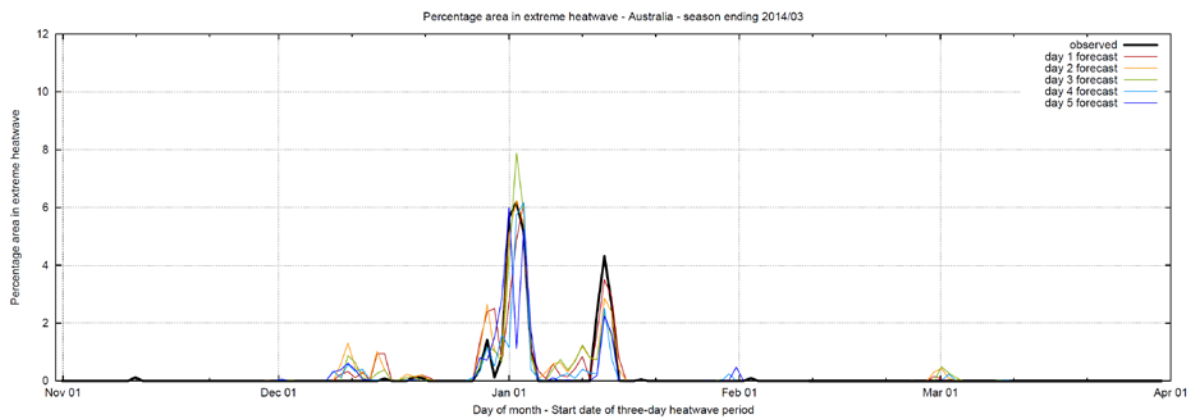


Figure 5: As per Figure 3 but for extreme heatwaves.

Six significant bursts of heatwave activity during the 2013/2014 summer may be identified in [Figure 3](#). These will now be described using the gridded EHF data. In each case a representative location will be chosen to present a time series of EHF interpolated from the grids, together with a map integrating the positive EHF values within the nominated period to characterise the spatial pattern of the episode. The interpolated data are representative of a larger area (the analysis grid cells are ~ 20 to 25 km across) than would be the case for site data at the same location.



## LATE NOVEMBER/EARLY DECEMBER

Although one fifth of the country was simultaneously in heatwave conditions, this was a mild event in terms of intensity. It covered much of inland Australia (Figure 6) and extended far into the southeast, but reached severe levels only in central and northwest Western Australia. It did not impact upon major population centres.

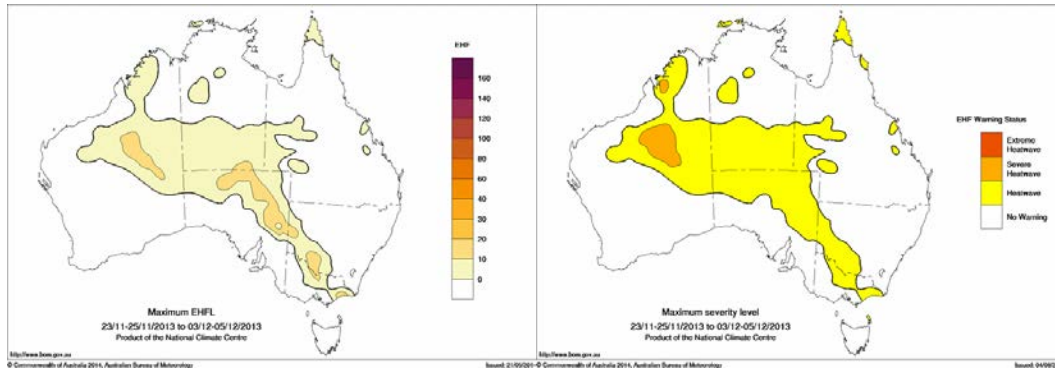


Figure 6: Maximum EHF attained during the first heatwave episode of the 2013/2014 Australian summer, expressed in terms of EHF values (left) and severity level (right).

## MID-DECEMBER

This episode covered much of southern Australia (Figure 7), although without the southeast coastal regions being much affected. Mildura (Victoria) went into severe heatwave (Figure 8, peaking on 18/20 December), as did Adelaide and Oodnadatta (South Australia, not shown). Kalgoorlie-Boulder (southwest Western Australia) also experienced severe heatwave conditions (not shown, peaking on 15/17 December), but a few days earlier.

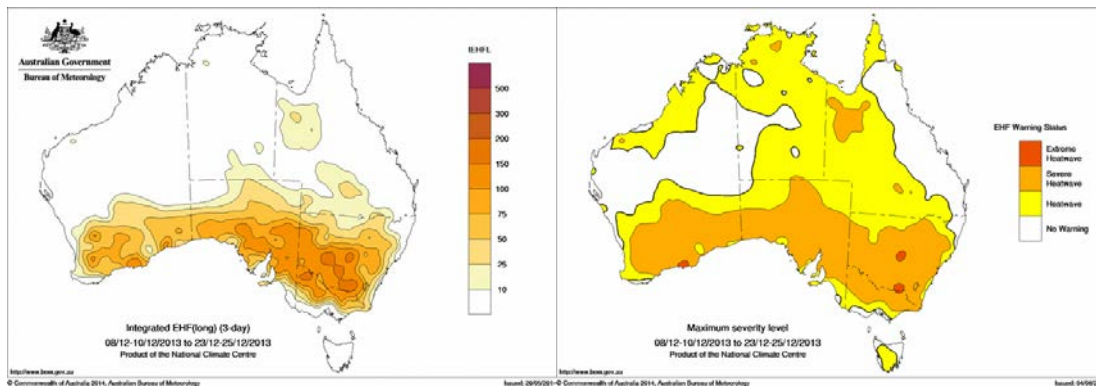


Figure 7: Integrated EHF across Australia for the period 08/10 to 23/25 December 2013 (left) and maximum EHF within that period expressed in terms of severity level (right).

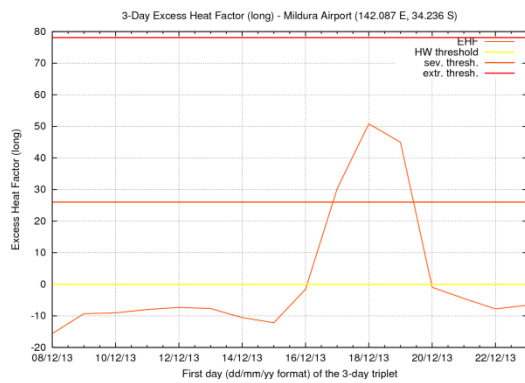


Figure 8: Time series of EHF (left) for Mildura (Victoria) for the period 08/10 to 23/25 December 2013. The peak intensity was 1.95 times the severity threshold (horizontal orange line). The yellow line denotes the non-severe heatwave threshold, and the red line the extreme heatwave threshold.

### LATE DECEMBER/EARLY JANUARY

This episode was active across Queensland and the Northern Territory (Figure 9), although extending into South Australia and inland Western Australia. The peak intensity (19.8 K<sup>2</sup>, on 03/05 January) at Brisbane (Figure 10) was more than 3.8 times the severity threshold, making this an extreme event there. Archerfield in suburban Brisbane reached 43.5°C on the 4<sup>th</sup>, its hottest day on record. This was also an extreme event further inland at locations such as Dalby (not shown).

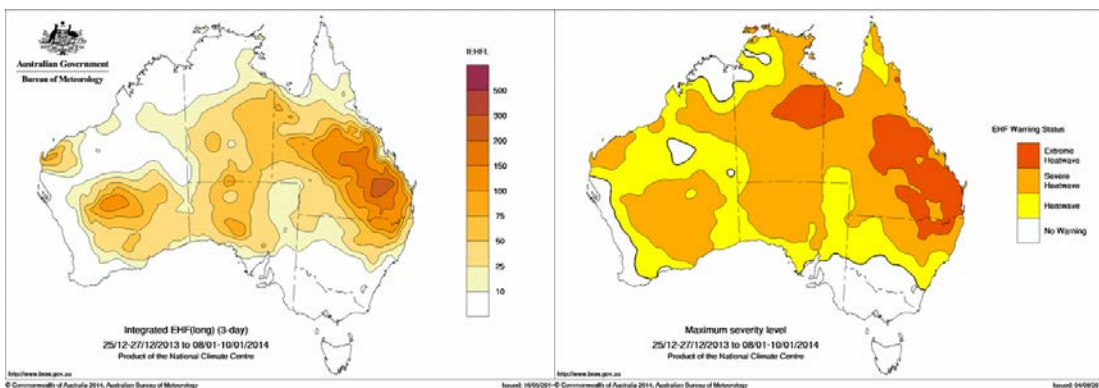


Figure 9: As per Figure 7 but for the period 25/27 December 2013 to 08/10 January 2014.

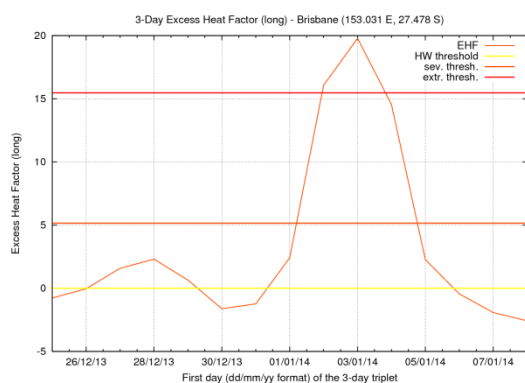


Figure 10: As per Figure 8 but for Brisbane (Queensland) for the period 25/27 December 2013 to 08/10 January 2014. The peak intensity was 3.8 times the severity threshold.



## MID-JANUARY

This episode was in many respects a typical southeast Australian heatwave, although a particularly intense one. Peak intensities were across Victoria and adjacent parts of South Australia (Figure 11). Early assessments suggested that this heatwave resulted in at least 100 excess deaths in Victoria (ABC 2014). For Melbourne, the peak intensity was 5.5 times the severity threshold (Figure 12), for Adelaide 3.5 times (implying that it was slightly less intense than the 2009 event there).

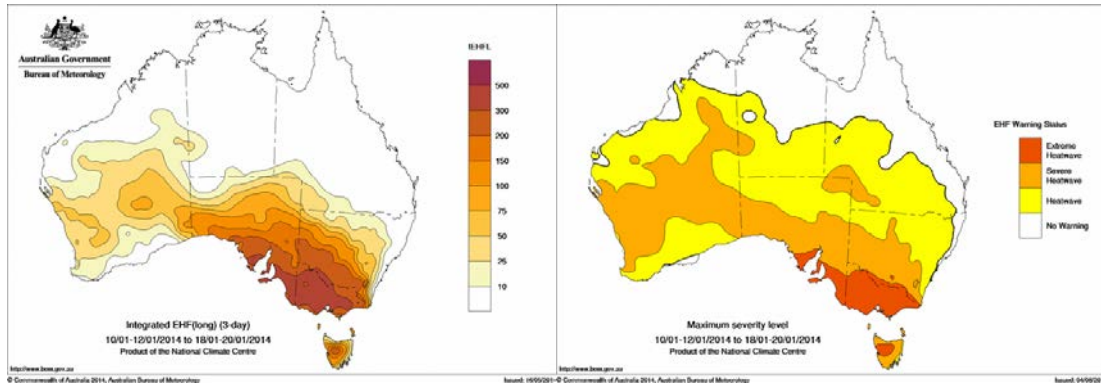


Figure 11: As per Figure 7 but for the period 10/12 to 18/20 January 2014.

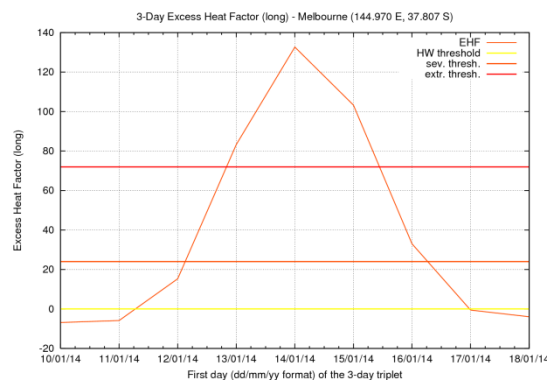


Figure 12: As per Figure 8 but for Melbourne (Victoria) for the period 10/12 to 18/20 January 2014. The peak intensity was 5.5 times the severity threshold.

## LATE JANUARY

This episode, while affecting much the same area as the previously described episode, had a reduced impact along the Victorian coast (Figure 13). Accordingly, Mildura is chosen as the representative location (Figure 14) for this episode. With peak intensity 2.2 times the severity threshold, this event was well into the severe category at Mildura. The event was also severe at Adelaide (not shown, 1.3 times the severity threshold).

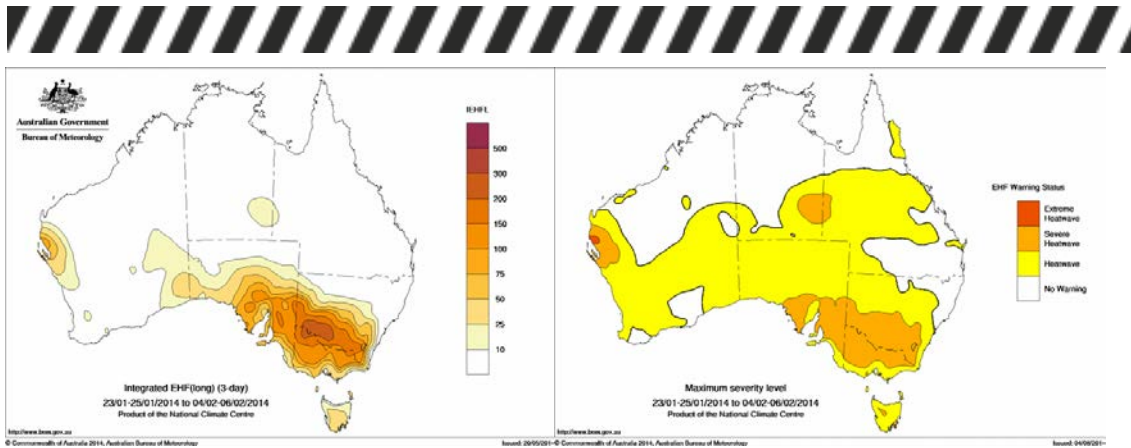


Figure 13: As per Figure 7 but for the period 23/25 January to 04/06 February 2014.

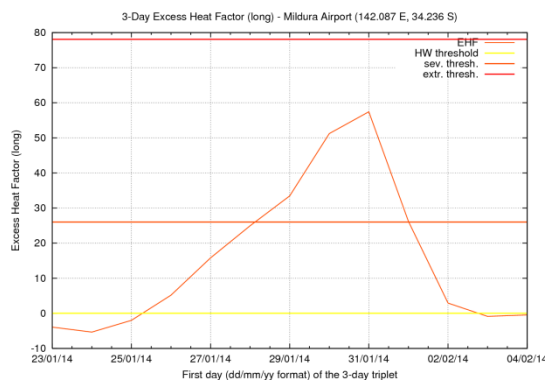


Figure 14: As per Figure 8 but for Mildura (Victoria) for the period 23/25 January to 04/06 February 2014. The peak intensity was 2.2 times the severity threshold.

### EARLY FEBRUARY

This last episode of the summer mainly affected inland parts of southeast Queensland and the southeast States (Figure 15). Peak EHF severity levels were attained along the Queensland-New South Wales border and around Carnarvon in Western Australia, at twice the local severity threshold. More (New South Wales) is chosen in Figure 16 as a representative location. During the period represented in Figure 15, nearly all the southern half of the country experienced non-severe heatwave conditions at some point.

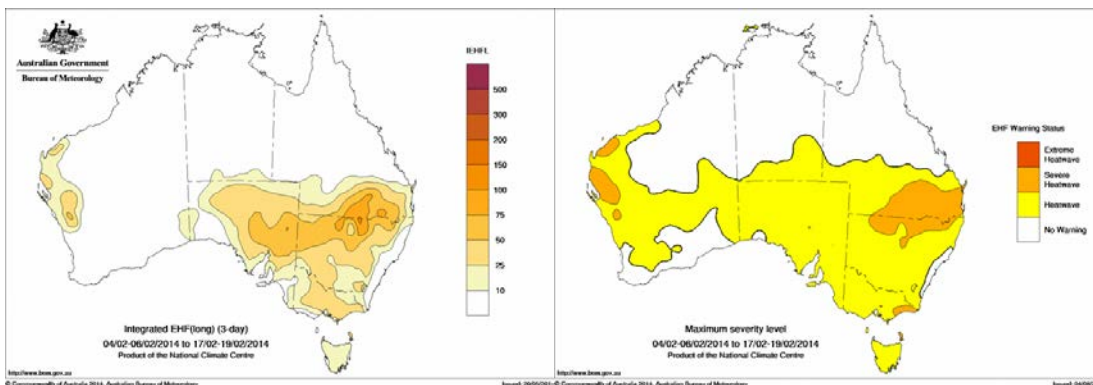


Figure 15: As per Figure 7 but for the period 04/06 to 17/19 February 2014.



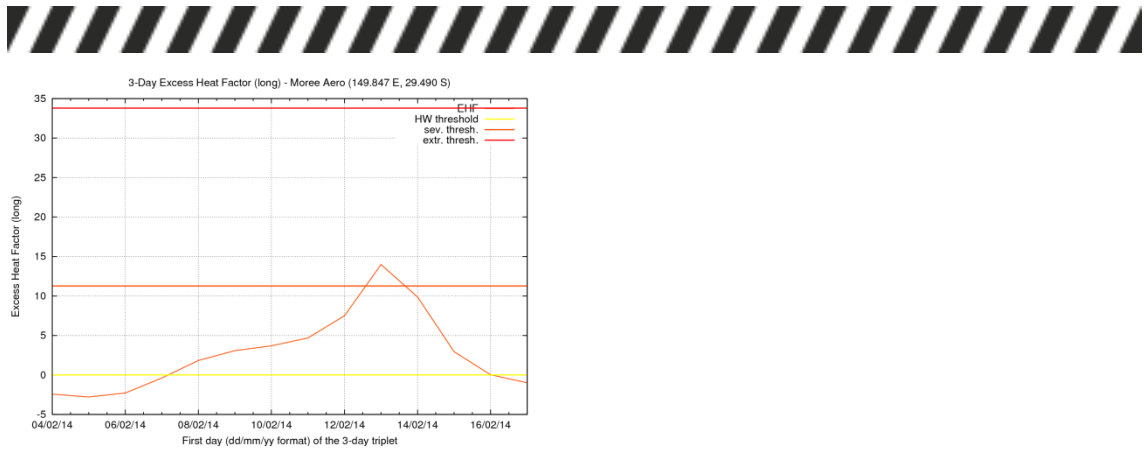


Figure 16: As per Figure 8 but for Moree (New South Wales) for the period 04/06 to 17/19 February 2014.

## DISCUSSION

The 2013/2014 Australian summer saw some very significant heatwaves, comparable to the worst previously seen in the historical record. For Melbourne, this meant a lapse of just five years since the previous event of a comparable magnitude. It should be noted that the site data used to generate the results shown in Figure 2 are quality-controlled but not homogenised and that lack of homogenisation may have some bearing on the interpretation of the results. Across the period represented by the results (1875 to 2014) the observing site (086071) has moved once (January 1908), with a possible change in the screen used to house the thermometers. Ashcroft (2013) found statistical evidence for a minor inhomogeneity in minimum temperature around the time of the site move, but none for maximum temperature, so its impact on the EHF would likely not be large. In recent decades the site has seen significant building construction nearby, and so a significant urban heat island (UHI) effect may be present in the minimum temperatures. On the other hand, the UHI is thought to be more noticeable on cool, clear nights which would not normally be associated with spikes in the EHF at this site. In the preparation of homogenised temperature time series, the removal of non-climatic signals such as those caused by site moves, changes in observing practices (including instrumentation and instrument housing) and changes in site surroundings is required. This normally motivates an avoidance of city sites affected by the UHI effect, although for some purposes the UHI effect is only significant (and therefore to be removed) if it *changes* across the duration of the time series. In the heatwave context, while most of the above noted non-climatic signals should be removed in a temperature homogenisation process, we would recommend the retention of the UHI effect in the temperature data contributing to the EHF calculation because of its direct relevance to the human experience of heatwave.

Figure 3 indicates that there is considerable skill in forecasting the national percentage area in heatwave, even at long lead-times (e.g., four days), although the percentage area may sometimes be over-forecast or under-forecast. None of the major severe heatwave events (Figure 4) or extreme heatwave events (Figure 5) were missed, although there were some false alarms (i.e., events forecast which did not subsequently occur). It should be noted that the ability to forecast EHF essentially arises from the ability to forecast daily maximum and minimum temperatures. At short range, daily maximum and minimum temperatures are well forecast, although forecast skill does typically degrade with increasing lead time, and the consequences of this can be seen to some extent in Figure 3 and Figure 4. The ability to forecast the extreme events (Figure 5) is not as good as that achieved for severe events (Figure 4). This is not an unreasonable result when considering the infrequency of extreme heatwaves in comparison to severe heatwaves.

The pilot heatwave forecast service product consists of an image graphic supported by limited text. As such this service is not integrated with the Bureau's official digital forecasts and warnings system. The



Bureau's Next Generation Forecast Warning System (NexGenFWS) is responsible for the generation and distribution of Australia's official forecasts and warnings, which is held in the Bureau's Australian Digital Forecast Database. The Bureau is investigating community interest in the generation of a national heatwave warning system within the NexGenFWS, which would enable multiple formats and delivery channels for the delivery of heatwave forecasts and warnings.

## REFERENCES

ABC 2014. *Heatwave blamed for large spike in the number of deaths in Victoria last week*. Australian Broadcasting Corporation, 23 January 2014 (<http://www.abc.net.au/news/2014-01-23/heatwave-death-toll-expected-to-top-almost-400/5214496>), accessed 21 May 2014.

Ashcroft L C 2013. *Extending the instrumental climate record of southeastern Australia*. Ph.D. thesis, School of Earth Sciences, University of Melbourne.

Nairn J and Fawcett R 2013. *Defining heatwaves: heatwave defined as a heat-impact event servicing all community and business sectors in Australia*. CAWCR Technical Report No. 60. The Centre for Australian Weather and Climate Research, Melbourne, Victoria. 84pp.

Jones D A et al. 2009. *High-quality spatial climate data-sets for Australia*. Australian Meteorological and Oceanographic Journal 58 233-248.

Pyne S J 1991. *Burning bush: a fire history of Australia*. University of Washington Press. 520pp.

Reeves J et al. 2010. *Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009*. The Institute for Sustainable Resources, Queensland University of Technology, Brisbane Queensland. 172pp.

VBRC 2010. *2009 Victorian Bushfires Royal Commission Final Report*. The State of Victoria. Government Printer for the State of Victoria, Melbourne, Australia.

VDHS 2009. *January 2009 Heatwave in Victoria: an Assessment of Health Impacts*. Victorian Department of Human Services, Melbourne, Victoria. 24pp.



# MITIGATING THE EFFECTS OF SEVERE FIRES, FLOODS AND HEATWAVES THROUGH THE IMPROVEMENTS OF LAND DRYNESS MEASURES AND FORECASTS

Proceedings of the Research Forum at the Bushfire and Natural Hazards CRC  
& AFAC conference  
Wellington, 2 September 2014

Imtiaz Dharssi<sup>1,3</sup>, Vinod Kumar<sup>1,3</sup>, Claire S. Yeo<sup>2</sup>, John Bally<sup>2,3</sup>  
and Jeff D. Kepert<sup>1,3</sup>

<sup>1</sup>Centre for Australian Weather and Climate Research

<sup>2</sup>Bureau of Meteorology

<sup>3</sup>Bushfire and Natural Hazards CRC

Corresponding author: [i.dharssi@bom.gov.au](mailto:i.dharssi@bom.gov.au)





## ABSTRACT

Knowledge of landscape dryness is critical for the management and warning of fires, floods, heatwaves and landslips. This project will address fundamental limitations in our ability to prepare for these events. Currently landscape dryness is estimated using simplified soil moisture accounting systems developed in the 1960's. Similarly, flood prediction, runoff potential and water catchment/dam management also are not using the best available science and technology.

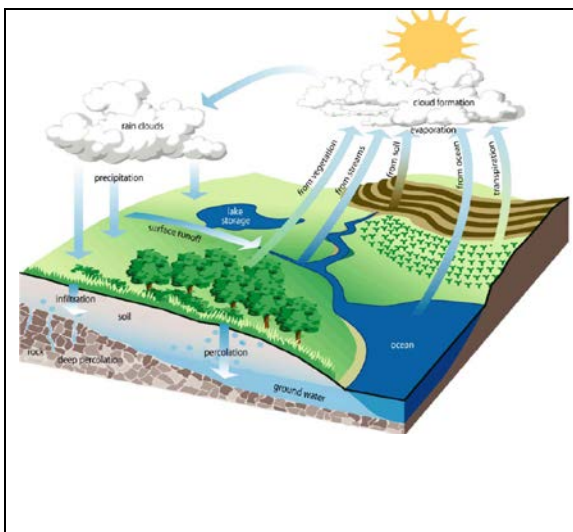
This paper describes research to be carried out by the Bushfire and Natural Hazards Cooperative Research Centre that will examine the use of detailed land surface models, satellite measurements and ground based observations for the monitoring and prediction of landscape dryness. The new information will be calibrated for use within existing fire and flood forecasting systems.

An inter-comparison will be performed of the traditional Keetch-Byram Drought Index and Soil Dryness Index with weather prediction models, satellite measurements, ground based measurements, and rainfall-runoff models. Soil moisture from weather prediction and reanalysis will be calibrated for the calculation of a high resolution historical dataset of KBDI and SDI. These datasets will be a valuable resource for researchers working on fire climatologies across Australia. The outputs of this project will improve Australia's ability to manage multiple hazard types and create a more resilient community, by developing a state of the art, world's best practice in soil moisture analysis that underpins flood, fire and heatwave forecasting.

Longer term work will explore the use of multi-model predictions and data assimilation to forecast soil dryness indices for operational application to fire, flood and heat wave hazards. The vegetation and soil parameterisations in current land surface models will be developed to match Australian conditions.

## THE PROJECT

Good estimates of landscape dryness underpin fire danger rating, fire behaviour models, flood prediction and landslip warning. Soil dryness also strongly influences heatwave development by driving the transfer of solar heating from the soil surface into air temperature rise.



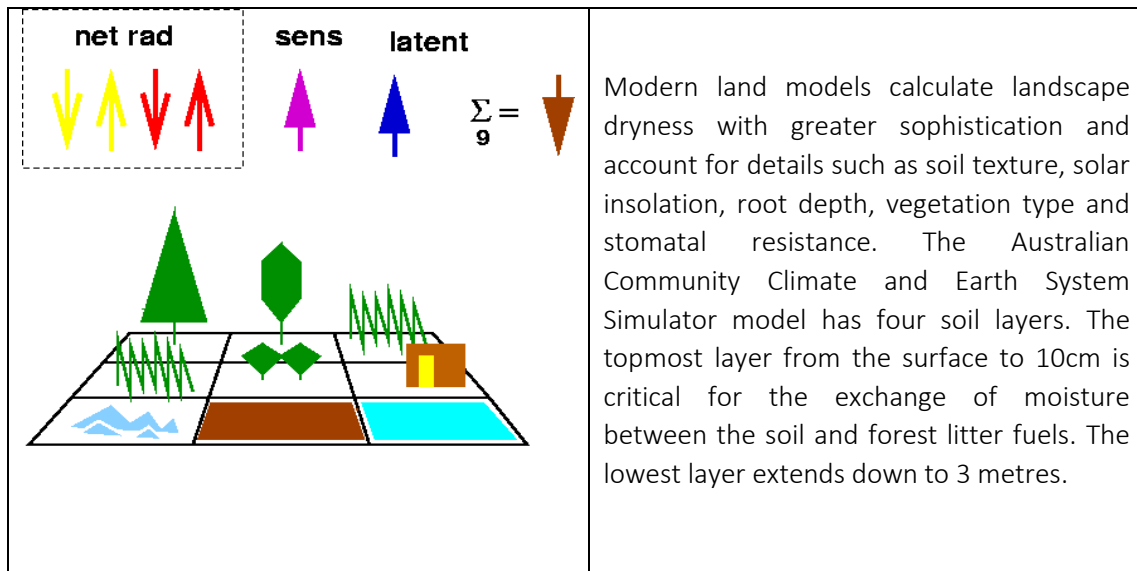
Strong positive feedbacks between soil moisture and rainfall give the Earth system a long memory allowing extreme conditions to persist for long periods. Accurate knowledge of soil moisture conditions is crucial for accurate prediction of fires, heatwaves, droughts and floods. Soil moisture is important both for short term forecasting, from a few hours to a few days, as well as long range seasonal forecasting.



Fire intensity, spread rate and ignition are very sensitive to the fuel dryness which is strongly linked to soil moisture content. For example, Dutta et al. (2013) show using a neural network that knowledge of soil moisture is essential for the accurate prediction of wildfire incidence. Estimates and forecasts of fuel and soil moisture are the foundation of the fire danger calculations used to rate and manage wildfires and to warn of developing fire danger. Similarly estimates and forecasts of soil moisture are essential ingredients to be able to forecast with accuracy river flows on a seasonal scales (one to three months), which is very much in demand by water managers and reservoir operators.

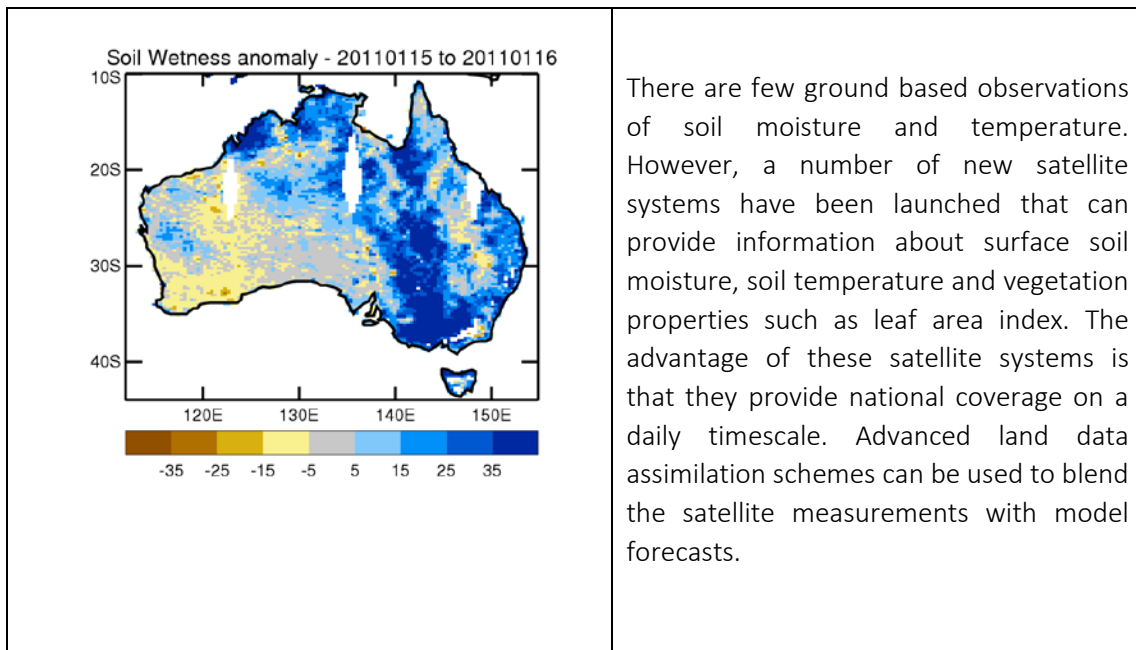
Currently landscape dryness is estimated using very crude models developed in the 1960's. The most prominent of these used in Australia are the Keetch-Byram Drought Index (KBDI; Keetch & Byram 1968) developed by the US Forest Service, and the related Soil Dryness Index (SDI; Mount 1972) developed by Forestry Tasmania. These simple empirical soil moisture models are designed to be easily hand calculated once per day for a small number of points across the landscape. These empirical calculators do not work effectively in dryer environments, which are typical in the Australian landscape and is predicted to become worse as the climate changes. They do not take into account different soil types, slope, aspect and many other factors. They are poor drivers of the sophisticated fire models used by fire agencies, and the Bureau of Meteorology to manage and warn for dangerous fire conditions as the science is out-dated and has been verified as not effective in fire spread prediction. Flood prediction, runoff potential and water catchment/dam management also are not using the best available technology and use simplified soil moisture accounting systems.

Modern Numerical Weather Prediction (NWP) systems also calculate landscape dryness. For example, the Australian Community Climate and Earth System Simulator (ACCESS; Puri et al. 2013) NWP system uses 5 vegetation classes, 4 non-vegetation surface types and 3 soil texture classes. The ACCESS NWP model soil moisture is adjusted each model run, every six hours, to better match the recent history of surface air temperature and moisture patterns.



The current fire systems only use landscape dryness assuming one soil layer, soil type and vegetation, at one point in the day. It is imperative to the Australian community that best science and technology

that is available to Emergency Management is used effectively and incorporated into warnings systems.



The problems being addressed by this research are:

1. The need to calibrate NWP and remotely sensed measures of landscape dryness so that they can be incorporated into operational prediction models for fire, flood and water resource management, while maintaining the calibration of the application of the original operational systems.
2. Applying corrections to measures of landscape dryness for a range of natural hazard types to improve the monitoring and prediction of events.
3. Exploring the relationship between soil dryness measures and litter fuel moisture content.

In the first year, the work will focus on:

1. Calibration and rescaling of NWP soil moisture measures. This will retain the accuracy, temporal and spatial resolution of NWP based soil moisture without changing the overall climatology of Fire Danger Index and other calculations based on soil moisture.
2. Inter-comparison of traditional soil dryness models (KBDI, SDI) with soil moisture/dryness from:
  - a. Numerical Weather Prediction models (ACCESS and others);
  - b. Satellite measures of landscape dryness;
  - c. Water resource assessment models (Australian Water Resources Assessment and Australian Water Availability Project/WaterDyn);
  - d. Rainfall-runoff models used for flood and river flow prediction; and in situ measurements of soil moisture.
3. Produce a historical dataset of the KBDI and SDI from reanalysis. This new gridded dataset of SDI and KBDI will be compared with the much used Finkele-Mills dataset (Finkele et al. 2006) and will be a valuable resource for researchers working on fire climatologies across Australia.





A full eight year program will be developed to follow up progress in the first year by:

1. Adaptation of remotely sensed, NWP and numerical seasonal prediction model dryness measures to support operational short and medium time frame forecasts by providing more accurate data of soil moisture deficits and runoff potential.
2. Explore the use of multi-model ensembles to forecast soil dryness indices. This work will support objective risk based forecasts and management of fires by informing emergency managers about the probability of reaching soil moisture thresholds based on a range of weather forecast scenarios.
3. Develop downscaling techniques for landscape moisture measurements and forecasts using a range of statistical and full model based approaches. The benefits will be improved local-scale estimates and forecasts of landscape moisture that better match local soil type and depth, slope, aspect vegetation and other factors.
4. Use data assimilation methods (e.g. Dharssi et al. 2013) to extract the maximum amount of useful information by optimally blending remotely sensed and model land surface data. The only practical way to observe the land surface on a national scale is through satellite remote sensing. Unfortunately, such satellite data is prone to biases and corruption. Therefore, it is essential to quality control and bias correct the satellite data. In addition, satellite measurements are infrequent with measurement repeat times of about one day and contain gaps. Data assimilation can filter the random errors from the satellite measurements and fill in both the spatial and temporal gaps in the measurements.
5. Extend current land surface models to include a wider range of vegetation types, and better matching of model vegetation characteristics to Australian vegetation. Explore the relationship between soil dryness and litter fuel moisture content using land surface models.
6. Calculating a high resolution Fire Danger Index (FDI) dataset based on land surface reanalyses and calibrated, rescaled NWP soil dryness measures. This will supplement the SDI and KBDI datasets and be a valuable resource for other researchers in the Emergency Service sector and at universities working on fire danger climatologies, fire danger rating schemes and fire impact models.

The benefits of this project will be:

- ✓ More accurate, detailed and confident estimates and forecasts of fuel moisture, and hence more accurate predictions of fire danger and fire behaviour, flood forecasting, landslide warning and heatwave events.
- ✓ Benefits extend from landscape management and fuel reduction burns to the highest intensity wildfires.
- ✓ Benefits extend to water resource management, dam catchment monitoring and function of dams in flood mitigation.
- ✓ Datasets of landscape dryness to support a wide range of other research in fire, flood and heatwave prediction.



## REFERENCES

Dharssi, I. et al., 2013. *Analysis of the linearised observation operator in a land surface data assimilation scheme for numerical weather prediction*. 20th International Congress on Modelling and Simulation (MODSIM2013), Adelaide, Australia, The Modelling and Simulation Society of Australia.

Dutta, R., Aryal, J., Das, A. & Kirkpatrick, J. B., 2013. Deep cognitive imaging systems enable estimation of continental-scale fire incidence from climate data. *Scientific reports*, Volume 3.

Finkele, K., Mills, G. A., Beard, G. & Jones, D. A., 2006. National gridded drought factors and comparison of two soil moisture deficit formulations used in prediction of Forest Fire Danger Index in Australia. *Australian Meteorological Magazine*, 55(3), pp. 183-197.

Keetch, J. J. & Byram, G. M., 1968. *A drought index for forest fire control*: US Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Mount, A. B., 1972. *The derivation and testing of a soil dryness index using run-off data*: Forestry Commission, Tasmania.

Puri, K. et al., 2013. Implementation of the initial ACCESS Numerical Weather Prediction system. *Aust. Meteorol. Oceanogr. J.*, Volume 63, pp. 265-284.

## ACKNOWLEDGEMENTS

The support of the Commonwealth of Australia through the Cooperative Research Centre program is acknowledged. Much of the project description is based on original material prepared by John Bally, Claire Yeo and Jeff Kepert.



# DISRUPTION OF CRITICAL INFRASTRUCTURE DURING PROLONGED NATURAL DISASTERS

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

Emma Phillips<sup>1,2</sup>, Felipe Dimer de Oliveira<sup>1,2</sup>, Valentina Koschatzky<sup>1,2</sup>  
and Paul Somerville<sup>1,2</sup>

<sup>1</sup>Macquarie University, Risk Frontiers

<sup>2</sup>Bushfire and Natural Hazards CRC

Corresponding author: [emma.phillips@mq.edu.au](mailto:emma.phillips@mq.edu.au)





## ABSTRACT

Recent events such as the 2010 and 2011 Canterbury earthquakes, New Zealand; 2009 Southeast Australia heatwave; 2010 eruption of Eyjafjallajökull volcano, Iceland; and the 2011 Tohoku earthquake, tsunami and nuclear disaster in Japan, have highlighted the vulnerability of infrastructure and essential services to long-term disruption from prolonged and complex natural disasters. Prolonged natural disasters can impact surrounding areas for weeks to months after the initial event, causing vast and on-going disruption to utility, transport and communication networks; infrastructure that is vitally important for everyday living, the economy and emergency response. The quake-stricken Canterbury region of New Zealand endured thousands of disruptive aftershocks that continued for over two years following the initial earthquake in 2010. These aftershocks contributed to delays in repair and rebuilding, and caused significant additional damage. Our growing reliance on infrastructure and technology, along with the strong interdependent nature of these critical services, can potentially turn one failure into a cascading disaster. Local impacts to critical infrastructure can also lead to the interruption of essential services in regions that were not directly impacted by the physical hazard event. It has never been more important to understand network vulnerabilities and to analyse the cost of long-term disruption, both social and economic. Whilst significant work has gone into understanding the direct impacts from natural hazards, less emphasis has been placed on understanding the vulnerability of critical infrastructure, including indirect and long-term disruption.

## INTRODUCTION

Lifeline networks are the critical infrastructure and essential services that we rely on for day-to-day living, economic output and emergency response. These include, transportation, telecommunication, power and water networks. Continuing increases in population and urbanisation puts increasing pressure on these essential services. With this comes a growing reliance on infrastructure and technology, some of which has strong interdependencies, meaning one failure could potentially turn into a cascading disaster. Lifeline networks are particularly vulnerable to disruption from natural hazards and recent events around the world, including Australia and New Zealand, have highlighted this:

- In June 2014, Northland was hit by a severe storm; strong winds impacted the area and much of the North Island of New Zealand. At the height of the storm, there were over 90,000 power outages across Auckland and widespread power cuts in Tauranga, South Waikato and Coromandel; 30,000 residential and business customers lost power (NZ Newswire, 2014a). Most of the damage was caused by trees falling across lines, which the Electricity Networks Association (ENA) stated affected all suppliers (NZ Newswire, 2014b). Most power was restored the next day, but some residents were without hot water for up to a week (MediaWorks TV, 2014).
- In May 2014, Darwin airport was closed for around 24 hours after an ash cloud from Sangeang Api volcano in Indonesian blew over the Northern Territory. All flights in and out of Darwin were cancelled and flights around the country bound for Bail were also disrupted (Dmytryshchak, 2014).

Although disruptive, and not without cost, these events were relatively short lived and functionality was restored within days. However, this research project is particularly interested in prolonged and multi-hazard events.



A prolonged event is defined in this study as a natural hazard event with an extended duration (a week or more) or a series of events that occur in quick succession. The 2009 Southeast Australia heatwave and 2010 volcanic eruption in Iceland would therefore be classified as prolonged natural hazard events:

- The January/February 2009 southeast Australia heatwave caused localised power outages of various lengths throughout Adelaide and Melbourne over a period of 16 days (Australian Bureau of Statistics, 2013). On the 30th January nearly 500,000 residents in Melbourne City, northern suburbs, Geelong and western Victoria were without power (ABC, 2009). This loss of power resulted in evacuations from the Crown Casino and the Victorian Arts Centre, traffic light failures, and people requiring rescue from lifts. Train and tram services in Melbourne were cancelled not only due to the power outages, but also due to buckling of rail lines and air conditioner failures (McEvoy et al., 2012; ABC, 2009). As at 1 February 2009, the heatwave was estimated to have cost the Victorian economy \$100 million (Houston and Reilly, 2009).
- The 2010 eruption of the Eyjafjallajökull volcano, Iceland, caused extensive air travel disruption due to a seven day closure of large areas of European airspace, affecting the travel arrangements of hundreds of thousands of people. This affected economic, political and cultural activities in Europe and across the world and resulted in an estimated total loss for the airline industry of US\$1.7 billion (IATA, 2010).

A multi-hazard event is defined as an event that is associated with additional or secondary hazards (e.g. earthquakes causing liquefaction, landslides, fires and tsunamis):

- The Canterbury region of New Zealand endured thousands of disruptive aftershocks that continued for more than two years following the initial 7.1 quake in 2010, including the M6.3 quake in February 2011 that killed over 180 people. Larger earthquakes in the sequence triggered soil liquefaction and rock falls, which caused widespread power outages, the disruption of wastewater services, the closure of the international airport and damage to roads and bridges. These additional hazards disrupted rescue and rebuilding efforts (Parker and Steenkamp, 2012). ANZ chief economist Cameron Bagrie estimated that it will take the New Zealand economy 50-100 years to fully recover (MediaWorks TV, 2013).

Prolonged and multi-hazard natural disasters are of interest as they can cause vast and on-going disruption to utility, transport and communication networks, which are critical services for rescue and recovery. While various network vulnerability models have been developed (Murray, 2013; Moon and Lee, 2012), most models were not created specifically to look at shocks from natural disasters, and certainly not prolonged and/or multi-hazard events. There is currently a lack of comprehensive modelling to investigate indirect and on-going lifeline network disruption from complex natural disasters. Therefore, the aim of this project is to describe and quantify the impacts of prolonged and multi-hazard natural hazard events on lifeline networks and to also understand the interconnectedness of these critical services. Key research questions include:

- How does the interconnectedness of critical services lead to a cascade of failures?
- What influences network recovery and how long can they take to rebuild?
- How long can impacts from a natural hazard event remain and what is the cost of long-term network disruption?
- What scenarios could generate a potentially catastrophic disruption in the future?

This project has been partially funded by the Bushfire and Natural Hazard Cooperative Research Centre and is linked with the project "Using realistic disaster scenario analysis to understand natural hazard impacts and emergency management requirements" in the "Scenario and Loss Analysis" cluster. This



project will develop realistic disaster scenarios utilising catastrophe loss models to identify vulnerable areas, utilities and assets within major Australian cities. As well as helping to create a better understanding of the implications of potential long-term lifeline network disruption, key outputs of this study will include:

- Review of key historical Australia, New Zealand and international natural disasters and the impact they had on lifeline networks
- Review of existing network vulnerability models
- Development of new approaches to quantify network vulnerability

## PRELIMINARY STUDY – LATROBE VALLEY EARTHQUAKE

One example of a potential disaster that Australia could face is a damaging earthquake in the Latrobe Valley, Victoria, where ~80% of Victoria’s energy is generated. The Latrobe Valley is located over the Morwell Hotspot earthquake source (Burbidge and Leonard, 2011) and is one of the more seismically active regions in Australia. Numerous historical earthquakes have been recorded in this region, the latest event being the Moe earthquake sequence that began with a 5.4 magnitude earthquake 10 km south of Moe, near Thorpdale, on 19<sup>th</sup> June 2012. Based on the earthquake source model defined in Burbidge and Leonard (2011), the most likely scenario for a damaging earthquake in the Latrobe Valley would be a magnitude 6 earthquake within the Morwell Hotspot.

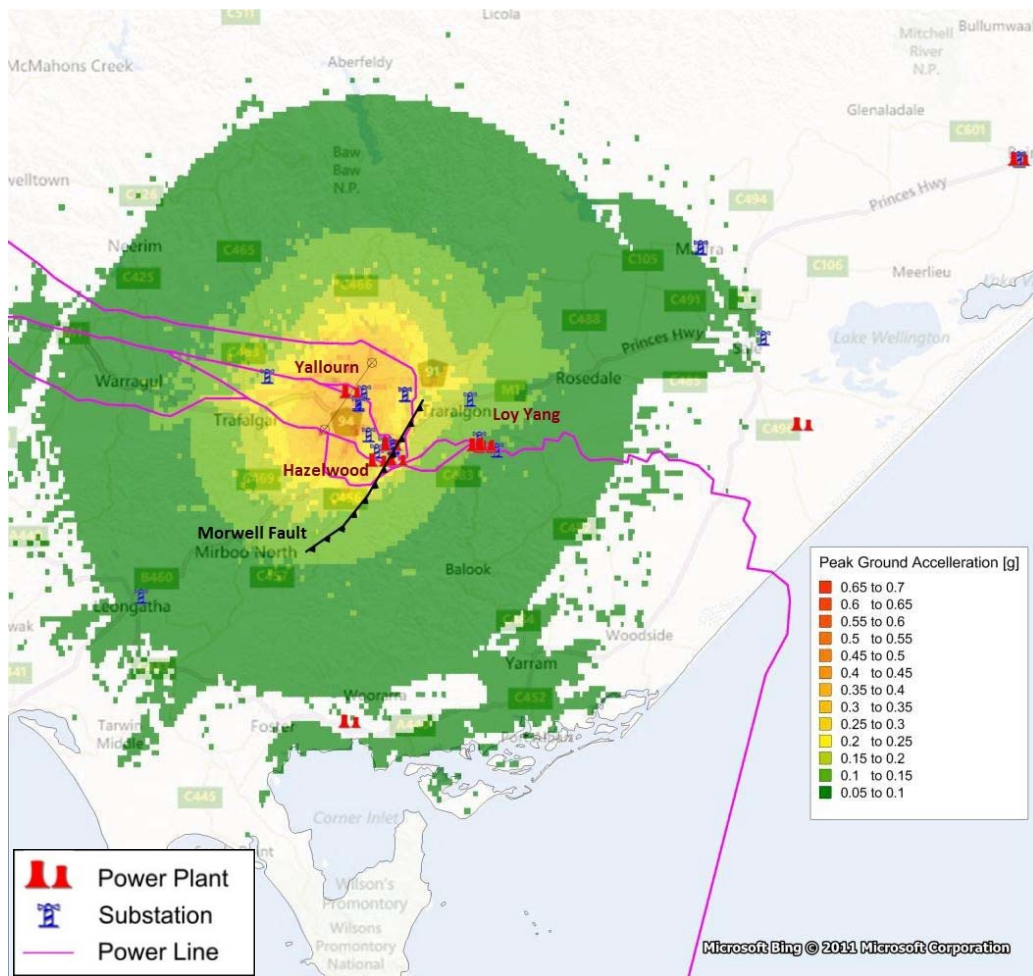


Figure 1: Peak ground acceleration in units of gravitational acceleration (g) for a M6.0 earthquake scenario along the Morwell Fault in the Latrobe Valley, VIC, and locations of main power infrastructure.





A preliminary scenario modelling exercise was commissioned by the Victorian Country Fire Authority (CFA) for emergency response planning purposes. The scenario we considered was a M6.0 earthquake occurring on the Morwell Fault (Figure 1). Loss and damage estimates were made from the ground shaking map shown in Figure 1, which was based on a ground motion prediction equations for bedrock conditions and took into account the quantifying efforts of the overlying soil. Losses to property and infrastructure were calculated using the methodology developed by the US Federal Emergency Management Agency (FEMA), through the HAZUS model. This methodology is based on deriving statistical models for a functional relationship between physical earthquake parameters such as peak ground acceleration (PGA), velocity (PGV), displacement (PGD) and response spectrum and a building’s response to shaking.

Six power stations (Yallourn, Hazelwood, Jeeraland, Loy Yang A, Loy Yang B and Valley Power) could potentially be impacted by a M6.0 earthquake along the Morwell Fault. The HAZUS model defines four types of damage states (slight, moderate, extensive and complete damage) for generation plants and the probability of damage (Table 1). See Table 2 and Figure 2 for estimated PGA at each power station and the probability of damage.

If any number of these power stations, their substations and/or the power lines supplying the State were damaged, there would undoubtedly be major disruption and wide-spread impacts. A significant seismic event in this region could potentially impact infrastructure that is responsible for producing 90% of Victoria’s required electricity. The true impact of a major power failure in Victoria cannot be fully described without understanding the ability of emergency services to conduct rescue operations with limited power supply; the length of time Victorian businesses will be able to operate without electricity; and the capacity of peaking facilities throughout the State to restore power to the grid in case of a major power failure.

Table 1: HAZUS definitions of damage states for generation plants

Damage state	Damage to generation plants
Slight/Minor Damage (ds <sub>2</sub> )	ds <sub>2</sub> is defined by turbine tripping, or light damage to diesel generator, or by the building being in minor damage state
Moderate Damage (ds <sub>3</sub> )	ds <sub>3</sub> is defined some by the chattering of instrument panels and racks, considerable damage to boilers and pressure vessels, or by the building being in moderate damage state
Extensive Damage (ds <sub>4</sub> )	ds <sub>4</sub> is defined by considerable damage to motor driven pumps, or considerable damage to large vertical pumps, or by the building being in extensive damage state
Complete Damage (ds <sub>5</sub> )	ds <sub>5</sub> is defined by extensive damage to large horizontal vessels beyond repair, extensive damage to large motor operated valves, or by the building being in complete damage state.



Table 2: Estimated PGA at power station site and each power station’s contribution to power production.

Power station	PGA (g)	Power generation
Yallourn	0.36	supplies approximately 22 percent of Victoria’s electricity needs and approximately eight percent of the National Electricity Market (NEM) (EnergyAustralia, 2014).
Hazelwood	0.26	supplies between 20 and 25 percent of Victoria’s energy requirements and 5.4 percent of Australia’s energy demand (GDF SVEZ Australian Energy, 2014a).
Jeeralang	0.21	The station is a peaking facility which is utilised only during periods of peak demand, it is also used as a black start facility to restore power to the grid in the event of major system failure.
Loy Yang A	0.1	Supplies approximately 30 percent of Victoria's power requirements (AGL, 2014).
Loy Yang B	0.09	supplies about 17 per cent of Victoria’s energy needs (GDF SVEZ Australian Energy, 2014b).
Valley Power	0.09	Peaking facility

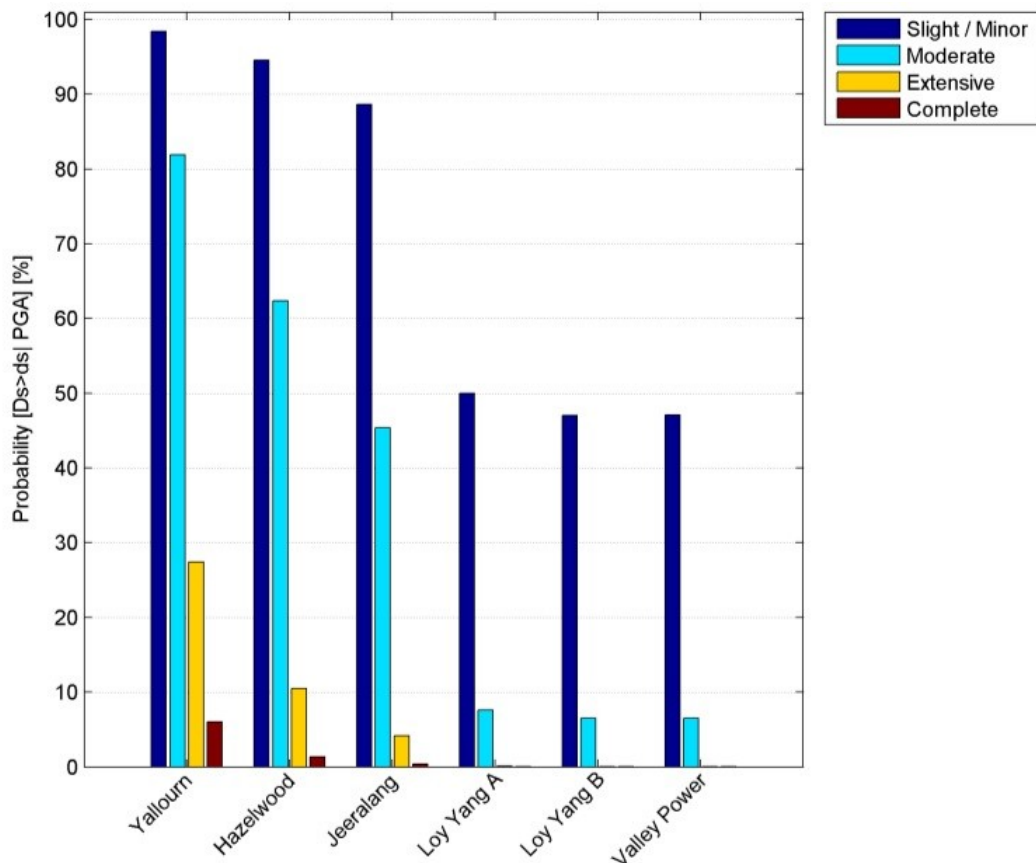


Figure 2: Probability of damage to power stations during at M6.0 earthquake on the Morwell Fault.



## CONCLUDING REMARKS

In the preliminary work carried out for Victoria CFA, we considered losses and disruptions to lifelines in isolation, not taking into account the interactions between different elements, and only in a very general manner addressed the long-range/long-term impacts of natural disasters.

The current research project will create a model that can help answer questions such as:

- which areas of Victoria would most likely be blacked out? and
- which hospitals and fire stations would be most under-pressure?

This integrated analysis will also shed light on the increased costs and travel times of transportation; how this could affect emergency response, and what would be the economic impacts both state- and Australia-wide. To be able to do so, this project will require the following steps:

1. Collection of data describing infrastructure networks, such as roads, power and water
2. Modelling as a connected network considering the interactions between different lifeline elements
3. Overlaying this modelling with event hazard layers, and developing vulnerability functions to estimate losses to nodes and/or links between nodes
4. Analysing the post-event network to establish its efficiency, possible bottlenecks and impact to hubs

Such realism in modelled scenarios can help emergency and planning agencies better prepare and allocate resources more effectively.

## REFERENCES

- ABC. 2009. *Melbourne blackout causes chaos* [Online]. ABC. Available: <http://www.abc.net.au/news/2009-01-30/melbourne-blackout-causes-chaos/278640> [Accessed 22/08/2014].
- AGL. 2014. *AGL Loy Yang* [Online]. Available: <http://www.agl.com.au/about-agl/how-we-source-energy/thermal-energy/agl-loy-yang> [Accessed 22/08/2014].
- AUSTRALIAN BUREAU OF STATISTICS. 2013. *The exceptional heatwave of January-February 2009 in south-eastern Australia* [Online]. Available: <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/D9CC49B3D42A8623CA25773700169C27?opendocument> [Accessed 18/8/2014].
- BURBIDGE, D. & LEONARD, M. 2011. The 2012 Australian Seismic Hazard Map - Draft Maps. *Australian Earthquake Engineering Society 2011 Conference, 18-20 November*. Barossa Valley, South Australia.
- DMYTRYSHCHAK, G. 2014. *Volcanic ash cloud grounds Bali flights* [Online]. Fairfax Media. Available: <http://www.smh.com.au/travel/volcanic-ash-cloud-grounds-bali-flights-20140531-39b0k.html> [Accessed 18/08/2014].
- ENERGYAUSTRALIA. 2014. *Yallourn Power Station* [Online]. Available: <http://www.energyaustralia.com.au/about-us/what-we-do/generation-assets/yallourn-power-station> [Accessed 22/08/2014].



- GDF SVEZ AUSTRALIAN ENERGY. 2014a. *Hazelwood* [Online]. Available: <http://www.gdfsuezau.com/about-us/asset/Hazelwood> [Accessed 22/08/2014].
- GDF SVEZ AUSTRALIAN ENERGY. 2014b. *Loy Yang B Power Station* [Online]. Available: <http://www.gdfsuezau.com/about-us/asset/Loy-Yang-B-Power-Station> [Accessed 22/08/2014].
- HOUSTON, C. & REILLY, T. 2009. *Heat leaves \$100m black hole* [Online]. Fairfax Media. Available: <http://www.theage.com.au/national/heat-leaves-100m-black-hole-20090131-7ugc.html> [Accessed 18/08/2014].
- IATA 2010. The impact of Eyjafjallajokull's volcanic ash plume. *IATA Economic Briefing*.
- MCEVOY, D., AHMED, I. & MULLETT, J. 2012. The impact of the 2009 heat wave on Melbourne's critical infrastructure. *Local Environment*, 17, 783-796.
- MEDIAWORKSTV. 2013. *Investing in Christchurch 'doesn't stack up'* [Online]. Available: <http://www.3news.co.nz/Investing-in-Christchurch-doesnt-stack-up/tabid/421/articleID/296005/Default.aspx> [Accessed 21/05/2013].
- MEDIAWORKSTV. 2014. *Aucklanders still without hot water after storm* [Online]. Available: <http://www.3news.co.nz/Aucklanders-still-without-hot-water-after-storm/tabid/423/articleID/348756/Default.aspx> [Accessed 30/07/2014].
- MOON, I. & LEE, L. 2012. Review on modelling and simulation of large-scale and complex disaster scenarios. *SCS M&S Magazine*. Society for Modeling & Simulation International
- MURRAY, A. T. 2013. An overview of network vulnerability modelling approaches. *GeoJournal*, 78, 209-221.
- NZ NEWSWIRE. 2014a. *Many without power as storm moves east* [Online]. Microsoft. Available: <http://news.msn.co.nz/nationalnews/8858242/wild-storm-wreaks-havoc-in-auckland> [Accessed 30/07/2014].
- NZ NEWSWIRE. 2014b. *Trimmed tress can prevent power outages* [Online]. Microsoft. Available: <http://news.msn.co.nz/nationalnews/8858905/trimmed-tress-can-prevent-power-outages> [Accessed 30/07/2014].
- PARKER, M. & STEENKAMP, D. 2012. The economic impact of the Canterbury earthquakes. *Reserve Bank of New Zealand: Bulletin*.



# URBAN SEARCH AND RESCUE OPERATIONS IN TROPICAL CLIMATES

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**M. Brearley<sup>1</sup>, I. Norton<sup>1</sup>, M. Hutton<sup>2</sup>, D. Rush<sup>3</sup>, S. Smith<sup>3</sup> and H. Fuentes<sup>4</sup>**

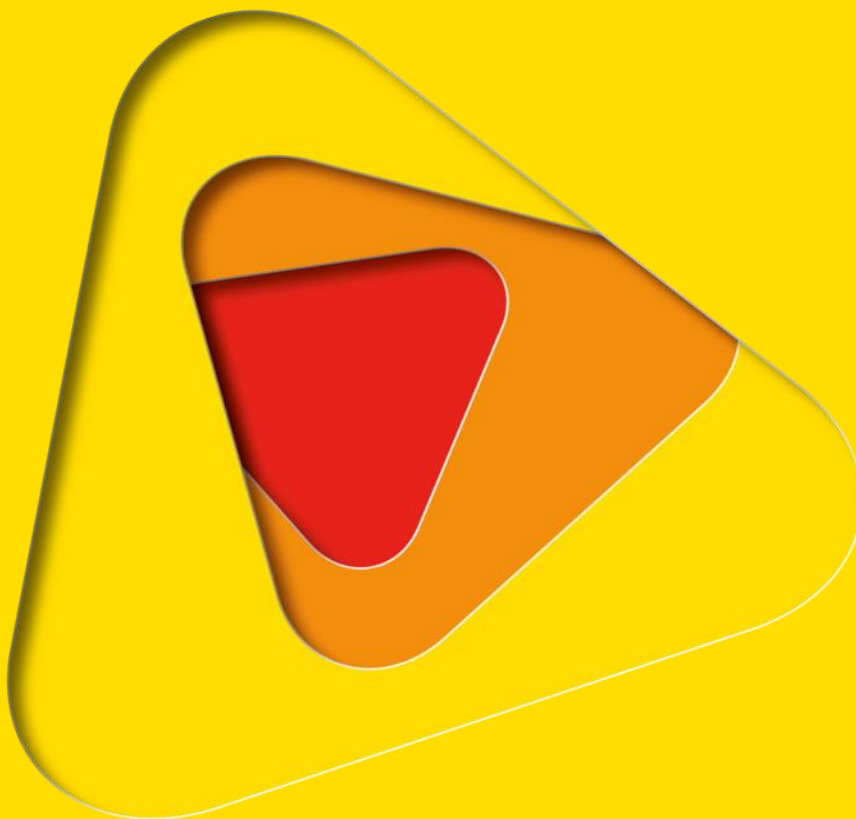
<sup>1</sup>National Critical Care and Trauma Response Centre

<sup>2</sup>Northern Territory Fire and Rescue Service

<sup>3</sup>Queensland Fire and Rescue Service

<sup>4</sup>Princess Alexandra Hospital

Corresponding author: [matt.brearley@nt.gov.au](mailto:matt.brearley@nt.gov.au)





## ABSTRACT

The physiological burden of Urban Search and Rescue (USAR) operations in the tropics is poorly understood. Sixteen trained USAR personnel (90.4kg, 1.81m, 39.6yrs) participated in a 24hr simulated exercise conducted during November in Northern Australia. Participants provided written informed consent for this study and were recruited from NT Fire and Rescue and QLD Fire and Emergency Services, resulting in 8 heat acclimatised (HA) and 8 non-heat acclimatised (NHA) responders. Physiological monitoring included core temperature ( $T_c$ ) through the use of ingestible thermometers based on established protocols<sup>1</sup>. The initial 4 hour shift (ambient 34.0°C, 48% relative humidity) resulted in 15 of the 16 participants exceeding the ISO9886  $T_c$  safe working limit of 38.5°C. From the 80<sup>th</sup> minute of the initial shift, HA sustained a significantly ( $p < 0.01$ ) higher  $T_c$  (38.6°C) than the NHA cohort (38.1°C) despite both groups perceiving their body temperature equally as hot. Following the initial shift, only 2 participants exceeded  $T_c$  38.5°C, likely due to crews suffering from the heat strain endured during the first 4 hours. Seven (5 NHA, 2 HA) of the 16 participants presented to medical staff during this period with symptoms of headache, nausea and exhaustion. Pacing of effort was apparent for non-heat acclimatised personnel. Year round heat acclimatisation through physical training is likely to improve operational capability of deployed teams. More frequent rotation of crews to permit monitoring through a rehabilitation sector, inclusive of active cooling options, is likely to reduce physiological strain and heat related illness during deployment to tropical regions.

## INTRODUCTION

Emergency and disaster response in austere environments, particularly extreme heat, pose significant challenges to response teams. Urban Search and Rescue (USAR) teams, are expected to respond within a matter of hours to an earthquake affected site and provide rescue for those entrapped in collapsed buildings. Teams work long hours, inclusive of night and day shifts for up to 14 days, in confined space and sometimes impermeable protective clothing irrespective of the climatic conditions or individual heat acclimatisation status. Australia's proximity to the earthquake prone Asia-Pacific region (Simpson et al., 2008) increases the likelihood of USAR response to hot climates that are conducive to body heat storage, increasing the likelihood of acute heat illness and/or cumulative heat stress and impacting operational capability.

While emergency responders have been studied exercising at standardised workloads in climate control chambers (McLellan and Selkirk, 2006), little is known of their physiological and perceptual responses to working in tropical field conditions. Unlike laboratory trials, field based simulations incorporate self-pacing. Hot and humid field settings are yet to be examined to determine if non-heat acclimatised (NHA) emergency responders experience greater physiological perturbation than their heat acclimatised (HA) counterparts, potentially impacting upon productivity due to pacing of effort. Therefore, this investigation examined the physiological and perceptual responses of heat and non-heat acclimatised USAR personnel during a 24-hour exercise in tropical field conditions.

## METHOD

Sixteen USAR personnel provided written informed consent prior to participating in a simulated 24hr exercise at the Yarrowonga training facility on the outskirts of Darwin, Northern Territory (NT), Australia. Five heat acclimatised men were recruited from NT Fire and Rescue with the remaining 11 men from Queensland Fire and Rescue. Of the Queensland (QLD) recruits, three were from the





Northern tropics and considered heat acclimatised, resulting in groups of eight heat and eight non-heat acclimatised (Table 1). The QLD recruits travelled via Brisbane, QLD to Darwin on the morning of the exercise, the four hour commercial flight simulated travel to deployment region. Immediately following collection of equipment and supplies, the crew travelled from Darwin Airport to the USAR training facility where they met with the research team and the five local USAR responders to commence the exercise. The exercise was conducted in mid-November, known for its harsh tropical environment with high ambient temperatures and elevated humidity, replicating conditions experienced within the Asia-Pacific region. The exercise commenced at 1300, with the afternoon period considered the hottest part of the day. Two groups of eight USAR personnel with equal allocation of HA and NHA participants were formed and worked in unison for the initial ~3.5 hour period. Thereafter, the teams rotated such that each team worked ~14.5 hours of the 24 hour exercise.

### **GASTROINTESTINAL TEMPERATURE, HEART RATE AND RESPIRATORY RATE**

Participants had gastrointestinal temperature ( $T_{gi}$ ) measured by an ingestible temperature sensor (Jonah, VitalSense, Respronics, Pittsburgh, Pennsylvania, USA) consumed with food ~45 minutes prior to data collection. It's likely that the ingestible pill transmitted stomach temperature during the first hour of the exercise. Stomach temperature is susceptible to fluctuations with fluid consumption, however water was stored in ambient conditions that minimised the gradient between  $T_{gi}$  and water temperature. The initial stages of the ingestible pill has been validated as a measure of core temperature (McKenzie and Osgood, 2004), and transmitted  $T_{gi}$  to a wearable receiver (SEM, Equivital, Hidalgo Ltd, Cambridge, UK) that also recorded heart rate and respiratory rate for storage.

*Figure 1. Participants transporting a victim during the initial shift of the exercise.*





## FLUID BALANCE VARIABLES

Urine specific gravity (USG) was assessed with a calibrated refractometer (Atago UG- $\alpha$ , Tokyo, Japan) as an indice of hydration status pre- and post-exercise.

Dehydration was estimated from body mass change during the initial shift and from to start to end of the exercise. Prior to commencing the exercise, participants were weighed semi-nude on a portable calibrated platform scale (UC321 A&D Mercury, Adelaide, SA, Australia), accurate to 0.05kg. Following the initial shift and at the conclusion of the exercise, participants removed attire and towelled non-evaporated perspiration from the skin and hair prior to body mass measurement. The resultant dehydration estimation was expressed as a percentage of pre-exercise body mass according to the following equation:

$$\text{Dehydration (\%)} = (\text{Body Mass Loss} \times 100) / (\text{Pre-Study Body Mass})$$

USAR personnel had ad libitum access to their drink bottle and/or fluid reservoir during the exercise. Non-refrigerated bottled water was provided for participants and stored at ambient temperature in the 'clean zone', remote from operations. Each team delivered water to personnel in the 'work zone' at regular intervals. Fluid consumption was monitored by determining the mass of individual hydration reservoir and/or bottle(s) pre- and post-consumption. It was assumed that 1 kg was equal to 1 L of fluid, and the difference in mass was the volume of fluid consumed. Fluid consumption was measuring the difference between pre- and post-initial shift drink bottle mass/hydration reservoir mass according to the following formula:

$$\text{Fluid Consumption (kg)} = (\text{Pre Drink Bottle/Reservoir Mass} - \text{Post Drink Bottle/Reservoir Mass})$$

Fully clothed body mass was determined immediately prior to and following toilet breaks, with the body mass difference equalling urine volume.

Sweat loss and sweat rate were calculated by the following respective equations:

$$\text{Sweat Loss (L)} = \text{Dehydration} + \text{Fluid and Food Consumption} - \text{Urine and Faecal Output.}$$

$$\text{Sweat Rate (L.hour}^{-1}\text{)} = \text{Sweat Loss/Hours.}$$

## PERCEPTUAL VARIABLES

Perceptual ratings of thermal sensation and discomfort were assessed prior to and following each shift via the modified numeric and descriptive scales of Gagge et al. (1967). Participants were asked "How does your body temperature feel?", with a numerical rating of 7 corresponding with the descriptor 'neutral'. Ratings of 1–6 equated to unbearably cold to slightly cool, while 8–13 corresponded with slightly warm to unbearably hot. Thermal discomfort was assessed by asking "How does your body temperature make you feel?" A rating of 1 was comfortable whereas 5 represented extreme discomfort.

## ENVIRONMENTAL CONDITIONS

Ambient environmental dry bulb temperature (DBT), wet bulb temperature (WBT), relative humidity (RH) and black globe temperature (BGT) were continuously assessed and recorded by an environmental monitor (QuesTemp 36, Quest Technologies, Onoconomac, WI, USA). The unit will be



positioned in full sunlight adjacent to the work zone throughout the study. The monitor calculated the Wet Bulb Globe Temperature (WBGT) (Yaglou and Minard, 1957) index by the following equation.

$$\text{WBGT } (^\circ\text{C}) = (0.7 \cdot \text{WBT}) + (0.2 \cdot \text{BGT}) + (0.1 \cdot \text{DBT})$$

## STATISTICAL ANALYSIS

A clustered linear regression, controlling for participant body mass and time, was performed for each phase, to determine differences between the HA and NHA cohorts for  $T_{\text{gi}}$ , HR and RR.

A two sample t-test with equal variances analysed post-exercise USG, sweat rate ( $\text{mL} \cdot \text{hour}^{-1} \cdot \text{kg body mass}^{-1}$ ) and dehydration (% body mass) for differences between the HA and NHA groups. All statistical analyses were performed with Stata (version 13.1, StataCorp, College Station, TX, USA).

## RESULTS

### PARTICIPANT CHARACTERISTICS

The characteristics of the HA and NHA cohorts are summarised by table 1. The NHA cohort had significantly higher age, body mass and body mass index than the HA group ( $p < 0.05$ ).

Table 1. Participant composition.

	Heat Acclimatised	Non Heat Acclimatised
n	8	8
Age (years)	37.9	41.3*
Body Mass (kg)	86.2	95.7*
Height (m)	1.79	1.83
Body Mass Index ( $\text{kg} \cdot \text{m}^{-2}$ )	26.9	29.2*

\* denotes significantly different ( $p < 0.05$ ).

### ENVIRONMENTAL CONDITIONS

The mean environmental conditions of the initial 4 hour shift were  $34.0^\circ\text{C}$  DBT, 48% RH and WBGT of  $31.4^\circ\text{C}$ , confirming the hostile climate for thermoregulation. Mean environmental conditions for the exercise were  $29.4^\circ\text{C}$  DBT, 72% RH and WBGT of  $27.9^\circ\text{C}$ .

### INITIAL SHIFT RESPONSES

The results of the initial shift demonstrated the greatest physiological perturbation and are considered crucial to the responses observed in the subsequent stages of the exercise. While the combined mean  $T_{\text{gi}}$  during the initial shift was  $38.2^\circ\text{C}$ , the maximal  $T_{\text{gi}}$  was  $39.6^\circ\text{C}$ , with 6 participants attaining a  $T_{\text{gi}}$  of  $39.0^\circ\text{C}$  or more.

During the initial shift, the HA cohort exhibited a slightly higher mean  $T_{\text{gi}}$  ( $38.3^\circ\text{C}$ ) than the non-heat acclimatised group ( $38.1^\circ\text{C}$ ) ( $p = 0.09$ ), while sustaining similar mean heart ( $p = 0.35$ ) and respiratory rates ( $p = 0.41$ ) (Table 2). Figure 4 highlights the significantly higher mean  $T_{\text{gi}}$  sustained by the HA ( $38.5$  v  $38.1^\circ\text{C}$ ) cohort from the 70<sup>th</sup> minute of the initial shift ( $p < 0.01$ ). Just one of the 16 participants failed to attain a  $T_{\text{gi}}$  of  $38.5^\circ\text{C}$  during this shift, the recommended upper limit for  $T_{\text{gi}}$  of medically monitored, heat acclimatised employees by ISO9886. While individual workload was not quantified by this study, average HR of  $130.9 \text{ beats} \cdot \text{min}^{-1}$  confirms the considerable workload of the participants during the



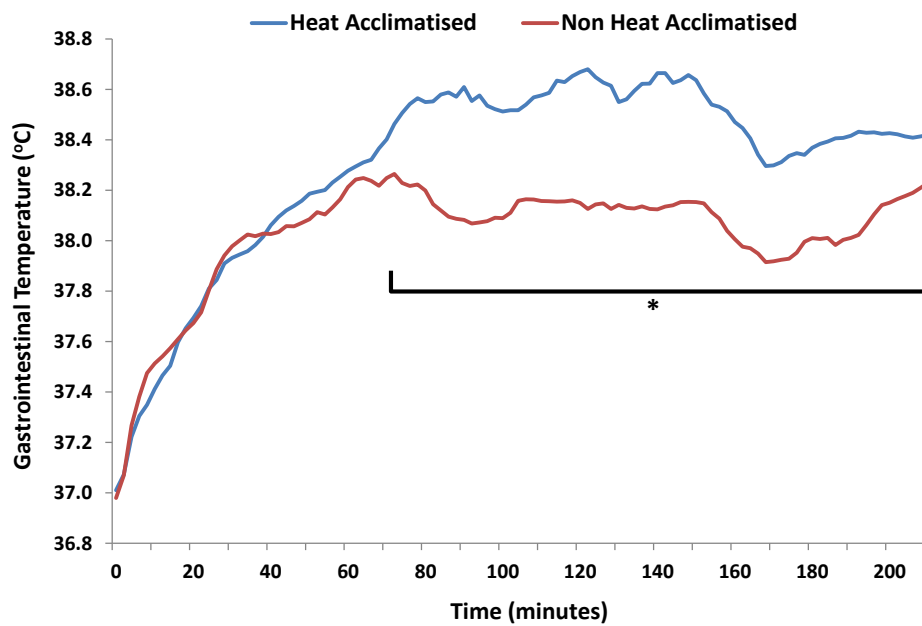
initial shift. Perceptual ratings from the first shift revealed that both cohorts rated their body temperature as hot, causing them to feel uncomfortable.

Table 2. Summary of physiological responses to the initial shift for the heat and non-heat acclimatised cohorts.

Physiological Variable	Non Heat Acclimatised	Heat Acclimatised	p value
Pre Shift USG	1.014 (0.009)	1.010 (0.008)	0.32
T <sub>gi</sub> (°C)	38.3 (0.5)	38.1 (0.4)	0.09 <sup>φ</sup>
HR (beats.min <sup>-1</sup> )	130.3 (18.8)	131.6 (24.2)	0.35
RR (breaths.min <sup>-1</sup> )	27.4 (6.1)	25.7 (6.8)	0.41
T <sub>gi</sub> >38.5 °C	8	7	-
T <sub>gi</sub> >39.0 °C	4	2	-
Fluid Consumption (L.h <sup>-1</sup> )	0.77 (0.21)	0.83 (0.19)	-
Fluid Consumption (mL.h <sup>-1</sup> .kg <sup>-1</sup> )	8.1 (2.5)	9.6 (2.1)	0.31
Sweat Rate (L.h <sup>-1</sup> )	0.84 (0.12)	0.98 (0.31)	-
Sweat Rate (mL.h <sup>-1</sup> .kg <sup>-1</sup> )	8.8 (0.9)	11.0 (3.2)	0.07 <sup>φ</sup>
Dehydration (%)	0.5	0.8	0.64
Thermal Sensation	10.2 (1.0)	10.1 (0.8)	0.89
Thermal Discomfort	3.0 (1.1)	3.1 (0.7)	0.89

<sup>φ</sup> Denotes a statistical trend (p<0.10)

Figure 2. Gastrointestinal temperature response of heat acclimatised and non-heat acclimatised USAR cohorts during the initial shift. \* denotes significantly different (p<0.01).





Pre-shift hydration was classified as minimally dehydrated (USG 1.013). Sweat losses ranged between 3.0 and 7.5L, averaging 4.8L for the initial shift, or  $0.89\text{L}\cdot\text{h}^{-1}$ , compared to fluid consumption of 4.3L or  $0.80\text{L}\cdot\text{h}^{-1}$ . Dehydration at the cessation of the first shift was 0.6% body mass with no difference between cohorts ( $p=0.64$ ). The HA cohort averaged a higher sweat rate of  $0.98\text{L}\cdot\text{h}^{-1}$  than the NHA ( $0.84\text{L}\cdot\text{h}^{-1}$ ) despite weighing a mean of 10.6kg less. When expressed as a factor of body mass, sweat rate was  $11.0\text{mL}\cdot\text{hr}^{-1}$  per kg body mass for HA that trended higher ( $p=0.07$ ) than the  $8.8\text{mL}\cdot\text{hr}^{-1}$  per kg body mass for NHA.

## OVERALL RESPONSES

Responses during the subsequent work shifts demonstrated lower physiological strain due to the cooler environmental conditions and a marked decrease in work rate (subjectively rated by research team). Of the 16 crew, just one participant exceeded  $38.5^{\circ}\text{C}$  during the evening/early morning shift, while one of the 14 participants (2 crew had passed pills during morning session) exceeded  $38.5^{\circ}\text{C}$  during the morning shift. The crews appeared to be suffering from the perturbation endured during the initial shift, a view supported by presentations to the medical team (Table 3).

## ILLNESS

Seven of the 16 participants reported to the medical team during the exercise with symptoms detailed by table 2. Presentations commenced 9.5 hours from commencement of the exercise and cannot be explained on the basis of their acute physiological observations or those of the preceding two hours (Table 3).

Table 2. Summary of presentations to the medical team during the exercise

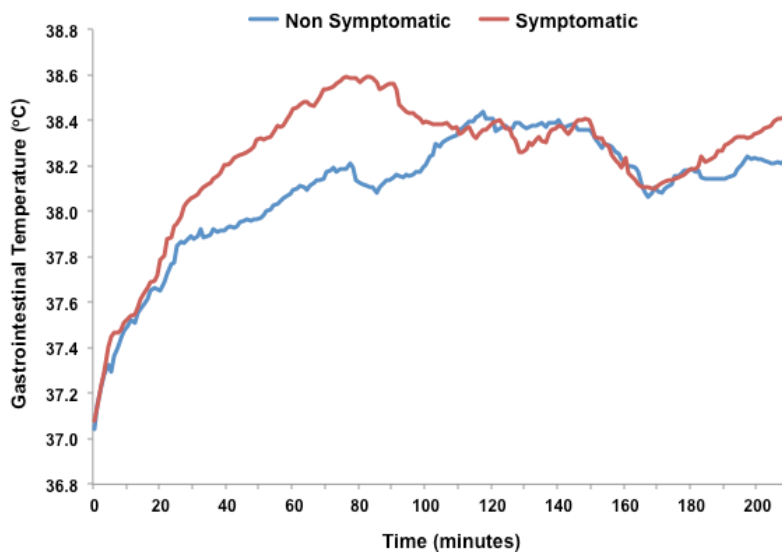
Participant	Elapsed Time (Hours)	Acute	Mean Observations	Presenting symptoms	Treatment or Outcome
		Observations (HR/T <sub>gi</sub> )	Previous 2 hours (HR/T <sub>gi</sub> )		
3*	9.5	104/37.3	114/37.5	N,H	Paracetamol and rested x20 minutes
15	9.5	131/37.8	113/37.3	N,H,F	Paracetamol and rested x20 minutes
1*	9.6	101/38.2	121/38.0	N,H	Paracetamol and rested x20 minutes
12	13.5	96/37.2	Sleeping	H,V	Ondansetron sublingual 8mg and continued work
16	18.0	117/37.4	96/37.3	N,H,F	Paracetamol and rested x20 minutes
10	20.7	132/38.2	130/37.4	N,H,F	Paracetamol and rested x20 minutes
13	21.3	125/37.4	113/37.3	N,H,F	Paracetamol and rested x20 minutes



\*denotes HA participant; N=Nausea; H=Headache; F=Fatigue; V=Vomiting

During the first hour of exercise, the likelihood of reporting to the medical team during the exercise was 1.5 times higher for every 10 beats.min<sup>-1</sup> increase in HR (p=0.05), and 1.9 times higher (although not statistically significant p=0.11) for every 0.3 °C increase in T<sub>gi</sub>. Figure 3 represents the T<sub>gi</sub> response of the symptomatic and non-symptomatic participants during the initial shift.

Figure 3. Gastrointestinal temperature response of symptomatic and non-symptomatic participants



## DISCUSSION

### INITIAL SHIFT

This study simulated a 24 hour USAR deployment to a tropical region, with the initial work shift permitting comparison of HA and NHA cohorts as all 16 participants worked the initial 3.5 hour shift. Based upon the HR data, a relatively high workload was sustained during the initial shift, an expected result given that well-being and motivation during such exercises are generally highest during the early stages. The outcome of the physical workload, combined with personal protective ensemble and the tropical climate manifested in substantial body heat storage beyond limits recommended for occupational groups during the initial stage. With 15 of the 16 responders exceeding ISO9886 recommendations for T<sub>gi</sub> limits, the initial shift represented a substantial physiological load. More moderate responses were observed for medical teams responding to a 3 hour simulated disaster in the tropics during milder conditions (Brearley et al., 2013), where mean T<sub>gi</sub> peaked at 37.8°C. In that study, the medical team were chronically HA and wore lightweight ventilated PPE, considered less insulative than the protective attire of the current investigation. Work rates of the medical responders based upon heart rate data appear substantially lower than the USAR personnel. Mean T<sub>gi</sub> during short duration (<3 hours) simulated field operations can approach 39.0 °C (Brearley et al., 2011; Walker et al., 2014), however, it's intuitive to expect lower T<sub>gi</sub> during longer duration exercises as responders pace their workload through the duration of deployment.





## HEAT ACCLIMATISATION

Appropriate pacing of effort requires an understanding of tasks, number of personnel available, timeframe for completion, anticipated climatic conditions and by factoring individual physical fitness, experience and acute physiological status (Edwards et al., 2010). While workload could not be accurately measured during this study, the physiological responses are indicative of pacing. Despite significantly higher  $T_{gi}$  of the HA responders from the 70<sup>th</sup> minute of the initial shift, the NHA and HA cohorts demonstrated similar HR, RR, thermal sensation and thermal discomfort. It's likely that responders selected their pace based upon their perception of body temperature in conjunction with physiological feedback to sustain their response. The result was a mean  $T_{gi}$  difference of 0.4 °C between cohorts. In laboratory settings with fixed physical workloads, excess body heat storage and higher cardiac frequency are observed for NHA due to an inferior ability to dissipate body heat (Lorenzo et al., 2010). This study is the first to show lower body heat storage of NHA in the field during a realistic simulation of emergency response.

Regular elevations in  $T_{gi}$  and associated sequale including elevated skin temperature, cardiovascular adjustments and perceptual strain induce physiological and psychological adaptations that manifest in superior tolerance of thermal stress. Such adaptations are beneficial when responding locally during seasonally hot conditions and to the Asia Pacific region that can be hot and humid year round. The lack of heat acclimatisation status of USAR personnel deploying from temperate regions will likely impact their ability to dissipate body heat and sustain moderate to high workloads, and should be factored into the overall operational capability of the team. In this regard, heat acclimatisation status can be considered a vulnerability of USAR personnel based in temperate regions. One group of emergency responders address heat acclimatisation on an individual basis. Australian Medical Assistance Team (AusMAT) members are encouraged to undertake training year round to maintain a level of physical fitness and operational readiness for tropical regions, and are provided individual guidelines for heat acclimatisation prior to deployment. Such an approach would assist USAR teams to dissipate body heat and limit pacing of effort during deployment.

## ILLNESS

The reporting of seven participants to the on site medical team highlights the physiological toll of responding in the tropics. Illness was not only an issue for NHA (5/8), but also the HA cohort (2/8). The acute HR and  $T_{gi}$  measurements could not explain the presentations, nor could the mean of the observations for the two hours preceding reporting ill. Interestingly, trends exist for higher HR or  $T_{gi}$  during the initial hour of the exercise influencing illness that was reported ~8 to 19 hours later. This is a novel finding worthy of additional research to identify the inflammatory response to working in the heat. Based upon the limited data available, excess heat exposure/body heat storage during the initial shift may have precipitated symptoms of headache and nausea, or what may be referred to as a 'heat hangover'. While more work is required, it's likely that limiting body heat storage during the initial stages of the response would mitigate the risk of illness during the latter stages of the exercise.

## FLUID BALANCE

It is not clear whether the trend for higher sweat rate relative to body mass for the HA cohort is due to the enhanced sweat production due to heat acclimatisation and/or the higher  $T_{gi}$ . Despite the substantial sweat rates, mean fluid consumption of 0.80L.h<sup>-1</sup> resulted in the crews minimising dehydration to less than 0.8% body mass during the initial shift. Ad libitum fluid consumption generally results in replacement of a lower proportion of fluid losses (Hendrie et al., 1997; Nolte et al., 2010),



indicating the proactive distribution of the unlimited supply of bottled water on site. Such fluid consumption rates are not likely to be matched during deployment unless USAR teams implement a structured approach to fluid provision. While fluid consumption is recognised as a strategy to limit the impact of dehydration however, hydration does not confer immunity against the development of exertional heat illness (Cuddy and Ruby, 2011). Prevention of significant dehydration in combination with strategies that limit body heat production and augment body heat loss (cooling, heat acclimatisation) are more likely to limit the health impacts of USAR response in harsh environmental conditions.

## **COOLING STRATEGIES**

A wide range of heat stress mitigation strategies that include establishing shade, rotation of teams, movement of air (fans), removal of PPE during rest periods, use of air conditioning, application of cold towels to torso, water immersion and ingestion of crushed ice are some of the cooling strategies available to transfer body heat of USAR personnel to the environment (Brearley et al., 2011). The applicability of strategies will be site and resource dependant, however, a rehabilitation sector is recommended irrespective of resourcing.

Overall, the outcomes of this study highlight the substantial challenge faced by USAR responders deployed into a tropical region. The combination of preparation for hot climates and heat stress mitigation strategies are required to maintain operational capability in the tropics.

## **RECOMMENDATIONS**

Based upon the findings of this study, we recommend the annual delivery of heat awareness and management training to USAR personnel, and year round physical training to induce serial elevations of core body temperature and maintain a base level of heat acclimatisation irrespective of season. Monitoring of the environmental conditions during deployment and monitoring of responder work rate, body mass and medical observations are required to effectively manage the workload of crews.

Rotation of responders through a rehabilitation sector to facilitate monitoring and cooling are strongly recommended. Medically trained responders are urged to prioritise monitoring of USAR personnel while minimising their personal physical workload during the initial days of response in hot climates.

## **ACKNOWLEDGEMENTS**

This project was funded by a Trauma and Disaster Management (TRADIM) research grant. The research team acknowledge the commitment of NTFRS and QFES firefighters and management to this project. We thank Linda Ward for her biostatistical support.



## REFERENCES

- Brearley MB, Heaney MF, Norton IN (2013) Physiological responses of medical team members to a simulated emergency in tropical field conditions. *Prehospital and Disaster Medicine* 28(2), 139-44.
- Brearley M, Norton I, Trewin T, Mitchell C (2011) Fire Fighter Cooling in Tropical Field Conditions. Technical Report: National Critical Care and Trauma Response Centre.
- Cuddy JS, Ruby BC (2011). High work output combined with high ambient temperatures caused heat exhaustion in a wildland firefighter despite high fluid intake. *Wilderness and Environ Medicine* 22(2), 122-5.
- Edwards AM, Bentley MB, Mann ME, Seaholme TS (2011). Self-pacing in interval training: a teleoanticipatory approach. *Psychophysiology* 48(1), 136-41.
- Gagge AP, Stolwijk JA, Hardy JD (1967). Comfort and thermal sensations and associated physiological responses at various ambient temperatures. *Environmental Research* 1, 1-20.
- Hendrie AL, Brotherhood JR, Budd GM, Jeffery SE, Beasley FA, Costin BP, Zhien W, Baker MM, Cheney NP, Dawson MP (1997). Project Aquarius 8. Sweating, drinking, and dehydration in men suppressing wildland fires. *International Journal of Wildland Fire* 7(2), 145-158.
- Lorenzo S, Halliwill JR, Sawka MN, Minson CT. Heat acclimation improves exercise performance. *Journal of Applied Physiology* 109(4), 1140-7.
- McLellan TM, Selkirk GA. The management of heat stress for the firefighter: a review of work conducted on behalf of the Toronto Fire Service. *Industrial Health* 44(3), 414-26.
- Nolte H, Noakes TD, Van Vuuren B (2010). Ad libitum fluid replacement in military personnel during a 4-h route march. *Medicine and Science in Sports and Exercise* 42(9), 1675-80.
- Simpson A, Cummins P, Dhu T, Griffin J, Schneider J (2008). Assessing natural disaster risk in the Asia-Pacific region. *AusGeo News* 90.  
<http://www.ga.gov.au/ausgeonews/ausgeonews200806/disaster.jsp>. Accessed August 11, 2014
- Walker A, Driller M, Brearley M, Argus C, Rattray B (2014). Cold water immersion and iced slush ingestion are effective at cooling firefighters following a simulated search and rescue task in a hot environment. *Applied Physiology, Nutrition and Metabolism*. In press.
- Yaglou CP, Minard D (1957). Control of heat casualties at military training centers. *Archives of Industrial Health* 16, 302-305.

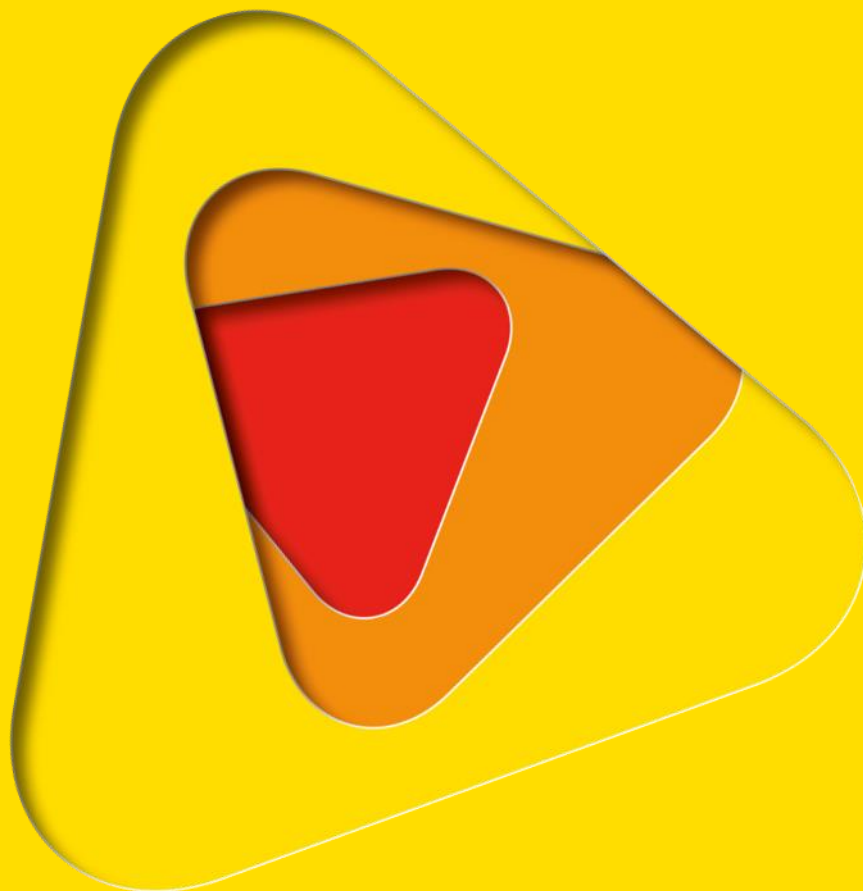


# MANAGING CRITICAL INFRASTRUCTURE IN A CHANGING CLIMATE: RISK, ROLES, RESPONSIBILITIES AND POLITICS

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**Karen Hussey and Stephen Dovers**  
Australian National University

Corresponding author: [karen.hussey@anu.edu.au](mailto:karen.hussey@anu.edu.au)





## INTRODUCTION

Critical infrastructure underpins essential services such as power, water, health, communications systems and banking and is vital to our way of life. However, a range of risks can damage or destroy critical infrastructure and disrupt these essential services. One such risk is that posed by natural disasters, and climate change may increase the frequency and intensity of those events and risks.

In 2010, the Australian Government released its *Critical Infrastructure Resilience Strategy*, which stressed that “the best way to enhance the resilience of critical infrastructure is to partner with owners and operators to share information, raise the awareness of dependencies and vulnerabilities, and facilitate collaboration to address any impediments.” While that Strategy, and similar initiatives such as the *National Strategy for Disaster Resilience*, provides a useful framework to guide action, there are a range of peculiarities, perverse incentives and governance barriers which need to be identified and considered, if Australia’s critical infrastructure is to become more resilient to current and future risks. These impediments exist particularly in relation to the allocation of risk associated with different types of infrastructure and the ownership and management arrangements thereof; the impacts to critical infrastructure from different natural hazards; and the role and responsibilities of State and Commonwealth governments, even where they neither own nor manage the infrastructure.

This paper focuses specifically on the role and responsibility of the Commonwealth in protecting critical infrastructure assets, and explores:

- How the definition of critical infrastructure may limit our understanding of climate-related risks to, and responsibilities for, assets
- The varied ownership arrangements of critical infrastructure assets and how this complicates the allocation of risk
- The explicit and implicit roles of the Commonwealth in managing critical infrastructure, and
- Where governance arrangements may need to be strengthened or altered in order to promote infrastructure adaptation, to reduce future risks.

## DEFINING CRITICAL INFRASTRUCTURE

How ‘critical infrastructure’ is defined influences the range of stakeholders that are deemed to have a role or responsibility in protecting it: what might seem trivial differences in definitions might make a big difference in policy and implementation. The Australian Government’s 2010 *Critical Infrastructure Resilience Strategy* (CIRS) defines critical infrastructure as “those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact on the social or economic wellbeing of the nation or affect Australia’s ability to conduct national defence and ensure national security” (2010: 8). This definition includes the traditional understanding of critical infrastructure as fixed, often stand-alone physical assets such as power plants, dams and sewerage treatment sites, as well as core transportation hubs such as airports and ports. The definition also includes infrastructure associated with the provision of health care and education, such as hospitals and schools, as well as the importance of non-physical assets, such as networks or supply chains. For example, bringing food from the paddock to the plate is dependent not only on particular key facilities, but also on a complex network of producers, processors, manufacturers, distributors and retailers and the infrastructure supporting them (2010: 8). In this definition, the communication capacities and roles of web-based systems also qualify these as



infrastructure, given their increasing importance in finance, trade, health information distribution and transfer payment enablement, disruption to which may be considered ‘critical’ in social and economic impact.

However, this definition of critical infrastructure overlooks the importance of natural assets in Australia’s long term economic and social welfare. For example, water catchments are in many locations the sole source of water resources to towns and cities but until recently, maintaining the integrity of a town’s water supply system has focused on the physical assets in the water supply system, and ignored the importance of the *catchment* in providing much-needed filtering and treatment of those water supplies. The compromising of the ACT water supply (Cotter catchment) following the 2003 bushfires was unprecedented, and similarly important catchments exist elsewhere and are potentially at risk (eg Sydney, Melbourne). In terms of disruption and consequence, whether, a city’s water supply is compromised by a catchment fire or an explosion that destroys a key transmission or treatment facility is immaterial. Similarly, the Great Barrier Reef is a natural asset of intrinsic worth, but it also underpins Queensland’s economy, contributing AUD\$1b in revenue annually: significant decay or destruction of the Great Barrier Reef – or even just access to it for a period of time - would be likely to have deleterious impacts on Queensland’s and Australia’s tourism industry.

In our view, it may be better to redefine critical infrastructure, altering the wording of the CIRS to:

“those assets which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact on the social or economic wellbeing of the nation or affect Australia’s ability to conduct national defence and ensure national security”.

Regarding climate risks and the issues of significance and national interest, extending the definition of ‘infrastructure’ might therefore be warranted, and this reveals new roles and responsibilities in the protection of critical infrastructure that are currently ignored.<sup>1</sup>

## **TYOLOGY OF CRITICAL INFRASTRUCTURE ASSETS**

Definitions of critical infrastructure vary, and thus typologies similarly vary, as do the regulatory and institutional arrangements that govern them. For example, infrastructure sectors range from unregulated competitive markets (ports and power generation) and regulated, private sector monopolies (energy networks and water) to state-procured public goods (motorways) (PWC 2010). The private sector is deeply involved in critical infrastructure, variously as investor, owner, operator, lender, insurer and, importantly, as a major user of economic infrastructure. It therefore has a key role in addressing the risks of climate change and ensuring the resilience of economic infrastructure in Australia. The nature of climate change risks, however, is that they generate broad social and economic externalities, which the private sector may not always take fully into account. In particular, in the absence of legislative or regulatory intervention, companies may be prepared to live with a level of climate change risk that is unacceptable to society.

Given that the focus of this paper is on the role of the Commonwealth Government in critical infrastructure risks and adaptation, the typology in Table 1 categorises critical infrastructure according to the *level of government* with de facto responsibility for the asset(s), and the type of *service* the

---

<sup>1</sup> An additional element to consider – but which is beyond the scope of this paper – is the link between the vulnerability of critical infrastructure assets to natural hazards and the knock-on threat to national security that may be created as a result of domestic unrest or home-grown terrorist threats. Threats to Australia’s national defence and natural security are traditionally seen as exogenous to the state, but it is not difficult to imagine a situation whereby the devastation caused by a natural disaster is exploited by domestic terrorist organisations to wreak yet more havoc.





infrastructure provides. The inclusion of ‘natural’ infrastructure is novel, but given the significant services these assets provide, we argue they are no less important.

The relationships and interdependencies between infrastructure assets is particularly important but also complex when considering the risks that climate impacts pose to critical infrastructure services. For example: the failure of water infrastructure can have perverse impacts on electricity infrastructure through loss of cooling agent; the failure of an electricity network can have impacts on hospitals and public transport; the failure of critical transport infrastructure can impact on functioning of key ports and trade, etc. In keeping with the broadening of the scope of the term to ‘systems of assets which support the provision of important services’, the typology indicates an approach that shifts attention from the piece of infrastructure to the actual social or economic role and value.

**Table 1: Local, State and Commonwealth government responsibilities for economic, social and natural infrastructure**

<b>Level of government</b>	<b>Economic infrastructure</b>	<b>Social infrastructure</b>	<b>Natural infrastructure (with social and/or economic significance)</b>
<b>Commonwealth</b>	Aviation services (air navigation etc) Telecommunications Postal services National roads (shared) Local roads (shared) Railways (shared)	Tertiary education Public housing (shared) Health facilities (shared)	Great Barrier Reef, Kakadu National Park
<b>State</b>	Roads (urban, rural, local) (shared) Railways (shared) Ports and sea navigation Aviation (some regional airports) Electricity supply Dams, water and sewerage systems Public transport (train, bus) Major goods distribution hubs.	Educational institutions (primary, secondary and technical) (shared) Childcare facilities Community health services (base hospitals, small district hospitals, and nursing homes) (shared) Public housing (shared) Sport, recreation and cultural facilities Libraries Public order and safety (courts, police stations, traffic signals etc) Prisons	Major water catchments Rivers, wetlands with major filtration or supply functions
<b>Local</b>	Roads ( local) (shared) Sewerage treatment, water and drainage supply Aviation (local airports) Electricity supply Public transport (bus)	Childcare centres Libraries Community centres and nursing homes Recreation facilities, parks and open spaces	Local/regional wetlands/ swales/bioretenion assets, protective dune systems



However, in many cases in Table 1, there is shared ownership of, and responsibility for infrastructure assets, sometimes in a legal or contractual sense with some clarity, or in an implicit sense in a realistic political context (see section 4). Whether that explicit or implicit shared ownership includes ‘ownership’ of new or exacerbated climate risk and recovery from disruption is highly variable and often ‘messy’. For example:

- Some infrastructure assets are solely government-owned assets, such as some highways, dams and some catchments,
- Some infrastructure assets are privately owned, such as some airports and ports, some electricity generation facilities,
- Some infrastructure assets are owned and operated through public-private partnership arrangements, such as a toll roads and trains, electricity distribution networks, and prisons
- Some infrastructure assets are community owned, such as irrigation systems and distributed energy systems, and
- Confusion exists with respect to the ownership versus service provision arrangements for some infrastructure assets, for example the supply and distribution of water resources from catchments.

It is this variation in ownership arrangements that makes the allocation of risk difficult to discern, especially for events that have yet to unfold. This area of complexity warrants further attention.

## **CRITICAL INFRASTRUCTURE AND THE ROLE OF THE COMMONWEALTH**

Identifying the appropriate role for the federal government, state/territory governments and private entities in adapting critical infrastructure to account for climate change is particularly complex because the threats posed by climate change are many, varied, inter-connected and almost inevitably uncertain in place, time and scale (IPCC 2012) and are subject to the complexity outlined in the previous section. The challenge is further complicated by the shift in recent decades towards a ‘shared responsibility’ model in dealing with natural hazards, involving ever-increasing numbers of state and non-state actors with varying degrees of responsibility and capacity (McLennan and Handmer 2011). Moreover, just as climate change impacts are location-specific, so too must adaptation responses be tailored to specific infrastructure assets and account for different threats to the same asset: in other words, there is unlikely to be a single one-size-fits-all tool which will be functionally applicable across all assets (Hussey *et al.* 2012).

Some authorities argue that adaptation is essentially a local-scale endeavour and that the role of the Federal Government should be minimal (Garnaut 2008), while others assert that promoting adaptation is a responsibility of all scales of governance (Dovers & Hezri, 2010). Stakeholders represented via reports such as Webb *et al* (2014) strongly believe that a crucial Commonwealth role is in the area of data provision/coordination and the promulgation of protocols, decision processes, etc. that *lie beyond the scope or capacity* of any other actor. Such a view is consistent with modern theories of governance in federal systems, where coordination (steering, not rowing) is an important role for national governments. Similarly, in responding to catastrophic national disasters, Eburn (2011) argues that the Commonwealth has significant interests in responding to disasters of national consequence and thus the role, powers and responsibilities of the Commonwealth should be enshrined in legislation to that effect (it is not, currently).

According to the CIRS, the role of the Australian Government lies in “understanding the vulnerabilities and dependencies in and across critical infrastructure sectors, and the risk mitigations being applied” as well as facilitating “national coordination where there are cross-jurisdictional issues, international treaty obligations, or where an incident would have national consequences or require a national response” (2010). However, in terms of public policy and responsibilities in a federal system, the term ‘critical’ is at once central and difficult to define. The CIRS uses ‘significant’ impacts on social or economic well-being,



and ‘national/international’ implications to imply a national/Commonwealth level of interest. International aspects of climate impact are clear enough, and ‘national’ may be interpreted as those matters within the Commonwealth’s (current or assumed) constitutional and legislative ambit. The matter of what is ‘significant’ enough is far more difficult to define, and may be measured, or at least debated, in terms of lives, severity or spread of non-fatal health impacts, social disruption or unrest, severity and spread of economic impact, and duration of disruption (drought versus heatwave, for example). There is little prospect of achieving quantified metrics defining a threshold of ‘national’ significance and thus Commonwealth involvement and, on the latter, the degree or largesse of that involvement. Also, there are thresholds of political imperative and moral obligation that are even more problematic (see below).

However, as a federated constitutional state, the areas in which Australia’s federal government is *legally* entitled to govern is laid down in the *Australian Constitution Act 1900* (UK) and is restricted to the ‘external affairs’ power and matters relating to taxation, health, postal and telegraphic communications, defence and counter-terrorism, insurance, trading corporations, and the payment of social security benefits (Australian Constitution s 51(xxix)). In practice, there are numerous issues and policy domains of relevance to climate change adaptation in which the Commonwealth has an interest in, or responsibility for, even in the absence of statutory powers. Successive Australian governments at both the state and federal level have designed and implemented a range of institutions to cope with those often-devastating events, including planning and development regimes, building codes, the provision of emergency services, mandatory insurance schemes and/or payments for exceptional circumstances, to name a few (see Appendix for further detail).

So the existence of numerous national strategies or policies that are climate-relevant suggests that while the degree of responsibility for the Commonwealth may be contested and vary between sectors, the fact that the Commonwealth has a role to play is not. Indeed, the Commonwealth’s role in funding relief and recovery efforts after the 2010-11 Queensland floods is a reminder of how pivotal the Commonwealth is in dealing with natural hazards; it is also a reminder of the duty the Commonwealth bears on behalf of the tax-payer to ensure relief and recovery bills are kept to a minimum (Wenger *et al.* 2013) and the on-going PC enquiry in this respect is welcome.

The following pose three bases for Commonwealth involvement, leaving aside the type and magnitude of that involvement:

***Because the Commonwealth has a legal responsibility:*** this is clear and relatively uncontested. The responsibility for adaptation lies with owners and operators of critical infrastructure assets, and as the typology in section 3 illustrates, there are a range of assets for which the Commonwealth is solely or in large part responsible.

***Because of the significance of the impact:*** this is much less clear and a future area of research lies in whether it is possible to identify a threshold beyond which the Commonwealth should get involved. Clearly, this would build on past experience around the declaration of natural disasters. However, there is a sizeable fiscal risk here, and the Commonwealth needs to explore the implications fully.

***Because of a political or moral obligation to act:*** this relates to the point above, though it is far more qualitative in nature. Loss of life, long-term disruption to services etc. may involve a political imperative or moral obligation on the Commonwealth to act. Government involvement is at times described as ‘political’ in a cynical sense of gaining political advantage or avoiding electoral costs. However, human suffering provokes reactions from governments (and others) that are validly and unavoidably based on social values and perceived moral obligations. That reality cannot be ignored in public policy. The lessons of 25 years of shifts in drought policy are apposite (Botterill and Dovers 2013).



The latter two situations mean that even where there may be no formal, legal arrangements that explicitly implicate the Commonwealth, their involvement may nevertheless be warranted. Perhaps the most significant lever the Commonwealth has to limit its exposure to climate-related risk is in the reallocation of disaster relief funds, but the following section outlines a range of other actions that could be implemented.<sup>2</sup>

## OPTIONS FOR COMMONWEALTH INVOLVEMENT

There is some evidence that asset owners (both public and private) here and elsewhere are beginning to take potential adaptation measures into account (Hussey et al 2013; PWC 2010). However, experience to date has highlighted a number of important challenges which the Commonwealth could usefully examine, key amongst which include:

**Information gaps:** The Australian Government has played a central role in the provision of information on climate change impacts and risks. This information is a public good, with wide application across society and the economy, and the important role by the Commonwealth in the provision of information about climate risks was reinforced by the recent PC report on climate adaptation and other studies (PC 2013; Webb 2013; Hussey et al. 2013; Wenger et al. 2013). However, given the broad remit of Government-led research, the information collected and provided through key initiatives tends to be generic or has a wider application, and many studies have found that the information currently available is not sufficiently detailed or tailored to their sectors and infrastructure to inform adaptation responses. Interestingly, efforts by individual companies and by industry collaborations in other countries are bridging these information gaps (PC 2010), which suggests there is growing awareness of the risk posed to private actors from climate risks. However, there is often a commercial incentive for industry to retain information and not share it in the public domain.

**Short-term regulatory focus:** In regulated sectors, regulators act upon the statutory duties determined by Government. Climate change adaptation is not explicitly prescribed as a statutory duty for many regulators, but is embodied within wider mandates (e.g. protection of short- and long-term consumer interest, security of supply). Regulators are adequately equipped with appropriate levers (including incentives and penalties, standards and regular pricing controls) to deliver these mandates and therefore incentivise adaptation. However, the strong emphasis on short-term value for money, especially against a backdrop of fiscal constraints, coupled with uncertainties around the severity of the long-term impacts of climate change mean that adaptation requirements are not yet being addressed on a systematic basis. Whilst in principle the regulatory framework is broadly fit for purpose in the context of climate resilience, there is a need to strengthen the focus on long-term resilience (Hussey et al. 2013). The Commonwealth could explore the potential benefits of a statutory duty on behalf of regulators to account for long term climate impacts in policy and investment decisions – much like occurred in the 1980s and 1990s in relation to health and safety concerns.

**Disclosing risks and managing uncertainties:** The most difficult challenge faced by many stakeholders in critical infrastructure sectors is the incorporation of uncertainties into the decision making process. There has been recent attention to processes, data needs and decision rules to insert climate risk considerations into decision making (e.g. Webb et al. 2014), though, again, confidence and consistency varies across sectors. Again, there is a critical role for the Commonwealth in providing a platform for the sharing of experiences, a role which is clearly articulated in the government's *Critical Infrastructure Resilience*

---

<sup>2</sup> The role of Commonwealth disaster relief funds are the subject of a Productivity Commission enquiry at the time of writing. Certainly, the need to shift the provision of DRR funds from post-disaster to prevention and mitigation measures is manifest (as evidenced by the vast majority of submissions to that enquiry).



*Strategy*, though whether the strategy has sufficient resources (human, financial and knowledge) supporting it remains to be seen.

A related point is that institutional investors in, and insurers of, infrastructure have a stake in timely adaptation and climate resilience. Greater disclosure of risks and actions by companies – possibly mandated by either state or commonwealth governments - could help to increase understanding within and between critical infrastructure sectors.

**Balancing priorities:** Even when climate change risks are considered, building in climate resilience needs to be balanced against other objectives, and with the exception of ‘no regrets’ or ‘quick win’ measures, adaptation tends to be a low priority. In competitive and unregulated sectors such as power generation and ports, adaptation investment faces competition for capital and for management time. Except for very large, long-life assets, or where the risk is particularly significant, adaptation may not always receive sufficient attention at Board level or from shareholders (PWC 2010). Grimsey and Lewis (2000: 111) identify nine risks to infrastructure projects: technical; construction; operating; revenue; financial; force majeure; regulatory/political; environmental; and project default risk due to a failure of the project from a combination of any of the above.

Some of these risks are highly relevant to climate impacts, but most refer to short term risks associated with the construction of critical infrastructure, and do not account for long term risks, the interdependencies between critical infrastructure assets, and the cumulative impacts of multiple climate impacts. And nor could they, because the framework for investment decisions does not provide incentives for such considerations, and, arguably, only governments are in a position to measure and account for those risks. However, even at procurement and construction stages, much can be done to mitigate longer term risks (e.g. consideration of physical design and location, changing or managing operational procedures, and building or retrofitting additional resilience features).

A point that has failed to garner much attention is the fact that by addressing climate risks, operators should see long-term benefits in more resilient infrastructure and enhanced security of supply and reduced costs, leading ultimately to a lower cost of capital, higher revenues (where customers are willing to pay for reliability and continuity of supply) and sustained long-term returns. It is therefore reasonable to expect long-term climate risk to be prominent in critical infrastructure design and management, and for organisations to work with other infrastructure companies, regulators and Government to address cross-sectoral risks and interdependencies. The Commonwealth has a role in – at the very least – facilitating that mainstreaming, and perhaps in some circumstances mandating it.

**Interdependencies between infrastructure assets:** There are strong inter-linkages within and between infrastructure sectors, as noted above. However the level of understanding of climate risks from these interdependencies is low (PWC 2012). Greater collaborative efforts between infrastructure sectors, regulators and Government are required to address these interdependencies. As suggested above, ‘working backwards’, from critical services to the asset systems that enable these, may be a useful perspective. The Australian Government’s *Trusted Information Sharing Network (TISN)* for Critical Infrastructure may be one fora where these issues could be explored.

## CONCLUSION

Australia has a high level of institutional capacity and extensive experience in managing climate-related risks, but our way of life is becoming increasingly integrated, inter-dependent and complex and as with all complex systems, the more integrated it becomes the more vulnerable it can be to shocks. As well as considering specific climate-related disaster events and emergency management and community capacities to deal with these, increasing attention is being paid to the resilience of ‘critical infrastructure’



in the face of future risks. This paper has (i) provided a more comprehensive typology of the assets that contribute to essential services (ii) identified some of the complexity in the ownership arrangements of critical infrastructure assets, and thus in the allocation of risk and (iii) defined areas of potential Commonwealth action. There is yet more complexity behind this brief analysis, all of which warrants further attention.





## REFERENCES

Botterill, L. and Dovers, S. 2013. Drought and water in the Murray Darling Basin: from disaster policy to adaptation. In: Boulter, S et al (eds). *Natural disasters and adaptation to climate change*. Cambridge University Press, Cambridge. PP67-74.

Cooper, B & Crase, L 2013, Leading gifted horses to water: The economics of climate adaptation in government-sponsored irrigation in Victoria, National Climate Change Adaptation Research Facility, Gold Coast, 67 pp.

Dovers, SR and Hezri, AA. 2010. Institutions and policy processes: the means to the end of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*. 1: 212-231.

Eburn, M. 2011. Responding to catastrophic natural disasters and the need for Commonwealth legislation. *Canberra Law Review*. 10(3): 81-102.

Garnaut, R. 2008. *Garnaut Climate Change Review*. Cambridge University Press: UK.

Grimsey, and Lewis, M. 2007, Public private partnerships and public procurement, *Agenda*, Volume 14, Number 2, 2007, pages 171-188

Handmer, J. and Brown, N. 2014 (in press). Disaster risk reduction. In: Lindenmayer, D., Dovers, S. and Morton, S. (eds). *Ten commitments revisited*. 2<sup>nd</sup> edition. CSIRO Publishing, Melbourne. PP289-98.

Hussey, K, Price, R, Pittock, J, Livingstone, J, Dovers, S, Fisher, D, Hatfield Dodds, S (2013) Statutory frameworks, institutions and policy processes for climate adaptation: Do Australia's existing statutory frameworks, associated institutions and policy processes support or impede national adaptation planning and practice?, National Climate Change Adaptation Research Facility, Gold Coast, pp. 193. Available at: <http://www.nccarf.edu.au/publications/statutory-frameworks-policy-processes>.

IPCC (Intergovernmental Panel on Climate Change).2012. *Special report on managing the risks of extreme events and disasters to advance climate change adaptation*. IPCC, Geneva.

McLennan, BJ. And Hander, J. 2012. Reframing responsibility-sharing for bushfire risk management in Australia after Black Saturday. *Environmental Hazards*. 11: 1-15.

PC (Productivity Commission). 2013. Barriers to effective climate change adaptation. March. Available: <http://www.pc.gov.au/projects/inquiry/climate-change-adaptation/report>

PWC (PricewaterhouseCoopers LLP), 2010, Adapting to climate change in the infrastructure sectors, Maintaining robust and resilient infrastructure systems in the energy, transport, water and ICT sectors. Available at: [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/183493/infrastructure-pwc-full.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/183493/infrastructure-pwc-full.pdf)

Webb. B., Petheram, L. and Weiske, P. 2014. LAPS 2 report to Department of Environment. Australian National University.

Wenger, C, Hussey, K, Pittock, J. (2013), Living with floods: Key lessons from Australia and abroad. National Climate Change Adaptation Research Facility, Gold Coast. Pp. 264. Available at: <http://www.nccarf.edu.au/publications/living-floods-key-lessons-australia-and-abroad>


## APPENDIX

### Key statutory and institutional frameworks to address selected climate impacts

Climate threat	Policy/regulatory frameworks categorized by level of governmental responsibility			Responsible Federal authority/institution
	Local government	State/Territory Government	Federal	
Disaster management (including emergency management), which contributes overarching policy and/or legislative responses to many of the threats listed below.		<p><i>Emergencies Act 2004 (ACT)</i></p> <p><i>State Emergency and Rescue Management Act 1989 (NSW)</i></p> <p><i>Disasters Act 1982 (NT)</i></p> <p><i>Disaster and Management Act 2003 (QLD)</i></p> <p><i>Emergency Management Act 2004 (SA)</i></p> <p><i>Emergency Management Act 1986 (Vic)</i></p> <p><i>Emergency Management Act 2005 (WA)</i></p>	<p>Australian Government Critical Infrastructure Resilience Strategy</p> <p>Australian Government Disaster Response Plan</p> <p>National Catastrophic Natural Disaster Plan</p> <p>National Strategy for Disaster Resilience</p>	<p>Attorney General's Department (Emergency Management Australia)</p> <p>National Emergency Management Committee (initiated by COAG)</p>



			National Risk Assessment Framework  National Partnership Agreement on Natural Disaster Resilience	
Increased frequency and intensity of <b>drought</b>	Local, regional and catchment-level water-sharing plans	Statutory planning for water sharing and allocation (All)  2010-2012 Pilot of drought reform measures in Western Australia (co-funded by Commonwealth)	2004 National Water Initiative and <i>2007 Water Act</i>  Funding (various): Farm Planning Program; Farm Management Deposits; Farm Family Support Program	National Water Commission (initiated by COAG)  National Rural Advisory Council (NRAC)
Projected global mean <b>sea-level rise</b> by 2100 of 0.18 to 0.59 m  <b>Storm surge and coastal flooding</b>	Coastal planning and development strategies	State planning and development legislation (All)  <i>QLD Coastal Protection and Management Act 1995</i>  Victorian Coastal Strategy 2008	<i>1999 Environmental Protection and Biodiversity Conservation Act</i> for lands under Commonwealth purview.  Framework for a National Cooperative Approach to Integrated Coastal Zone Management (ICZM)	Natural Resource Management Ministerial Council



Increased severity of tropical <b>cyclones</b>	Land planning and development strategies	State planning and development legislation (All)  State building codes	-	-
Reduced interval between <b>fires</b> , increased fire intensity, a decrease in fire extinguishments and faster fire spread	Land planning and development strategies	State planning and development legislation (All)  State building codes  Bushfire management plans (various)	<i>EPBC Act 1999</i> <sup>3</sup>	Nothing specific to bushfires <i>per se</i> - federal engagement is covered under the National Emergency Management Committee which services relevant COAG committees
Extreme precipitation leading to increased frequency and possibly intensity of <b>floods</b>	Local planning and development strategies	State planning and development legislation  Detailed planning provisions for floodplain management (various)	National Flood Management Guidelines  Emergency Management Manuals  - #19 Managing the Floodplain (1999) - #7 Land Use Planning for Natural Hazards (2002)	Nothing specific to floods <i>per se</i> - federal engagement is covered under the National Emergency Management Committee which services relevant COAG committees

<sup>3</sup> The state and territory governments have primary responsibility for care and management of the environment. National environment law does not generally regulate fire prevention measures taken by state and territory governments, and only applies in limited circumstances. Fire prevention activities only need federal environmental approval if (i) they are likely to have a significant impact on a nationally protected matter, and (ii) they are not specifically exempted by the national environment law.



		Coastal zone management	- #20-#23 Flood Risk and Management  National Water Initiative (indirectly)	
--	--	-------------------------	---	--



# THE EFFECTS OF FIRE-PLUME DYNAMICS ON THE LATERAL AND LONGITUDINAL SPREAD OF LONG-RANGE SPOTTING

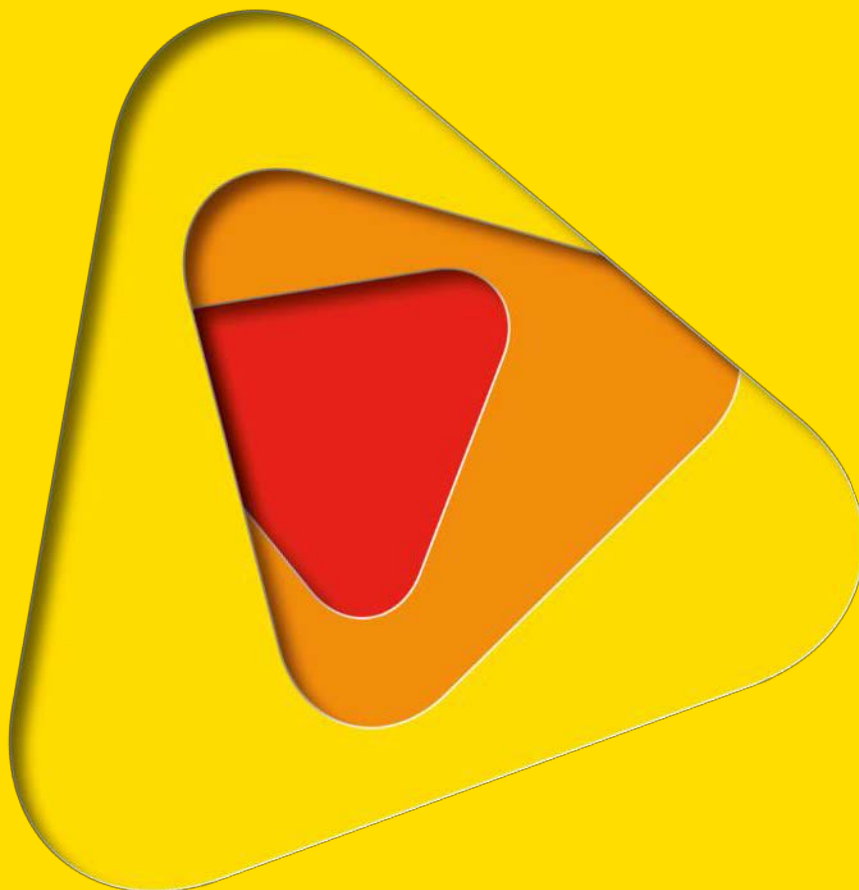
PROCEEDINGS OF THE RESEARCH FORUM AT THE BUSHFIRE AND  
NATURAL HAZARDS CRC & AFAC CONFERENCE  
WELLINGTON, 2 SEPTEMBER 2014

*William Thurston<sup>1</sup>, Kevin J. Tory<sup>1</sup>, Jeffrey D. Kepert<sup>1</sup> and Robert J. B. Fawcett<sup>1,2</sup>*

<sup>1</sup>Centre for Australian Weather and Climate Research

<sup>2</sup>The Bureau of Meteorology

Corresponding author: [w.thurston@bom.gov.au](mailto:w.thurston@bom.gov.au)







# The effects of fire-plume dynamics on the lateral and longitudinal spread of long-range spotting

William Thurston<sup>\*1,2</sup>, Kevin J. Tory<sup>1,2</sup>, Jeffrey D. Kepert<sup>1,2</sup> and Robert J. B. Fawcett<sup>1,2,3</sup>

<sup>1</sup>*The Centre for Australian Weather and Climate Research, Docklands, Vic. 3008, Australia*

<sup>2</sup>*Bushfire and Natural Hazards CRC, Albert Street, East Melbourne, Vic. 3002, Australia*

<sup>3</sup>*The Bureau of Meteorology, Docklands, Vic. 3008, Australia*

## Abstract

The lofting of firebrands from bushfires into a background atmospheric flow can lead to spotting downwind of the fire front. Spotting is a hazardous phenomenon because it leads to both unpredictable and accelerated fire spread, as winds aloft are often in a different direction from and faster than the near-surface winds. Here we use a two-stage modelling process to address some of the uncertainty associated with spotting, by quantifying the lateral and longitudinal spread in the landing location of potential firebrands and how this spread is affected by the dynamics of the fire plume.

Firstly, we present high resolution, three-dimensional numerical simulations of bushfire plumes using the UK Met Office Large-Eddy Model (LEM). Plumes are simulated under a range of background wind conditions and the intensity, size, morphology and temporal stability of the resulting plumes are examined. Secondly, we use a Lagrangian particle transport model to calculate the trajectories of particles released near the base of each plume. Particles are assigned fall velocities representative of common firebrands and then advected by the three-dimensional velocity fields from the LEM simulations minus the specified fall velocity. By calculating the trajectories of hundreds of thousands of potential firebrands for each plume, distributions of landing position are constructed. We find that: (i) interaction between the plume updraft and the background wind determines the distance travelled by firebrands, and (ii) the morphology of the plume determines the lateral and longitudinal spread of landing positions. These variations need to be properly accounted for in predictive models of fire spread and systematic studies such as this form the building blocks of better empirical spotting models.

## 1 Introduction

Fire spotting is a hazardous phenomenon which can lead to unpredictable fire behaviour and accelerated fire spread. Spot fires occur when firebrands are lofted into strong ambient winds and ignite new fires downwind; the process being called spotting. This spotting increases the unpredictability and speed of fire spread because winds aloft are often in a different direction from and faster than the near-surface winds. An idea of the magnitude of the problem is given by Cruz et al. (2012), who present evidence of long-range spotting in excess of 30 km during the Black Saturday bushfires of February 2009. A thorough knowledge of the potential for lofting from a fire is therefore desirable in order to accurately predict the rate of spread and coverage of bushfires. In this paper we attempt to address

---

\*W.Thurston@bom.gov.au

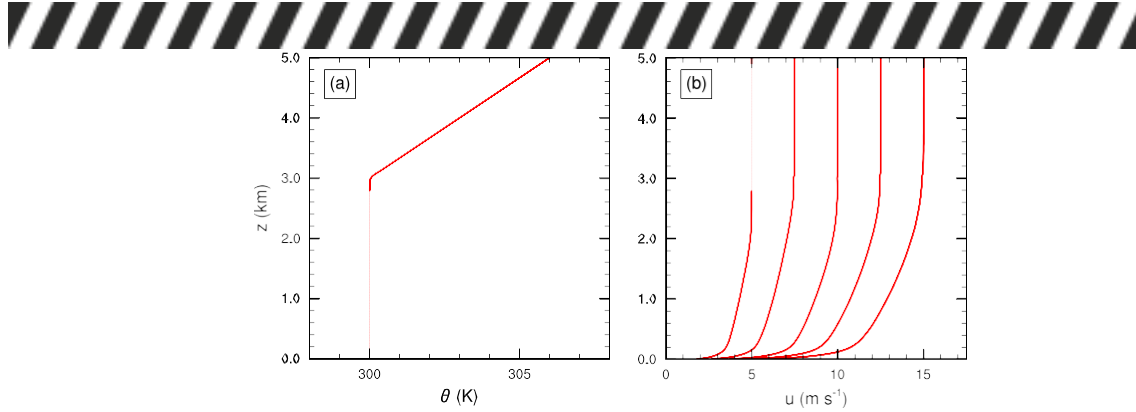


Figure 1: Domain-averaged profiles of the mean conditions in the spun-up quasi-steady state atmosphere prior to plume initialisation. (a) Potential temperature, K, and (b) horizontal wind speed,  $\text{m s}^{-1}$ , for each of the five different background-wind simulations.

some of the uncertainty associated with spotting by specifically considering how interactions between the fire plume and the atmosphere may affect (i) the distance travelled by potential firebrands and (ii) the lateral and longitudinal spread in potential-firebrand landing positions.

## 2 Methodology

We use a two-stage modelling approach to calculate the landing position of potential firebrands. Firstly we perform numerical simulations of idealised bushfire plumes under various wind conditions, using the UK Met Office Large-Eddy Model (LEM), Gray et al. (2001). We then use the three-dimensional velocity fields produced by the LEM to calculate the paths travelled by particles with assigned fall velocities that are released near the base of the simulated plumes.

### 2.1 Plume simulation

The plume simulation technique employed is fully described in Thurston et al. (2013), so we provide only a brief overview here. The plume simulations are carried out using the LEM. All plume simulations are performed in a domain of horizontal size 38.4 km by 19.2 km and a uniform horizontal grid length of 50 m. The vertical grid length increases smoothly from 10 m near the land surface to 50 m near the model top at 10 km above ground level (AGL). The plume simulations are themselves a two-stage process, which consists of firstly spinning up an appropriate base-state atmosphere in which to conduct the plume simulation and secondly simulating the plume itself.

The base-state atmosphere is spun up by initialising the model with the horizontally uniform potential-temperature profile shown in Fig. 1 (a). This profile consists of a 3.0-km deep well-mixed layer with constant potential temperature of 300 K, and a stably stratified troposphere with a gradient of  $3.0 \text{ K km}^{-1}$  above the mixed layer. The model is initialised with a horizontally and vertically uniform wind velocity throughout the domain. Small random perturbations with a maximum amplitude of  $\pm 0.1 \text{ K}$  are added to the initial potential temperature field below 3 km AGL to initiate turbulence within the mixed layer and the model is then run to a quasi-steady state, as determined by the domain-averaged turbulent kinetic energy (TKE).

We spin up five different base states which differ in the strength of their initialisation wind velocity, namely downwind speeds of  $u = 5.0, 7.5, 10.0, 12.5$  and  $15.0 \text{ m s}^{-1}$  and crosswind speeds of  $v = 0.0 \text{ m s}^{-1}$  for each case. The resulting wind profiles for the five different base states are shown in



Fig. 1 (b). Spinning up the turbulence has resulted in the development of a logarithmic wind profile within the mixed layer and little change to the potential-temperature profile. The 3-km deep mixed layer in the base state potential temperature profile is representative of moderately severe fire-weather conditions, but not as extreme as the 5-km deep mixed layer seen on Black Saturday (Fawcett et al., 2013), and the wind speeds represent a range from moderate to strong.

An idealised bushfire plume is simulated in each atmospheric base state by imposing a localised intense sensible heat flux anomaly at the model’s lower boundary to represent the heat that the fire inputs to the atmosphere. The anomaly is constructed of a circle with a radius of 250 m, within which a uniform sensible heat flux of  $1 \times 10^5 \text{ W m}^{-2}$  is specified. The centre of this circular heat source is located 2 km from the upwind boundary in the  $x$ -direction and equidistant from the lateral boundaries in the  $y$ -direction. A passive tracer is also emitted at a constant rate from the surface within the area of the sensible heat flux anomaly, for plume visualisation purposes. In each background-wind case the plume is well developed after 30 minutes of simulation time with the surface heat flux anomaly applied and the simulation is then continued for a further 60 minutes. During this period the three-dimensional velocity fields are saved at 5-second intervals to be used in the firebrand trajectory calculations.

## 2.2 Firebrand trajectory calculation

We use a very simple Lagrangian particle-transport model for calculating the trajectories of potential firebrands. This is justified as the focus of our study is to specifically investigate the effects of the plume dynamics on firebrand transport, rather than the many other factors involved, such as firebrand type, size, weight, rotation and burnout time, which are described by more complex firebrand models (e.g. Anthenien et al., 2006; Sardoy et al., 2007; Oliveira et al., 2014).

Virtual particles are initialised near the base of the plume and the three-dimensional velocity fields produced by the LEM at 5-second intervals are linearly interpolated in space and time to the position of each particle. A vertical velocity of  $w = -6.0 \text{ m s}^{-1}$  is added to the velocity field used to advect the particles, to represent a typical fall speed for flakes of jarrah and karri bark (Ellis, 2010). The particles are then advected forward in time, using a second-order Runge-Kutta method with a 0.05 s timestep (similar to the timestep used in the LEM plume modelling) until they reach the land surface.

In the trajectory calculations presented here particles are initialised in a cylinder of radius 250 m and depth 50 m, positioned between  $z = 50$  and  $z = 100$  m AGL. The particles are located on a Cartesian grid with equal  $x$ ,  $y$ ,  $z$ -spacings of approximately 10 m between particles, leading to a total number of 8265 particles occupying the cylinder. We release 8265 particles once every 5 seconds for 15 minutes and then calculate the trajectories of the particles until all have landed on the land surface. This means that we release 1,487,700 particles for each plume simulation. Many particles fall to the ground without being lofted or travelling any appreciable distance. As we are interested in the plume-modulated long-range spotting we only consider particles that have travelled a horizontal distance of greater than 1 km when compiling statistics of landing position. This represents about 30% of the initialised particles for each plume and we denote these “launched” particles.

## 3 Results

### 3.1 Plume simulations

We concentrate our analysis of plume dynamics on the two extreme cases simulated, the 5.0 and 15.0  $\text{m s}^{-1}$  background wind cases. Three-dimensional visualisations of the instantaneous passive-tracer field for these two cases are shown in Fig. 2. Under the weakest background winds the plume

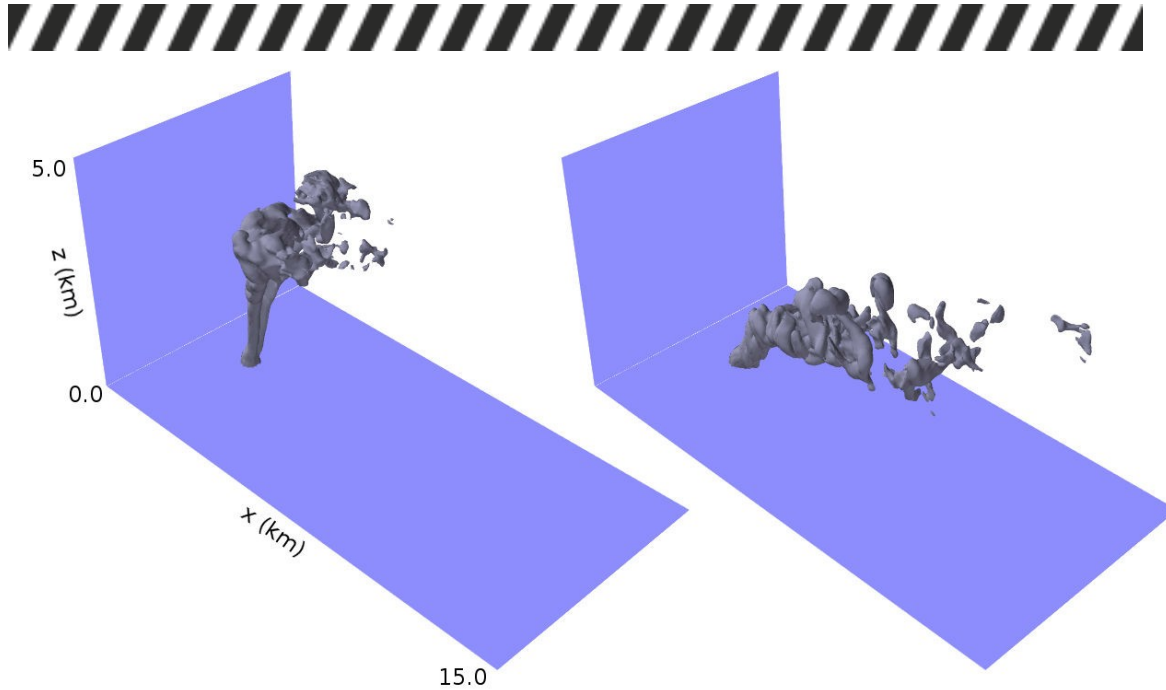


Figure 2: Snapshots of instantaneous concentration isosurface of a passive tracer released at a constant rate from the surface over the area representing the fire. The left-hand panel is the  $5.0 \text{ m s}^{-1}$  background-wind simulation and the right-hand panel is the  $15.0 \text{ m s}^{-1}$  background-wind simulation.

is almost upright. The lower half of the plume appears to be smooth and reasonably narrow, with the upper half of the plume broadening and becoming more turbulent. In comparison, the plume under the strongest background winds is much more bent over and is broader and more turbulent almost entirely throughout its vertical extent. Animations of the passive tracer field reveal that in the  $5.0 \text{ m s}^{-1}$  background wind simulation the lower half of the plume is steady, with the exception of some shear instability forming at the top of the smooth region. The lower half of the plume also appears to be bifurcating, a feature which is examined in more detail later. Animations reveal that in the  $15.0 \text{ m s}^{-1}$  background wind simulation the plume exhibits puffing and meandering behaviour.

Fig. 3 (a) shows a vertical cross-section along the plume centreline of the instantaneous vertical velocity associated with the plume in the  $5.0 \text{ m s}^{-1}$  background-wind simulation. This snapshot reveals a smooth, narrow and almost upright plume updraft which extends above the top of the mixed layer, located at 3.0 km AGL. The shear instability mentioned in Fig. 2 is visible along the leading edge of the updraft, in the form of three local updraft maxima located at heights of approximately 1.8, 2.4 and 3.0 km AGL. The updraft is strong, with vertical velocities in excess of  $25 \text{ m s}^{-1}$  present.

In Fig. 3 (b)-(d) we present plan views at three different heights of the plume vertical velocity and anomalous horizontal velocity, where the anomaly is defined with respect to the domain-averaged horizontal velocity at the height of the plan view being displayed. At a height of 242.7 m AGL the updraft has a kidney-like shape, with a much greater vertical velocity on the upwind side of the plume and strong inflow into the back of the updraft. By 1176.8 m AGL the plume has developed into two distinct updraft cores and there is strong rotation around each of these updrafts. This is indicative of a counter-rotating vortex pair. At 2495.7 m AGL, where we are approaching the top of the mixed layer, the horizontal symmetry in the updrafts has begun to break down. We no longer see two distinct rotating updrafts of equal magnitude, but rather some asymmetric horizontal stretching of the updrafts, to the point of some coherent secondary updrafts beginning to break away, maintaining some horizontal circulation. These are weak wake vortices being shed from the main updraft plume. The presence of shear instability, wake vortices and a counter-rotating vortex pair is consistent with the descriptions and visualisations of vortices generated by strong updrafts in the pioneering work of Fric and Roshko

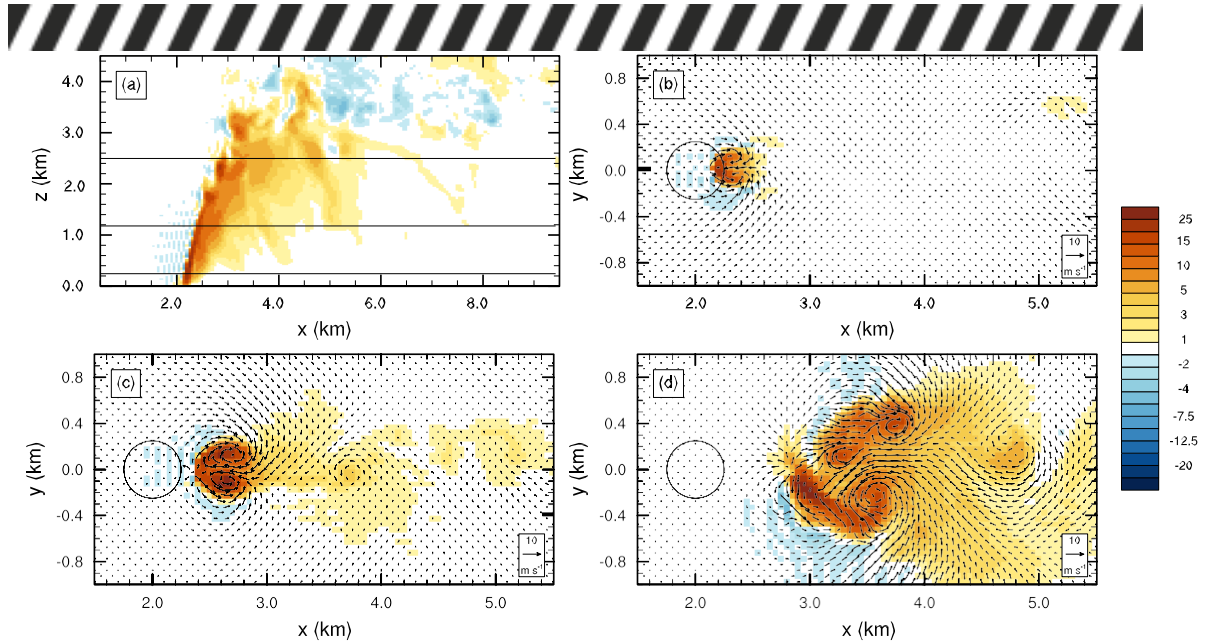


Figure 3: (a) Vertical cross-section (in the  $y = 0$  plane) of the instantaneous plume updraft (solid fill,  $\text{m s}^{-1}$ ) in the  $5.0 \text{ m s}^{-1}$  background-wind simulation. (b)–(d) Plan views of the instantaneous plume updraft (solid fill) and anomalous horizontal wind (curly vectors) at heights of  $z = 242.7, 1176.8$  and  $2495.7 \text{ m AGL}$ . The horizontal dashed lines in (a) denote the locations of the plan views shown in (b)–(d) and the circles in (b)–(d) denote the location of the surface heat source.

(1994), in particular, the schematic in their Fig. 1.

Inspection of the corresponding vertical cross section and plan views for the plume in the  $15.0 \text{ m s}^{-1}$  background-wind plume simulation (Fig. 4) highlights the different plume dynamics. The updraft has a smaller vertical velocity, does not reach the top of the mixed layer and is much less coherent. There are many local updraft maxima visible along the upper edge of the plume in the vertical cross section, highlighting the presence of many puffs. The plan views do not reveal any large-scale coherent rotation, but do confirm the turbulent nature of this plume with a little small scale rotation also visible around the individual updraft puffs.

### 3.2 Firebrand trajectory simulations

In Fig. 5 we present the trajectories of 100 individual potential firebrands, chosen at random, that were launched by plumes in the  $5.0$  and  $15.0 \text{ m s}^{-1}$  background wind simulations. In the case of the  $5.0 \text{ m s}^{-1}$  background wind simulation, the counter-rotating vortex pair which makes up the lower section on the plume is lifting the firebrands up in two distinct, but narrowly separated columns. Once the firebrands reach the more turbulent region of the plume, this narrow separation increases and by the time the firebrands begin to fall out of the plume they have a very wide lateral spread. In contrast, the paths travelled by the potential firebrands lofted by the plume in the  $15.0 \text{ m s}^{-1}$  background wind simulation have very little lateral spread, but enormous longitudinal spread. This is caused by the turbulent and very puffy nature of the plume, which leads to groups, or “clumps”, of particles being suspended only if they are within an updraft of sufficient strength to carry them. Not only does this lead to the large longitudinal spread, but it also leads to the potential firebrands falling out in clusters, as seen at approximately  $x = 4\text{--}6 \text{ km}$ ,  $x = 9\text{--}11 \text{ km}$  and  $x = 14\text{--}17 \text{ km}$ .

A more general view of the spotting characteristics of all of the particles launched by the plumes for all five background wind condition simulations is given by the two-dimensional landing position



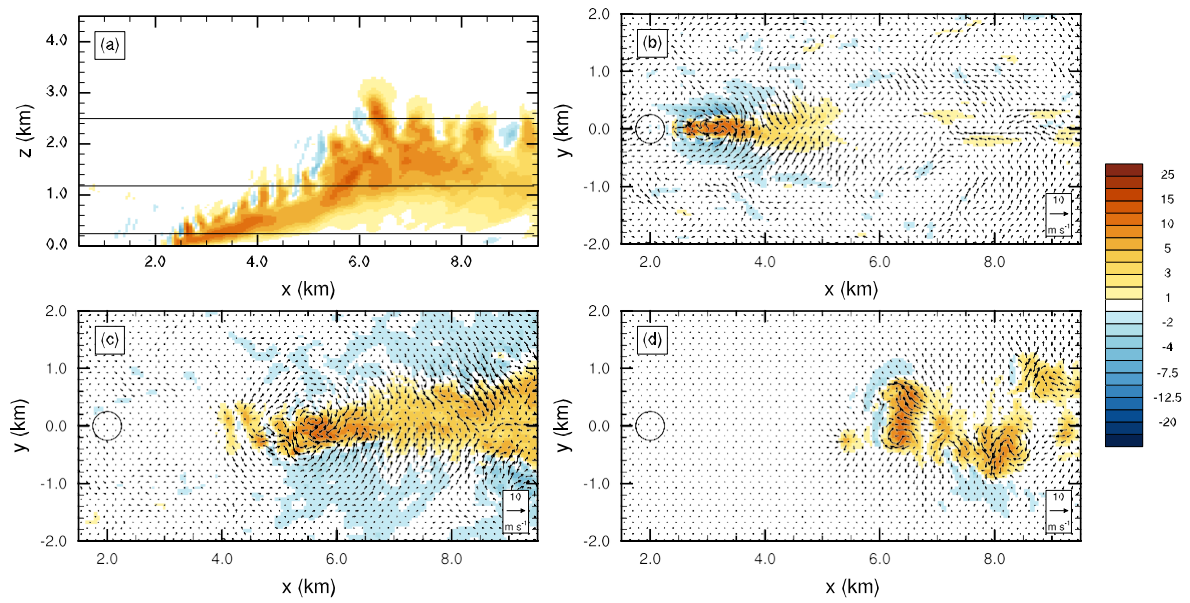


Figure 4: As in Fig. 3, but for the  $15.0 \text{ m s}^{-1}$  background-wind simulation.

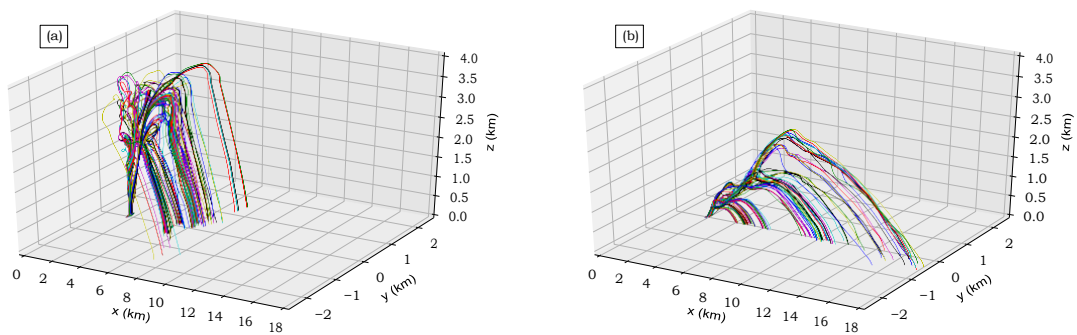


Figure 5: Three-dimensional trajectories of 100 randomly chosen potential firebrands lofted by plumes in the (a)  $5.0$  and (b)  $15.0 \text{ m s}^{-1}$  background-wind simulations.



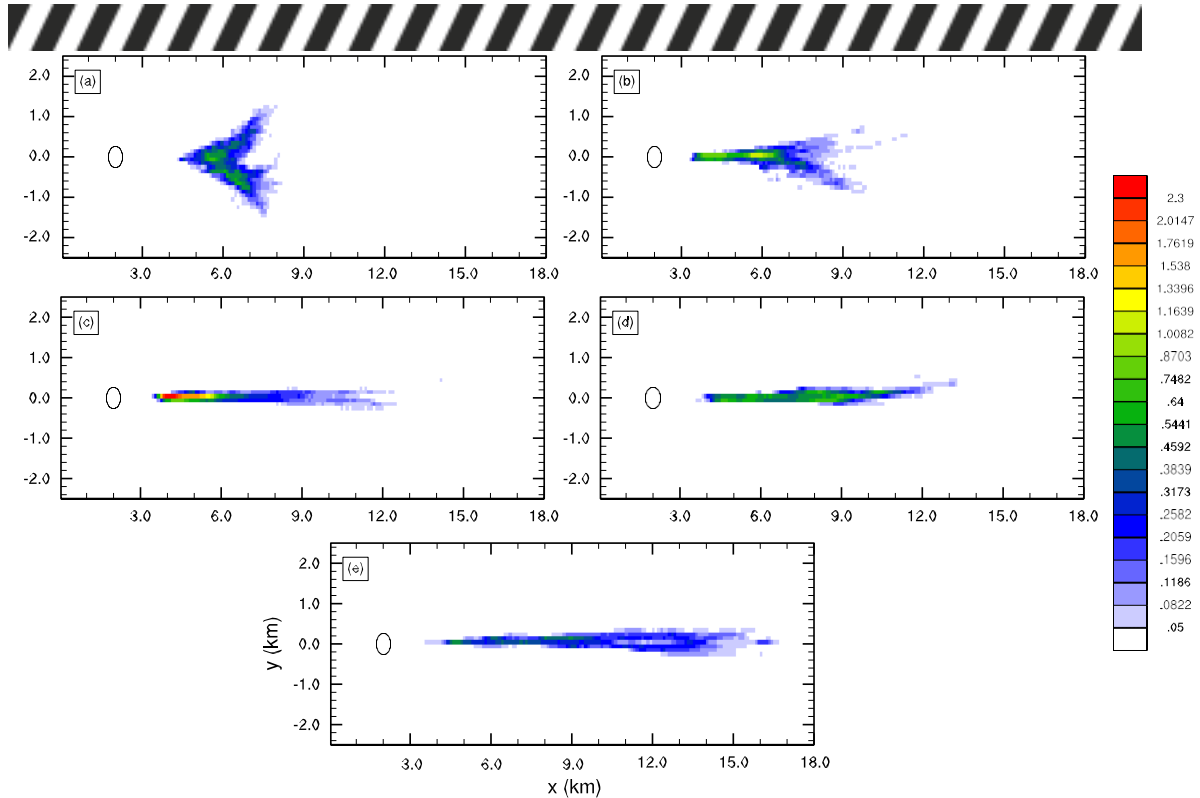



Figure 6: Two-dimensional spatial distributions of potential-firebrand landing position (solid fill, percent of particles launched per  $\text{km}^2$ ) in the (a) 5.0, (b) 7.0, (c) 10.0, (d) 12.5 and (e) 15.0  $\text{m s}^{-1}$  background-wind simulations.

distributions in Fig. 6. Under the weakest background winds, the strong lateral variability caused by the counter-rotating vortex pair has resulted in a v-shaped pattern of landing positions. As the strength of the background wind increases, three features are clear.

Firstly, the distance travelled by the potential firebrands increases. The mean (maximum) distance travelled by potential increases from 4.3 km (7.6 km) downwind of the launching position in the weakest background-wind simulation to 8.3 km (18.7 km) downwind of the launching position in the strongest background-wind simulation.

Secondly, the lateral spread of the landing positions decreases as the background wind increases and the v-shaped distribution gradually closes, until it lies around a narrow line aligned along the plume centreline. This is due to the increasing winds reducing the strength of the counter-rotating vortex pair. As a result the standard deviation of the landing position in the  $y$ -direction, a simple measure of the lateral spread, decreases from 0.55 km in the weakest background-wind simulation to 0.16 km in the strongest background-wind simulation.

Thirdly, the longitudinal spread in the landing position of potential firebrands increases with increasing background wind speed. This is due to the plumes becoming more turbulent and puffy as the background wind speed increases: The potential firebrands that get caught in a puff with a strong enough updraft are transported a long way, whereas potential firebrands that do not get caught in strong enough a puff fall out of the plume much sooner. As a result the standard deviation of the landing position in the  $x$ -direction, a simple measure of the longitudinal spread, increases from 0.81 km in the weakest background-wind simulation to 3.29 km in the strongest background-wind simulation.



## 4 Summary and conclusions

We have used a two-stage modelling process to investigate how the dynamics of bushfire plumes can affect long-range spotting and the variation in spread of the landing positions of potential firebrands. Firstly we used the UK Met Office LEM to perform simulations of idealised bushfire plumes under a range of background-wind conditions. Under weak background winds, plumes were intense and the updraft consisted of a coherent counter-rotating vortex pair. Under strong background winds, the plumes were weaker, more bent over and more turbulent, exhibiting pulsing behaviour. Secondly we used a simple Lagrangian particle transport model to explore how the different plume dynamics impacts the trajectories of potential firebrands.

Under the weakest winds the landing positions of potential firebrands exhibited moderate longitudinal spread and large lateral spread. The changes in the plume dynamics that were caused by increasing the background wind speed led to (i) an increase in the mean and maximum spotting distance; (ii) a decrease in the lateral spread of landings positions of potential firebrands; and (iii) an increase in the longitudinal spread of landings positions of potential firebrands. These variations need to be properly accounted for in predictive models of fire spread and systematic studies such as this will form the building blocks of better empirical spotting models.

## Acknowledgements

This work was partly supported by the Bushfire Cooperative Research Centre and the Bushfire & Natural Hazards Cooperative Research Centre. We acknowledge the UK Met Office for provision of the LEM code and the assistance of Adrian Hill and Ben Devenish (UKMO) in setting up the simulations.

## References

- Anthenien, R. A., S. D. Tse, and A. C. Fernandez-Pello, 2006: On the trajectories of embers initially elevated or lofted by small scale ground fire plumes in high winds. *Fire Safety J.*, **41**, 349–363.
- Cruz, M. G., A. L. Sullivan, J. S. Gould, N. C. Sims, A. J. Bannister, J. J. Hollis, and R. J. Hurley, 2012: Anatomy of a catastrophic wildfire: The Black Saturday Kilmore East fire in Victoria, Australia. *Forest Ecol. Manag.*, **284**, 269–285.
- Ellis, P. F. M., 2010: The effect of the aerodynamic behaviour of flakes of jarrah and karri bark on their potential as firebrands. *J. Roy. Soc. West. Aust.*, **93**, 21–27.
- Fawcett, R. J. B., W. Thurston, J. D. Kepert, and K. Tory, 2013: Modelling the fire weather of Black Saturday. *Proceedings of Bushfire CRC & AFAC 2012 Conference Research Forum, 28 August 2012, Perth Australia*, R. P. Thornton and L. J. Wright, Eds., Bushfire CRC, 135–149.
- Fric, T. F. and A. Roshko, 1994: Vortical structure in the wake of a transverse jet. *J. Fluid Mech.*, **279**, 1–47.
- Gray, M. E. B., J. Petch, S. H. Derbyshire, A. R. Brown, A. P. Lock, H. A. Swann, and P. R. A. Brown, 2001: Version 2.3 of the Met Office large eddy model: Part II. Scientific documentation. Turbulence and Diffusion Note 276, UK Met Office, 49 pp., Exeter, United Kingdom.
- Oliveira, L. A., A. G. Lopes, B. R. Baliga, M. Almeida, and D. X. Viegas, 2014: Numerical prediction of size, mass, temperature and trajectory of cylindrical wind-driven firebrands. *Int. J. Wildland Fire*, **23**, 620–630.
- Sardoy, N., J.-L. Consalvi, B. Porterie, and A. C. Fernandez-Pello, 2007: Modeling transport and combustion of firebrands from burning trees. *Combust. Flame*, **150**, 151–169.



Thurston, W., K. J. Tory, R. J. B. Fawcett, and J. D. Kepert, 2013: Large-eddy simulations of bushfire plumes in the turbulent atmospheric boundary layer. *MODSIM2013, 20th International Congress on Modelling and Simulation*, J. Piantadosi, R. S. Anderssen, and J. Boland, Eds., Modelling and Simulation Society of Australia and New Zealand, 284–289, ISBN: 978-0-9872143-3-1.



# CHALLENGES OF MEASURING EMERGENCY MANAGEMENT PERFORMANCE UNDER ADVERSITY: THE GOOD THE BAD THE UGLY

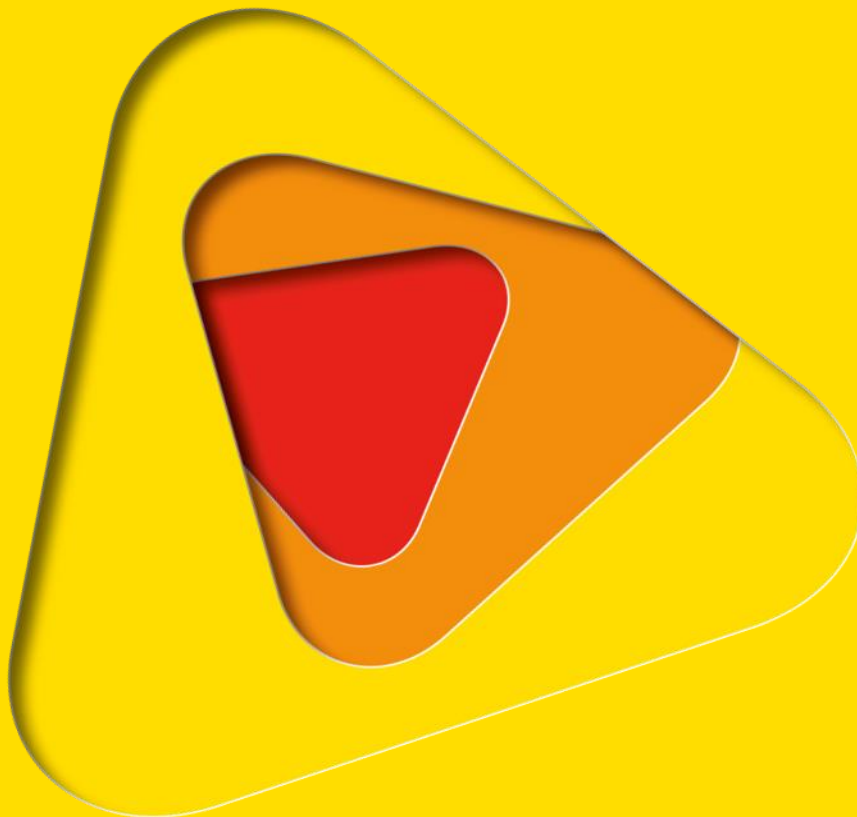
Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**C. Owen<sup>1</sup>, C.B. Brooks<sup>1</sup> and C. Bearman<sup>2</sup>**

<sup>1</sup>University of Tasmania

<sup>2</sup>CQUniversity

Corresponding author: [christine.owen@utas.edu.au](mailto:christine.owen@utas.edu.au)





## ABSTRACT


Senior emergency management personnel face more extreme events and more complex challenges than their predecessors and these challenges will increase in the future. One of the key challenges that senior emergency managers face is the evaluation of operational performance in the context of increasing scrutiny from media, legal and political spheres. To investigate this issue we collected survey data from 38 senior emergency management leaders who operate at the strategic level (above the local IMT) as part of a broader survey examining the challenges of strategic emergency management (funded by the Bushfire CRC, Owen et al., 2013). Participants reported concerns that operational performance is currently judged by external sources (such as the media) in an often post-hoc and arbitrary manner and is dependent on whether or not what happened in the end was perceived as a good outcome. Reliance on the outcome of a complex event is problematic because there is not an absolute correlation between the process of managing an emergency and the outcome. Bad outcomes can occur despite good operational processes and good outcomes can occur despite bad operational processes. For example, all the best processes might have been in place and performed well but the outcome was bad because of unexpected climatic conditions, such as a wind change. This paper will outline the views of senior leaders in emergency management about what needs to be taken into account when measuring operational performance

## INTRODUCTION

Emergency events are becoming more common and are increasing in complexity and duration, due to factors such as climate change, increased carbon emissions and deforestation (Few 2007). Large scale emergency events can be difficult to manage and success in such situations is often highly dependent on a range of factors. While many of these may be within the control of emergency response personnel many others are externally driven (e.g., weather).

In this respect managing emergency events is more complicated than managing in other complex socio-technical systems. This contrasts with many other safety-critical domains where much of the work is procedural, and where safety is attained through collective mindfulness and adherence to well-established doctrine and protocols. These processes are important in the emergency services sector – however, the people responding to and managing emergency events have to also manage other layers of complexity. These include high levels of uncertainty to make time-critical decisions using information that may be incomplete, inconsistent, or ambiguous, in part because the information available varies in quantity and quality; experiencing stress and fatigue as well as information overload and managing multiple and sometimes conflicting stakeholder objectives (Owen & Hayes, 2014).

Recent research into emergency management incident control systems (see Abrahamsson, Hassel & Tehler, 2010; Hunt, Smith, Hamerton, & Sargisson, 2009; Jensen & Waugh 2014; Scholtens, Jorritsma & Helsloot 2014, Rake & Nja 2009) suggests that there is a tension between the need for control and quality assurance and flexibility, and that this in fact can inhibit effectiveness. Indeed according to the literature (e.g., Bowersma, Comfort, Groenendaal & Wolbers 2014; Scholtens, et. al, 2014), there is evidence that control in the first phases of a large scale incident is hard and perhaps impossible to achieve, making evaluation of performance in this phase also



problematic. Moreover, Scholtens, et al., (2014) for example illustrate how the application of standard procedures within ICS may hinder action to protect communities through delays created by the need for bureaucratic authorisations. In this respect incident control systems, through their organisational efforts to define a set of systematic terms, responsibilities, rules and procedures can have the opposite effect – inhibiting the very flexibility that was sought by developing such systems in the first place.

At issue is the need to develop process measures which provide a process measure of performance, rather than the more common outcome measures. Outcome measures in the context of emergency management (e.g. number of houses lost, area of land burnt) are problematic in evaluating performance because they can be subject to uncontrollable events and are thus not necessarily indicative of operational performance. The development of process measures is an important way for agencies to evaluate their performance during and after an event so that they are better able to control their evaluation by external bodies (such as the media and Royal Commissions) and to manage community expectations.

In earlier research conducted through the Bushfire CRC (see Owen, Bosomworth, Fogarty & Conway, 2013), it was also reported that assessing the effectiveness of emergency management objectives was problematic. In this research a survey was distributed to 25 emergency services agencies in Australia and New Zealand, one of the questions asked “*what mechanisms are in place to assess the effectiveness of the objectives for managing the event*”. Of the 206 survey participants, 35 or only 17% offered a comment that indicated that there were internal evaluation criteria in place within the agency. Other responses indicated that in such evaluation occurred if the ends justified the means (e.g., “*it worked out okay*”). Intrigued, these findings were then discussed with industry personnel in workshops to discuss the research and its implications. Following confirmation that evaluating the effectiveness of emergency management performance was indeed a challenge, 38 senior emergency management leaders were approached to ascertain their views on this and other challenges reported in the research (see Owen, Bosomworth, Bearman & Brooks, 2013 and Owen, Bosomworth & Curnin, 2014 for further discussion of these challenges).

## **METHOD**

A consultation survey was distributed to the leaders of all 36 fire and emergency services organisations in Australia, under the sponsorship of the Australasian Fire and Emergency Services Authorities Council (AFAC) CEO who invited these leaders to nominate at least two personnel well placed within their agency to consider the challenges and what needs to be done. The potential pool of responses therefore was 76 persons, and 38 responses represent a response return of 50%, which is in keeping with response rates for organisational surveys of this type (see Baruch & Holtom, 2008).

Given the importance of the challenge associated with measuring emergency management response effectiveness, the survey included the following questions:





1. At a strategic level, what constitutes an appropriate set of objectives for out-of-scale events?
2. At local, regional or state levels, what are the indicators of "trouble" that may signal movement toward vulnerability in emergency response and its management?
3. How would we know that major/out-of-scale events had been well-managed?

### **THE SAMPLE**

The contributors were all senior emergency services leaders within their own agencies with considerable experience within the emergency services sector. The median number of years that contributors have been in the industry was 24, and the median number of years within their agency was 13, thus demonstrating the level of experience of those responding. All were currently working at the state or strategic level of emergency management coordination. In addition, there was a good representation of emergency service organisation types with rural services (n= 10); urban services (n= 7), land management agencies (n= 8) and agencies responsible for different kinds of hazards (n=12) including natural hazards (fire, flood, storms, cyclones, earthquake, tsunami) and human hazards (oil and gas explosions; maritime collisions/oil spills).

In terms of the statements provided to the survey questions, where a sentence statement made by a participant covered multiple topics these were separated so that each individual sentence or topic could be separately coded. The coding and analysis was guided by an interpretational qualitative approach that begins by first gaining an understanding of the entire collected material and then looks for key topics or themes. The comments across all three questions were found to be addressing the five themes which are summarised in Table 1, including the number of comments coded to each theme within each of the questions asked.



Table 1. Themes found in data and number of times each was mentioned in each question

Themes found in data	Data extracts coded to theme		
	Q1: Approp objectives?	Q2: Indicators of trouble?	Q3: Well managed?
To be prepared and ready	9 (4%)	13 (5%)	2 (1%)
To ensure that the incident control system is maintained appropriately (achieving objectives, managing risks)	111 (48%)	117 (48%)	78 (44%)
To coordinate with other stakeholders	24 (10%)	16 (6%)	3 (2%)
To maintain the confidence of the affected and general public and its elected leaders	85 (37%)	85 (35%)	90 (52%)
To support whole of government strategic decision making for consequence management	1 (0.5%)	14 (6%)	3 (2%)
TOTAL	230	245	176

Once codes were identified these were then discussed by all authors to identify the issues outlined below.

## FINDINGS

### EFFECTIVE EMERGENCY MANAGEMENT OBJECTIVES

According to most participants, effective emergency management objectives emphasise what happens in response, however the levels of preparedness before the event and the efficiency of a transition toward recovery were also mentioned as needed in any articulation of emergency management objectives. In terms of the operational response, an emphasis on the sanctity of life of responders and community members is paramount and should guide all other deliberations. As one participant noted:

“The critical issues must evolve around community safety” [#27].

In addition appropriate objectives include strategies to minimise losses (life, property, and environment) and that these are documented within systems (e.g., IAP). As one participant noted:



“there are clear strategic plans in place to manage both the event and consequences”  
[35]

Others highlighted the need for an explicit goal to promote shared situation awareness of the full impact of the current and emerging situation (including worst case scenario modelling) so the best decisions can be made both within the command and control structure and in coordination with key stakeholders.

“there is a shared understanding and common operating picture as to the current and emerging situation” [#30].

However another participant noted the tensions that sometimes arise in relation to what responders can do:

“I think we need to be settling on a realistic outcome and that may at times not necessarily be a palatable outcome...it may for instance include some loss of property and in fact loss of life but given the circumstances on the day that in fact may have been a great result... I don't think we are of a mindset to ensure that the public knows just how difficult a task is undertaken at times and perhaps we need to use the media more to our advantage” [#28]

And in relation to the need for a longer term strategic view another observed:

This pre-supposes that response is where we should focus. I would argue that an out of scale response should be perceived as a failure to manage risk.” [#31].

From this perspective objectives need to be contextualised within the environment that has either contributed to (or mitigated) the level of impact as well as taking into account the “timeliness and smoothness of the recovery phase” [#10].

## **INDICATORS OF TROUBLE**

At local, regional or state levels, the indicators of "trouble" that may signal movement toward vulnerability in emergency response and its management included unanticipated surprises that indicate that planned objectives are not matching the event or are inadequate as the following participant noted:

“The incident continues to escalate faster than the escalation of effort (or control), resulting in an increasing capability shortfall. The risk in these situations is that incident managers may narrow their focus to a heightened operational awareness, at the expense of considering potential impacts beyond the immediate theatre of operations (i.e. a community that might be impacted in the next 3-4 hours, critical infrastructure etc.).” [#13]

The consequences of this perturbation then threaten the objectives discussed earlier.

“Inaccurate or non-timely information provided to the community resulting in loss of life. Not recognising the requirements of maintaining primacy of life” [#21].

In addition disconnects within the incident control structure or conflict are other signs of trouble.



“Disconnect between the commanders intent, the events mission and the actions of practitioners through their tactics at the event” [#6]

“There is conflicting information / intelligence” [#4] “plans or priorities between stakeholders are in conflict” [#6]. This is likely to lead to as one participant commented: “an inability to articulate the situation and to predict immediate and future outcomes and resource needs” [#30].

Some felt that indicators of trouble could be quantified in for example “between 50-66% of state capability have already been assigned” [#31]. Another indicator of trouble would also be if “there was no plan for commencement of recovery activities” [#32] and that “We lose, or fail to establish, contact/engagement with the community at risk” [#2].

There were also comments of indicators of trouble beyond the operational response phase and instead in the preparedness phase. These included:

- “Increasing loss of experienced staff within agencies.” [#10]
- “Lack of implementation of lessons learnt into doctrine and practice.” [#10]
- “Rationalising resources - i.e. removing a surge capacity from an organization.” [#16]

## INDICATORS OF SUCCESSFUL EMERGENCY MANAGEMENT

The commentary discussed above as well as that provided to address indicators of successful emergency management can be grouped around four themes.

- **Maintenance of ICS and stakeholder engagement.** Assurance that the incident control system is operating effectively.

Managing an emergency response is successful when there is an understanding of the personnel involved and their actions, as the following participant noted.

“At all times each ESO should have no problems articulating the following: Exactly who from the agency is involved in every level of the response? (this means full details including names, addresses, NOK, positions etc.). Exactly where are they at any moment in time during the response? Exactly what are they doing in relation to the IAP?, and Exactly who is supervising them? If these questions can't be answered in exact detail, the strategic level is not even connected to the rest of the organisation and operating with these unknowns = vulnerability” [#13].

Monitoring and safety assurance also means looking ahead for planning in anticipation of what might be unfolding, as the following participant noted:

“the incident status needs to be constantly monitored and current priorities for resourcing etc. is set for each 24 hr. period. This means that capability and capacity can be mapped against demand daily and reasonable worst case scenarios modelled daily. It is also important that current information on existing and forecast conditions are available to the community in a range of media and also that State risk /asset owners are involved in decision making on a daily basis [#31].



These safety assurance elements feed into stakeholder engagement to support whole-of-government strategic decision making for consequence management as well as supporting critical stakeholders in assessing their own risk and vulnerability. Indicators of successful stakeholder engagement include “having already established MOU’s between relevant stakeholders defining needed relationships and having response plans that are understood and have been practiced” [#12].

- **Confidence:** that the confidence of the public and its elected leaders is maintained.

This is indicated in timely information to communities which includes informing communities of developing risks, as the following participant commented “communities, media and politicians say ‘well done’, particularly with regard to information flows”. This indicates that elected leaders and other areas of government need to be kept well informed so that they too can make good decisions about direct and indirect consequences.

This is also indicated in how quickly community conditions are normalised, as one participant noted:

“The level of community recovery - a comparative analysis of the capacity of a community before and after the event; can it do/provide what it did before the event or has there been a change in that capacity and if so what is the size of that change. Ongoing and adverse psychological, social and physical effects on the community and individuals impacted - long term studies required [#10].

- **Reflexivity and learning** for continuous improvement.

A number of comments related to the capacity of the industry to learn from these events. This required having support and confidence to be able to name up what really happened, which may include mistakes. As one participant noted “we need to be able to create a learning environment where triumphs and mistakes can be shared in blame free environment for future benefit” [#3].

This paper has highlighted some of the comments emerging from research into what needs to be taken into account when measuring emergency response performance.

## **CONCLUSIONS: THE GOOD, THE BAD, THE UGLY**

There appears to be a readiness in the industry to move towards articulating a set of indicators that can assist in measuring emergency management performance. As the comments highlight while the emphasis is mostly on how well the response phase is managed, it is also important to see this within a broader context of preparedness and recovery.



There are still concerns about whether the public and our elected leaders are prepared to accept risk and vulnerability as well as to acknowledge that managers of emergency events sometimes make mistakes. A framework is needed that acknowledges that sometimes personnel operate in degraded conditions. Degraded conditions include: failures in critical equipment or technology; the required human resources are either unavailable or are over-stretched or fatigued; and personnel are operating in hazardous (sometimes life threatening) conditions (Owen & Hayes, 2014).

Brooks (2014) developed a heuristic to help personnel operating in situations that might be degrading and thus migrating work practices towards unsafe conditions, which he called "Zone of Coping Ugly" (ZOCU). More work needs to be done to advance an understanding of what coping ugly might look like to help articulate the risks and emerging vulnerabilities within emergency management work. This concept is supported by others such as Phillips, Klein & Sieck, (2004, p. 305)

*An important attribute of expert decision-makers is that they seek a course of action that is workable, but not necessarily the best or optimal decision.... time pressures often dictate that the situation is resolved as quickly as possible. Therefore it is not important for the course of action to be the best one; it only needs to be effective.*

There is still much work to do in this area. An appropriate framework to establish the basis for identifying both values and constraints inherent in emergency management work. This is necessary to avoid the hindsight bias that frequently occurs in media and in inquiries. As Abrahamsson, et al (2010) contend there are four challenges encountered when evaluating performance of emergency management response systems. These include:

**Values.** Making explicit the value judgements upon which the evaluation of performance is based.

**Complexity.** Acknowledging and addressing the complexity involved in the work.

**Validity.** Issues related to the validity on which the evaluation of performance will be based.

**Limiting conditions.** A need to explicitly name up the limiting conditions present in any performance assessment.

As they note: "There is a need to explicitly try to make the limiting conditions under which the emergency response performance occurred visible when analysing and evaluating its performance. Were there other ways of affecting the objectives of the system in a positive way that were not exploited, or were the actions taken the only ones or the best possible?" Abrahamsson et al 2010, p. 17). These ideas align closely with strategic initiatives within the Australasian fire and Emergency Services council to support professionalization in the industry and acknowledge the initiatives of individual agencies that are operating as early adopters. Future work will involve closely working with stakeholders to develop indicators with so that emergency management performance can be assessed in real time and to identify any problems individuals and teams are experiencing.





## **ACKNOWLEDGEMENTS**

The research was supported funding through the Bushfire Cooperative Research Centre. However, the views expressed are those of the author and do not necessarily reflect the views of the Board of the funding agency.



## REFERENCES

- Abrahamsson, M, Hassel, H, & Tehler, H, (2010) Towards a System-Oriented Framework for Analysing and Evaluating Emergency Response. *Journal of Contingencies and Crisis Management*, **18**(1), 14–25.
- Baruch, Y & Holtom, BC (2008) Survey response rate levels and trends in organizational research. *Human Relations*, **61**(8), 1139–1160.
- Boersma, K, Comfort, L, Groenendaal, J, & Wolbers, J, (2014) Editorial : Incident Command Systems : A Dynamic Tension among Goals , Rules and Practice. *Journal of Contingencies and Crisis Management*, **22**(1), 1–3.
- Brooks, B, (2014) Errors, decisions, coping and training. Non-technical skills and implications for emergency management training approaches. In *Human Factors Challenges in Emergency Management: Enhancing Individual and Team Performance in Fire and Emergency Services*. (Ed C Owen) pp. 171-194 (Ashgate publishing: Aldershot, UK)
- Few, R, (2007) Health and climatic hazards: Framing social research on vulnerability, response and adaptation. *Global Environmental Change*, **17**(2), 281-295.
- Hunt, S., Smith, K., Hamerton, H., & Sargisson, R. J. (2009). An Incident Control Centre in Action : Response to the Rena Oil Spill in New Zealand. *Journal of Contingencies and Crisis Management*, **22**(1), 20–23.
- Jensen, J, & Jr, WLW, (2014) The United States ' Experience with the Incident Command System : What We Think We Know and What We Need to Know More About. *Journal of Contingencies and Crisis Management*, **22**(1), 1–17.
- Owen, C, & Hayes, P, (2014) Introduction: why human factors in emergency services? In *Human Factors Challenges in Emergency Management: Enhancing Individual and Team Performance in Fire and Emergency Services*. (Ed C Owen) pp. 1-18 (Ashgate publishing: Aldershot, UK)
- Owen, C, Bhandari, R, Brooks, B, Bearman, C, & Abbasi, A, (2013) Organising for effective incident management: Bushfire Co-operative Research Centre Report. (Melbourne, Aus)
- Owen, C, Bosomworth K, Fogarty, L, & Conway, G. (2013) Strategic-level emergency management: some challenges and issues for the future. Bushfire Co-operative Research Centre Report. (Melbourne, Aus).
- Owen, C, Bosomworth K, & Curnin, S, (2014) The challenge of change in future emergency management: conclusions and future developments, In *Human Factors Challenges in Emergency Management: Enhancing Individual and Team Performance in Fire and Emergency Services*. (Ed C Owen) pp. 219-230 (Ashgate publishing: Aldershot, UK)
- Phillips J, Klein G, & Sieck WR, (2004) Expertis in judgement and decision-making: A case for training intuitive decision skills, In *Blackwell handbook of judgement and decision making*. (Eds Koehler DJ, & Harvey, N. pp. 297-315 (Blackwell Publishing: Malden MA).
- Rake, EL, & Njå, O, (2009) Perceptions and performances of experienced incident commanders. *Journal of Risk Research*, **12**(5), 665–685.
- Scholtens, A, Jorritsma, J, & Helsloot, I, (2014) On the Need for a Paradigm Shift in the Dutch Command and Information System for the Acute Phase of Disasters. *Journal of Contingencies and Crisis Management*, **22**(1), 39–51.



# INTEGRATED DISASTER DECISION SUPPORT SYSTEM INCORPORATING MITIGATION PORTFOLIO OPTIMISATION

Proceedings of the Research Forum at the Bushfire and Natural Hazards CRC  
& AFAC conference  
Wellington, 2 September 2014

J. P. Newman<sup>1,4</sup>, H. R. Maier<sup>1,4</sup>, H. van Delden<sup>2,4</sup>, A. C. Zecchin<sup>1,4</sup>, G. C. Dandy<sup>1,4</sup>  
and E. Pikusa<sup>3,4</sup>

<sup>1</sup>University of Adelaide

<sup>2</sup>Research Institute for Knowledge Systems

<sup>3</sup>South Australian Fire and Emergency Services Commission

<sup>4</sup>Bushfire and Natural Hazards CRC

Corresponding author: [jeffrey.newman@adelaide.edu.au](mailto:jeffrey.newman@adelaide.edu.au)





## ABSTRACT

Investing in mitigation activities before a natural disaster occurs can be very effective in reducing disaster losses. However, there can be a number of obstacles to developing and implementing long term mitigation schemes, including a tendency to invest in works with clearer short-term benefits, and the difficulty in accurately attributing risk and benefits to natural disasters and mitigation options, respectively. Decision support systems (DSSs) can be advantageous in helping overcome these obstacles, because of their analytical capabilities to combine various sources of information and support trade-off analysis. However, DSSs for natural disaster mitigation have so far tended to focus on disaster preparedness and the immediate and post-crisis response to emergencies. Consequently, an integrated natural hazard mitigation DSS is being developed. This DSS will optimise the choice of mitigation options in a multicriteria sense, through assessing the performance of various policy options in the long term. Models will be used to evaluate the performance of mitigation options across a number of natural hazards in an integrated way, whilst taking account of land use and climate change. The system will be developed through participatory processes, involving stakeholders from various organisations responsible for hazard mitigation, to ensure the system addresses the most pertinent issues, as well as the decision making process for hazard mitigation. To test the approach in different contexts, it will be applied to three case studies, the first being Greater Adelaide. This paper introduces the proposed DSS.

## INTRODUCTION

The effects of natural disasters on society are of great concern due to their impact on economies, communities and the environment. In 2013, there were 890 loss events worldwide (excluding famine) that resulted in 20,500 fatalities, and US\$135 billion in losses. Although this economic loss is a small portion (less than 0.2%) of the US\$87 trillion global GDP, natural disasters are localised and may have severe impact on local economies and communities, and recovery may take a very long time.

Because natural disasters are low probability, high impact events, the potential losses can far exceed those that have occurred in recent years. For example, Shah (1994) predicted that a magnitude 7 earthquake hitting Los Angeles would cause over US\$170 billion in economic losses, over US\$95 billion in insured losses, over 3,000 deaths and up to 20,000 injuries. A repeat of the 1906 San Francisco earthquake would result in similar losses, and the repeat of the 1923 Tokyo earthquake is predicted to cause over US\$2.0 trillion in economic losses, over US\$30 billion in insured losses, and over 40,000 deaths (See also Grossi and Muir-Wood 2006).

Pertinently, the losses that occur from natural hazards can often be reduced through mitigation measures. Mitigation has been shown to be very effective, and economically responsible. For example, Rose *et al.* (2007) found that the overall benefit-cost ratio (BCR) across nearly 5,500 US Federal Emergency Management Agency (FEMA) mitigation grants was about 4:1. The UK Environment Agency reports that strategies for maintaining existing and investing in new flood risk management assets across England have BCRs ranging from 4:1 to 11:1 (UK Environment Agency 2009), and Deloitte Access Economics (2013) analysed three Australian mitigation projects and found that the BCRs for these projects were all greater than one, with BCRs up to 9 possible when investments are made that target high risk locations with appropriate combinations of structural and non-structural mitigation measures.

Despite its obvious advantages, investment in mitigation is relatively low. For example, over the last six years, the Australian government has contributed AU\$7.2 billion in response and relief funding



through the National/Natural Disaster Relief and Recovery Arrangement payments, but only 2.3% of this amount (AU\$171 million) has been spent on mitigation through the Natural Disaster Reduction Program. This can be attributed to a number of factors that have been identified within the literature (For example, see Wood 2004; Sadiq and Weible 2010; Vaziri *et al.* 2010; Hennessy *et al.* 2014; IPCC 2014b; Stein and Stein 2014). One of these is the lack of data to make a business case for mitigation, as this requires analysis to quantify the expected benefits of mitigation activities, using a transparent process and a scientifically robust methodology. Additional factors include competing objectives and a lack of measurable criteria. Furthermore, given the large number of mitigation options, and limited mitigation budgets, it is important to sift through and select options that result in optimal trade-offs between objectives.

There are potential benefits to using decision support systems (DSSs) for developing mitigation plans. This is because DSSs have the ability to combine various sources of information and support trade-off analysis in a transparent way. Because of the obstacles to investment in mitigation identified above, such DSSs should: (1) quantify the expected benefits of mitigation investment across multiple criteria; (2) assess the likelihood and consequences of natural disasters across multiple criteria; and (3) use formal optimisation techniques to find optimal or near-optimal mitigation portfolios.

In this paper, a framework is presented that can be used to identify the optimal set of options for hazard mitigation in a region, which is a deliverable of a project funded by the Bushfire and Natural Hazard Cooperative Research Centre (BNHCRC). This framework is novel, as it (1) combines the use of formal optimisation techniques with simulation approaches, (2) takes a multi hazard perspective, (3) incorporates a spatially-explicit and dynamic land use model to assess land use mitigation policy over the long-term, and (4) takes climate change into account. These aspects have not previously been combined into a single decision support platform in the literature. Based on this framework, a prototype decision support system is introduced for the Greater Adelaide region in South Australia.

## PROPOSED FRAMEWORK FOR DECISION SUPPORT OF MITIGATION PLANNING

The proposed mitigation planning decision support framework is illustrated in Figure 1 and discussed in detail in the following subsections.

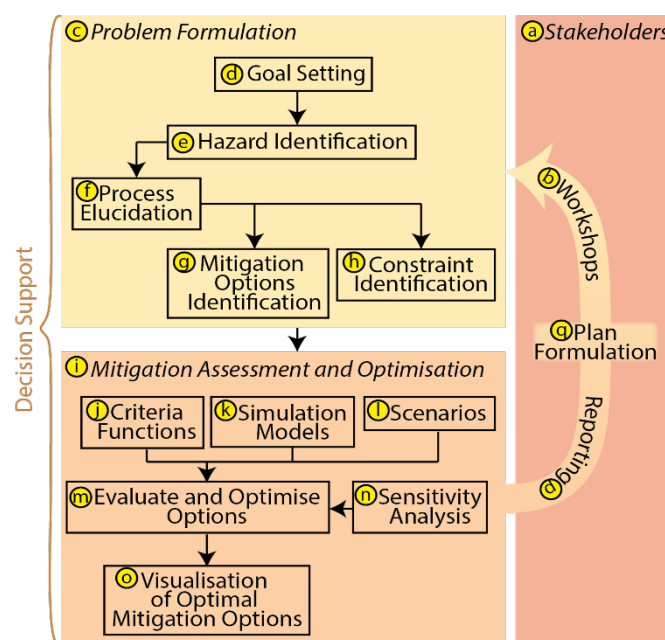


Figure 1. Proposed framework for the development of mitigation planning decision support systems



## STAKEHOLDER DRIVEN

As shown in Figure 1(a), stakeholder engagement is an integral component of the proposed DSS framework, as this has long been identified as a critical component of DSS adoption (Belardo and Karwan 1986). As part of the proposed framework, stakeholder engagement is achieved via workshops (Figure 1, part b), whereby (i) workshops are held to formulate the decision tasks that need to be addressed by the decision support system, and (ii) portfolios of optimal mitigation options, as identified by the decision support system, are reported back to the stakeholders for review. The workshops involve an iterative process of communication and social learning amongst decision makers, end-users and other stakeholders, domain knowledge experts, and IT specialists, so architects of the DSS system understand the requirements of users, the nature of the decision problem being addressed, and the process by which decisions are made (Geertman 2006; van Delden *et al.* 2011).

## PROBLEM FORMULATION

Problem formulation concerns the specification of DSS requirements (Figure 1, part c). This includes defining the objectives, constraints and decision variables of the decision task, as in conventional operations research approaches, but also includes the identification of process protocol (the steps that are necessary for arriving at the desired DSS), and information protocol (identifying what information/data is required for the decision task).

As can be seen in Figure 1(d), the first task is identifying the goals of the stakeholders. These can include the minimisation of the total expected costs of natural disaster management and other community objectives, such as maximising economic growth, natural amenity, community resilience and environmental measures of ecosystem health. Next, the natural hazards that would impact these goals need to be identified (Figure 1, part e). From this, domain knowledge experts are called upon to identify the environmental and social processes that give rise to these hazards (Figure 1, part f). The identification of these processes enables the comprehensive identification of relevant mitigation options, as mitigation measures act to reduce losses through the modification of these processes (Figure 1, part g).

Mitigation options can be categorised into structural works, management techniques and land use planning tools (Burby 1998). Structural works include elevating, protecting and strengthening structures, sea walls, dikes, groynes, dams, and levees. Management techniques relate to how landscapes and structures are managed and maintained. For example, management measures for bushfire mitigation include fuel load reduction and maintenance of fire retarding measures constructed into buildings. However, in recent decades the predominant form of mitigation has been through land use management, as the level of hazard in a location is very sensitive to the land use occurring at that location.

In this respect, land use strategies for disaster impact mitigation include building standards (regulations for new and retrofit buildings), development regulations (including zoning and setback requirements), property acquisition in high risk areas, taxation and other fiscal policies (Olshansky and Kartez 1998). These land use management options often take many years to become fully effective. For example, building codes applicable to new buildings only affect 1.3% of the total building stock in any year (Deloitte Access Economics 2013); and changing the zone of a land parcel does not directly cause the land use to change. This is because development is a gradual process in which land is transformed into residential, commercial, and industrial areas.

The final step in the problem formulation, as shown in Figure 1(h), is the identification of constraints that are placed on the decision making process (such as budgetary ceilings, land use, demographic and environmental constraints, and constraints relating to the incompatibility of various mitigation



options). It should be noted that the availability of simulation models, which are required in order to assess the impact of particular mitigation options on the desired goals, should also be considered during the problem formulation stage, as discussed in the following section. The gaps that exist between the problem formulation and what models are available can be addressed in later versions of the DSS, as DSSs are developed for long term use and can be improved over time.

## **MITIGATION ASSESSMENT AND OPTIMISATION**

In the second phase, a first prototype of the DSS can be developed, based on the inputs from the problem definition phase and according to the steps outlined in Figure 1(i). First, criteria functions, simulation models and scenarios are selected. Using the goals identified during the workshop, criteria functions are developed with which to evaluate the utility of mitigation portfolios, which consist of a subset of the options also identified within the workshop.

As can be seen in Figure 1(j), values of the criteria functions corresponding to different mitigation portfolios are obtained with the aid of simulation models. Two factors are important in relation to the selection of these models. Firstly, they should adequately simulate the relevant processes, such that the system impacts of mitigation options are captured. Secondly, criteria functions should be calculable from the model outputs. It should be noted that in some situations, such models might not be available or not be able to be developed, which might affect which mitigation options and objectives can be considered. Consequently, this issue needs to be considered during the problem formulation stage, as mentioned previously.

Also, as mentioned previously, land use management is the predominant form of natural hazard mitigation. Given the strong relationship between land use and natural hazard risk, and the slow rate of land use change, it is important to simulate long-term land use changes through spatially-explicit and dynamic land use models within mitigation DSSs (Figure 1, part k). In addition, populations and economic development are continuing to increase. This has historically caused populations and investments to be increasingly concentrated in vulnerable locations, causing a larger magnitude of losses (Changnon and Pielke Jr 2000; Neumayer and Barthel 2011; Deloitte Access Economics 2013). Therefore models of population and economic growth should be included in the DSS.

Finally, climate change is generally causing natural hazard events to become more frequent and severe. The 5th IPCC assessment report concludes that climate change is increasing the hazards associated with storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, drought, aridity, water scarcity, and bushfires, which will have widespread negative impacts on communities and on economies and ecosystems (IPCC 2014a, 2014b). Therefore, assessing the impact of mitigation options over the long term requires the use of models that take the impacts of climate change into account, which need to be run for scenarios representing various plausible future conditions. Consequently, the evaluation of different mitigation portfolios is achieved by running the integrated hazard model across different scenarios and using the model outputs to calculate the required criteria functions (Figure 1, part l).

Unfortunately, due to the large number of mitigation portfolios that could be implemented, evaluating each potential portfolio is computationally intractable. However, it is important to identify portfolios that result in good outcomes according to stakeholder goals, in order to understand the tradeoffs between these goals in an unbiased way, and to ensure the most efficient use of mitigation budgets. Therefore, there is value in the use of formal optimisation techniques to assist with sifting through the available options in order to identify mitigation portfolios that result in better trade-offs between the selected criteria (Figure 1, part m). Evolutionary algorithms (EAs) such as genetic algorithms (GAs), ant colony optimisation (ACO) and differential evolution (DE) are used as the





optimisation engine in the proposed approach as they tend to be robust towards problems characterised by nonlinearity, multi-modality, large decision spaces and interactions between decision variables. While not guaranteeing convergence to near-optimal designs over polynomial time, they have shown to do so across a wide spectrum of test problems. In addition, EAs can be adapted for multi-objective optimisation with relative ease.

Once optimal portfolios of mitigation options have been identified, sensitivity analysis may be conducted to test the robustness of optimal mitigation portfolios against a number of modelling assumptions (Figure 1, part n). The results of these analyses need to be visualised in a meaningful way (Figure 1, part o) with results reported back to stakeholders and decision makers so that the best mitigation options can be selected more effectively (Figure 1, part p).

Finally, based on the results of the process described above, stakeholders may identify additional scope and modelling improvements that should be included, thereby reformulating the decision task. Therefore, an iterative refinement of the DSS through a number of workshops will generally be required to ensure the system is fit for purpose and to foster system adoption for the formulation of mitigation plans (Figure 1, part q).

## THE GREATER ADELAIDE MITIGATION DECISION SUPPORT SYSTEM

As part of the BNHCRC project, this framework will be applied to three case studies, producing a prototype DSS for each. The first of these case studies is focussed on the Greater Adelaide region, as shown in Figure 2, which is home to 1.3 million people. This section will describe the Greater Adelaide DSS being developed for this case study.

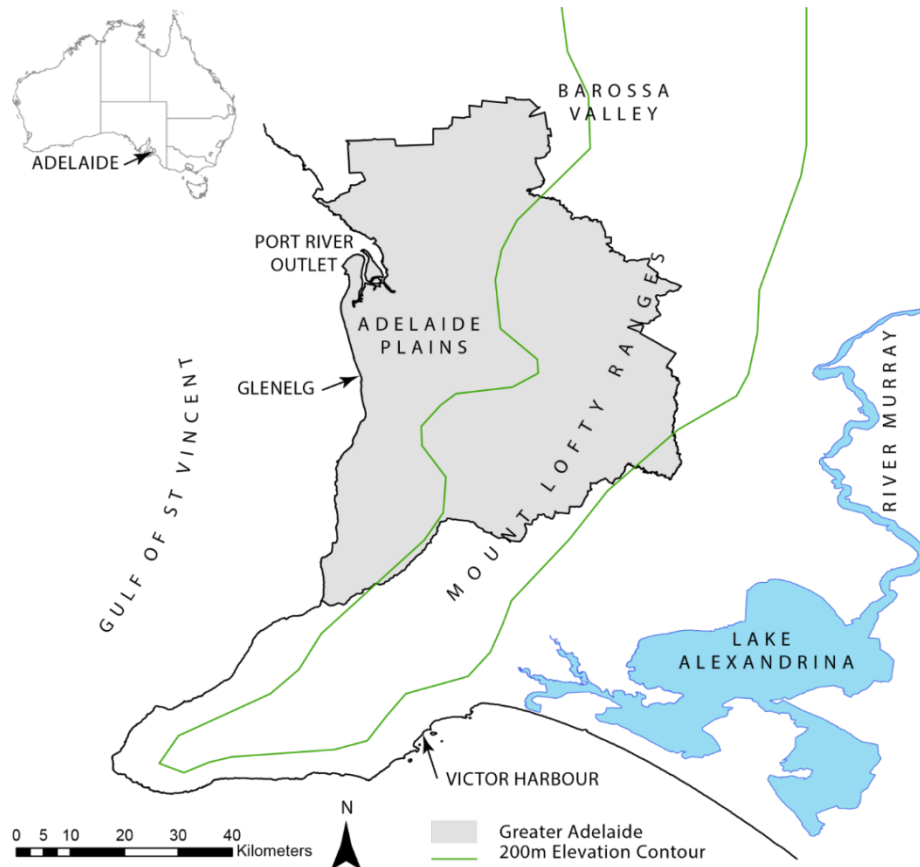


Figure 2. The Greater Adelaide Region in South Australia



## **PROBLEM FORMULATION**

The hazards that will be considered in this DSS are flooding (both coastal and floodplain), bushfire, earthquake, storms and heat waves. With regard to flooding, sustained periods of high rainfall are rare in the Greater Adelaide region. However, short intense storm events are more common, which can bring localised flooding across the Adelaide plains (South Australian Government 2004). Low lying areas near the Port River outlet are most susceptible to coastal flooding and surge. Concerning bushfire, regions of South Eastern Australia are generally considered to have some of the greatest risks of bushfire in the world (South Australian Government 2004). Within Greater Adelaide, the Mt Lofty Ranges contain most of the region's high bushfire risk areas, with large tracts of highly flammable vegetation. Greater Adelaide also has one of the highest earthquake risks amongst all Australian capital cities. However, amongst these natural hazards, storms and heat waves cause the greatest losses. Storms bring the greatest economic damage to infrastructure and property, while heat waves claim the most lives in the study region.

The first workshop for developing the Greater Adelaide DSS is scheduled to be held in September 2014. Attendees at this workshop include registered end users of the decision support system, South Australian practitioners and subject matter experts, and interstate practitioners likely to be involved in the development of the remaining two DSS case studies conducted as part of this research program. The workshop will consist of a pre-workshop interview, involvement in round-table discussions during the workshops, and the completion of a post-workshop survey. Through this engagement, this workshop aims to solicit information in relation to (1) the distribution of mitigation decisions and activity across government agencies in Greater Adelaide, and how these decisions are made (including what data and models may be used), (2) the key factors that will affect mitigation activity in Greater Adelaide, both in the present and the future, (3) the mitigation options that could be considered, both now and in the future, and (4) feedback from the demonstration of a prototype DSS developed for the case study (Figure 3).

## **MITIGATION ASSESSMENT AND OPTIMISATION**

The Greater Adelaide decision support system is being developed using the Metronamica modelling framework. Metronamica is a flexible software framework that includes a spatially explicit and dynamic land use model based on cellular automaton simulation; and a software interface that is designed for the integration of other spatially explicit simulation models. This software interface will be used to integrate the natural hazard data and/or models currently being used for the Greater Adelaide region.

As shown in Figure 3(a), the DSS is able to simulate the impact of different external factors, policy measures, model parameters, and scenarios through specifying these options through the main window. Once the model is run (Figure 3, part b), the DSS allows the visualisation of these options through dynamic year-by-year maps of spatially explicit land use, economic, ecologic and social indicators, as shown in Figure 3(c), therefore allowing the user to explore the spatial and temporal impact of different mitigation options.

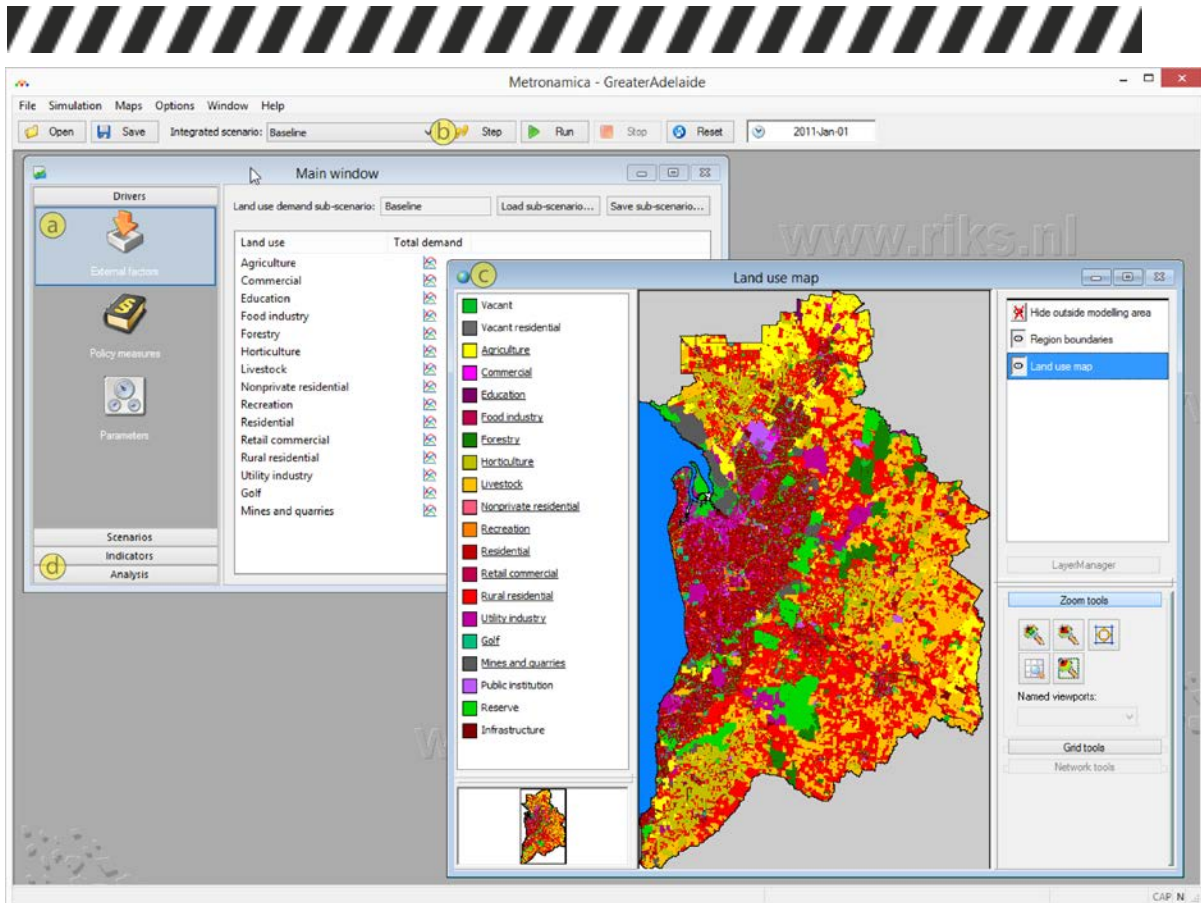


Figure 3. Screenshot of the Greater Adelaide mitigation planning decision support system

The specific indicators to record during the model run, and what statistical analysis to perform on these indicators can also be specified by the user in the main window (Figure 3, part d).

Metronamica will be linked to a multi objective EA for the sifting through and selection of mitigation options that result in optimal trade-offs between criteria. Due to long model run times (in the order of minutes for a run of 30 years into the future) and the relatively high computational cost of EAs, work is being undertaken to parallelise the evolutionary algorithm across clusters of computers.

## CONCLUSION

In this paper, a framework has been presented for the development and use of DSSs to aid the development of disaster impact mitigation plans. This framework includes a participatory approach for developing simulation-optimisation DSS software that sifts through and presents portfolios of mitigation options that result in optimal trade-offs between decision criteria for comparing different mitigation options. The framework is sufficiently general so that it can be applied to hazard mitigation in different regions of the world.

Using the framework, a prototype DSS is currently being developed for Greater Adelaide. The advantages of this planned DSS are:

- The incorporation of a spatially-explicit and dynamic land use model that allows assessment of the impacts of land planning on hazard mitigation under various socio-economic and climate scenarios.
- The incorporation of evolutionary algorithms for identifying optimal tradeoffs between performance criteria.
- A user interface targeted towards mitigation impact assessment.



## REFERENCES

- Belardo, S, Karwan, KR (1986) The development of a disaster management support system through prototyping. *Information & Management* **10**, 93-102.
- Burby, RJ (1998) 'Cooperating with Nature : Confronting Natural Hazards with Land Use Planning for Sustainable Communities.' (Joseph Henry Press: Washington, D.C.)
- Changnon, SA, Pielke Jr, RA (2000) Human Factors Explain the Increased Losses from Weather and Climate Extremes. *Bulletin of the American Meteorological Society* **81**, 437.
- Deloitte Access Economics (2013) Building our nation's resilience to natural disasters. Australian Business Roundtable for Disaster Resilience and Safer Communities, Kingston, ACT. Available at <http://australianbusinessroundtable.com.au/assets/documents/White%20Paper%20Sections/DAE%20Roundtable%20Paper%20June%202013.pdf>.
- Geertman, S (2006) Potentials for planning support: a planning-conceptual approach. *Environment and Planning B: Planning and Design* **33**, 863-880.
- Grossi, P, Muir-Wood, R (2006) The 1906 San Francisco earthquake and fire: Perspectives on a modern super cat. Risk Management Solutions (RMS).
- Hennessy, K, Stafford Smith, M, Wang, X, Dormer, A, Chard, S, Rush, R, Rentmeester, A, Healey, M, Pikusa, E, Cornell, V (2014) Disaster mitigation workshop report. Proceedings of workshop held on 23 May 2014 in Melbourne. CSIRO, the Attorney-General's Department, and the Risk Assessment, Measurement and Mitigation Sub-committee, Melbourne.
- IPCC (2014a) 'Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.' (Cambridge University Press: Cambridge, United Kingdom and New York, USA)
- IPCC (2014b) 'Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.' (Cambridge University Press: Cambridge, United Kingdom and New York, USA)
- Neumayer, E, Barthel, F (2011) Normalizing economic loss from natural disasters: A global analysis. *Global Environmental Change-Human and Policy Dimensions* **21**, 13-24.
- Olshansky, RB, Kartez, JD (1998) Managing Land Use to Build Resilience. In 'Cooperating with Nature: Confronting Natural Hazards with Land Use Planning for Sustainable Communities.' (Joseph Henry Press: Washington, D.C.)
- Rose, A, Porter, K, Dash, N, Bouabid, J, Huyck, C, Whitehead, J, Shaw, D, Eguchi, R, Taylor, C, McLane, T, Tobin, LT, Ganderton, PT, Godschalk, D, Kiremidjian, AS, Tierney, K, West, CT (2007) Benefit-cost analysis of FEMA hazard mitigation grants. *Natural Hazards Review* **8**, 97-111.
- Sadiq, A-A, Weible, CM (2010) Obstacles and Disaster Risk Reduction: Survey of Memphis Organizations. *Natural Hazards Review* **11**, 110-117.
- Shah, HC (1994) 'Casualty, damage estimates of great quakes revised upward.' Available at <http://news.stanford.edu/pr/96/960110greatquake.html>



South Australian Government (2004) 'Atlas of South Australia: Natural Hazards.' Available at <http://www.atlas.sa.gov.au/resources/atlas-of-south-australia-1986/environment-resources/natural-hazards> [Accessed 15 August 2014].

Stein, J, Stein, S (2014) Gray swans: comparison of natural and financial hazard assessment and mitigation. *Natural Hazards* **72**, 1279-1297.

UK Environment Agency (2009) Investing for the future: Flood and coastal risk management in England - a long term investment strategy. Environment Agency, Bristol, UK.

van Delden, H, Seppelt, R, White, R, Jakeman, AJ (2011) A methodology for the design and development of integrated models for policy support. *Environmental Modelling & Software* **26**, 266-279.

Vaziri, P, Davidson, R, Nozick, L, Hosseini, M (2010) Resource allocation for regional earthquake risk mitigation: a case study of Tehran, Iran. *Natural Hazards* **53**, 527-546.

Wood, RS (2004) Earthquake Entrepreneurs: Local Policy Systems and the Regulation of Public Risks in California. *State & Local Government Review* **36**, 198-211.



# THRESHOLD BEHAVIOUR IN DYNAMIC FIRE PROPAGATION

PROCEEDINGS OF THE RESEARCH FORUM AT THE BUSHFIRE AND  
NATURAL HAZARDS CRC & AFAC CONFERENCE  
WELLINGTON, 2 SEPTEMBER 2014

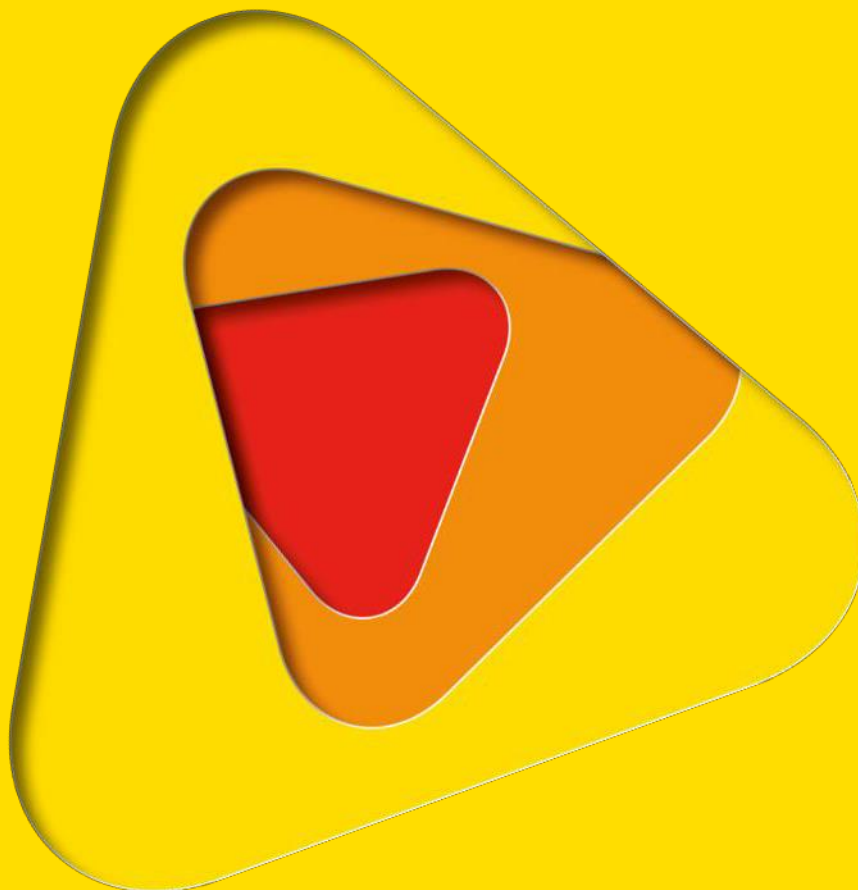
**J. J. Sharples<sup>1</sup>, C. C. Simpson<sup>1</sup>, J. P. Evans<sup>2</sup> and R. H. D. McRae<sup>3</sup>**

<sup>1</sup>University of New South Wales, Canberra

<sup>2</sup>University of New South Wales, Sydney

<sup>3</sup>ACT Emergency Services Agency

Corresponding author: [j.sharples@adfa.edu.au](mailto:j.sharples@adfa.edu.au)





## ABSTRACT

Recent research has demonstrated that under conditions of extreme fire weather, bushfires burning in rugged terrain can exhibit distinctly dynamic patterns of propagation, which can have a dramatic effect on subsequent fire development. Coupled fire-atmosphere modelling using large eddy simulation has been useful in shedding light on the physical mechanisms underlying these phenomena, for example highlighting the important role of fire-induced vorticity. In particular it has confirmed that the onset of dynamic modes of fire propagation is subject to a number of environmental thresholds. This is not the first time that the existence of threshold behaviour in combustion-related systems has been identified. In this paper we provide a brief summary of some combustion-related systems that exhibit threshold behaviour. Specifically we discuss the emergence of dynamic modes of fire propagation in exceedingly simple representations of combustion systems, and the existence of environmental thresholds relating to the propagation of wildfires in rugged terrain. Most significantly, we present new research that specifically investigates the environmental precursors necessary to drive a particular type of dynamic fire propagation known as vorticity-driven lateral spread (VLS). This research extends previous coupled fire-atmosphere modelling, to specifically consider the effect of wind speed and topographic slope in generating the fire-induced vorticity necessary to drive VLS.

The modelling results indicate the existence of environmental thresholds beyond which VLS is likely to occur. The results also indicate that the transition from quasi-steady to dynamic fire propagation can be quite abrupt, requiring only minimal changes in wind speed and slope for onset. The propensity for dynamic interactions to produce erratic and dangerous fire behaviour has strong implications for firefighter and community safety.

**Keywords:** Dynamic fire spread, VLS, threshold, bifurcation, extreme fire behaviour, wind-terrain-fire interaction.

## INTRODUCTION

Dynamic escalation of wildland fires into large conflagrations represents a significant challenge to the management of fires in the landscape. Multi-scale interactions between a fire and the local environment, which includes fuels, weather and topography, can produce highly complex patterns of fire spread that are currently beyond the capabilities of operational fire spread models. Understanding the physical processes that underpin these complex modes of fire propagation is a key step in developing the next generation of fire propagation models and in improving the way extreme bushfires are managed. Recent research into the behaviour of wild-fires has identified a number of dynamic modes of fire propagation. These modes of fire spread are referred to as dynamic because they are manifestly at odds with quasi-steady fire propagation, whereby a fire spreads at an approximately constant rate given uniform environmental conditions.

Viegas (2005) and Dold and Zinoviev (2009) examined the ability of a fire to exhibit exponentially increasing rates of spread up steep slopes and canyons, while Viegas et al. (2012) discussed the abrupt increases in rate of spread that can occur when two lines of fires intersect at some oblique angle. Another form of dynamic fire propagation was identified by Sharples et al. (2012) in connection with the 2003 Canberra bushfires. This phenomenon, which will be referred to as vorticity-driven lateral spread (VLS), involves the rapid lateral propagation of a fire across a lee-facing slope in a direction approximately perpendicular to the prevailing wind direction.

While the emergence of dynamic modes of fire propagation in wildfire situations has only recently begun to attract particular attention from researchers, the existence of dynamic modes of fire propagation in other combustion-related systems has long been acknowledged and studied (Zel'dovich et al. 1985; Weber et al. 1997; Merzhanov and Rumanov 1999; Gubernov et al. 2003; Sharples et al. 2009). Indeed, it has been shown that even the most elementary mathematical representations of combustion systems allow for the possibility of dynamic modes of fire spread (e.g. Sharples et al. 2009). These arise as a consequence of the inherent properties of dynamical systems and are defined by bifurcation (i.e. threshold) points relating to the various system parameters.





Although these simple combustion systems differ quite markedly from those encountered in wildfire situations, it is interesting to note the presence of dynamic modes of propagation in even the most simple representations of combustion systems. Given the inherent dynamics of simple combustions systems, it is then not surprising that dynamic modes of fire propagation also exist in wildfire situations.

In this paper we provide a brief summary of the various forms of dynamic fire propagation that arise in a number of situations. We begin with a very simple representation of a combustion system, namely that of a combustion wave propagating through a fuel bed. A mathematical model for the propagation of the combustion wave is derived based on single-step chemistry with Arrhenius kinetics and conservation of energy and mass. Despite the simplistic nature of the model system, dynamic modes of fire propagation are a mathematical certainty (Gubernov et al. 2003; Sharples et al. 2009) and we present some examples of these dynamic propagation modes. We next consider the phenomenon of flame attachment and discuss how it is critically dependent on the slope of the terrain. The vertical rise of flames into the air, which is perhaps considered typical, will in fact only occur on slopes below a threshold angle. For fires burning on slopes inclined above this threshold angle, dynamic interactions between the fire, the atmosphere and the terrain can cause the fire's plume to attach to the surface. In these instances the surface will be effectively bathed in flames. While this effect is well understood for certain geometric configurations, there is little knowledge of how the effect manifests in terrain geometries that are found in the landscape. We report on some initial progress in this area and discuss plans for future work. Finally, we turn our attention to the VLS phenomenon and provide a brief account of some recent findings relating to environmental thresholds for VLS occurrence. In particular we consider the sensitivity of VLS to changes in wind and topographic slope.

## COMBUSTION WAVE DYNAMICS

To illustrate the emergence of dynamic modes of fire propagation in simple combustion systems, we will consider the propagation of a combustion wave through a reactive medium. Figure 1a gives an example of such a phenomenon. The fuel is ignited at the top and the fire spreads down through the fuel as a front, which can be thought of as the interface between burnt and unburnt fuel. Such a front is an example of a *combustion wave*. To determine the profile and speed of a combustion wave, we invoke conservation of energy and conservation of mass (i.e. fuel). Applying the appropriate book-keeping to the system, it follows that the combustion wave at time  $t$  and position  $x$  is given by the (non-dimensional) temperature  $u(x, t)$  and the fuel-fraction  $v(x, t)$ , which are determined through solution of the system of partial differential equations (Weber et al. 1997):

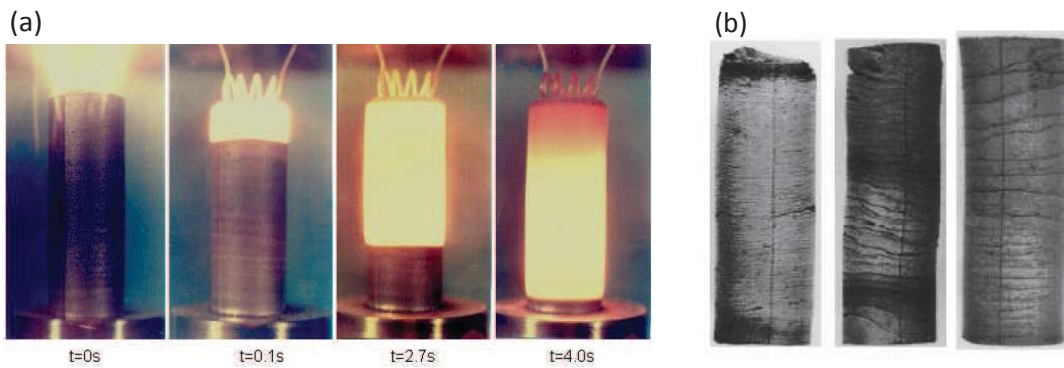
$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + v e^{-1/u} \quad (1)$$

$$\frac{\partial v}{\partial t} = Le^{-1} \frac{\partial^2 v}{\partial x^2} - \beta v e^{-1/u} \quad (2)$$

Note that equation (1) guarantees conservation of energy, while equation (2) guarantees conservation of fuel. The system parameters  $Le$  and  $\beta$ , describe the state of the fuel, and the exothermicity of the combustion reaction, respectively. Note that smaller values of  $\beta$  correspond to more exothermic reactions.

Figure 2 shows how the speed of the combustion wave varies with time when  $Le = 8$  and  $\beta$  assumes various values. For instance, when  $Le = 8$  and  $\beta = 7.5$  we find that the combustion wave propagates with a constant speed of just over 0.02 (Figure 2a). However, if the value of  $\beta$  is increased from  $\beta = 7.5$  to  $\beta = 7.6$ , we find that now the combustion wave propagates with a wave speed that varies periodically; that is, the fire will spread with a speed that continually oscillates between 0.01 and 0.035, approximately (Figure 2b). Figures 2c and 2d, show that as  $\beta$  is increased further, more complicated dynamic combustion wave propagation arises. Figure 2c shows a doubly-periodic wave speed, while Figure 2d shows an essentially chaotic wave speed.

The dynamic modes of fire propagation evident in Figure 2b arise due to the presence of a Hopf bifurcation in the dynamical system representing the combustion reaction. The more complicated behaviours seen in Figures 2c and 2d arise through the presence of further period-doubling bifurcations. Mathematical niceties



**Figure 1.** (a) A combustion wave propagates through a reactive medium in an example of the Self-propagating High-temperature Synthesis (SHS) process (b) laminar defects in SHS products due to dynamic (periodic) variations in combustion wave speed. The figure has been adapted from Makino (2000).

aside, the main point is that even in the most elementary representations of combustion systems, there are inherent dynamics that can emerge under certain configurations of the system. Moreover, the emergence of dynamic behaviour in these simple combustion systems has real and important consequences. Figure 1b shows the consequences of a dynamic wave speed in an industrial combustion process called self-propagating high-temperature synthesis (Makino 2000).

We now extend our attention to consider the emergence of dynamic behaviour of fires burning in steep and confined terrain.

## TERRAIN-RELATED THRESHOLDS FOR FLAME ATTACHMENT

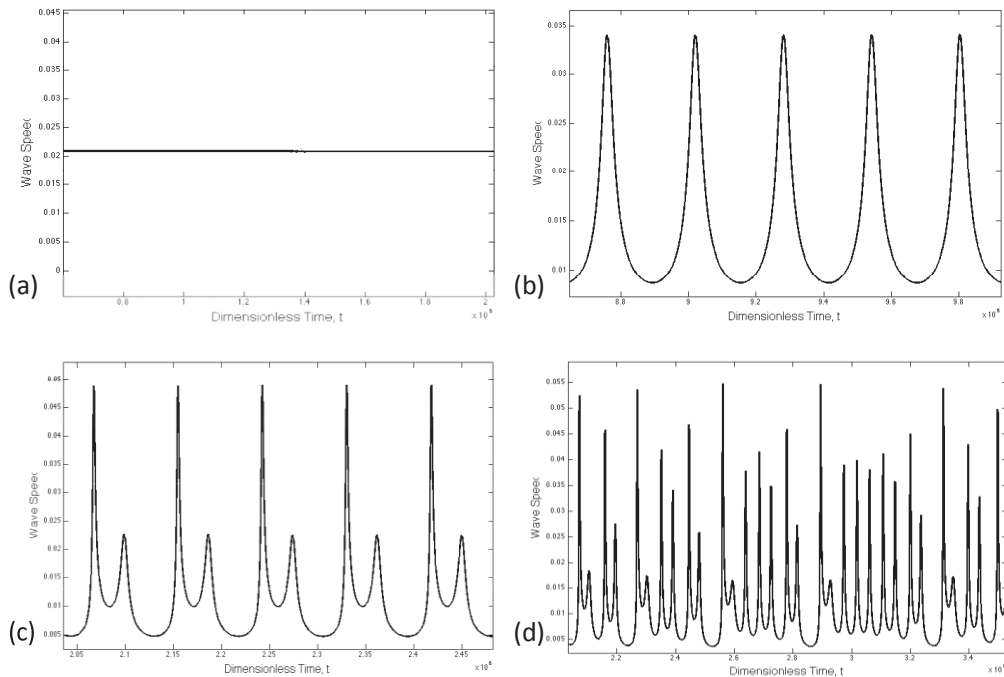
It appears the Rothermel (1984) was the first to discuss the possibility of flames attaching to a sufficiently inclined surface. Indeed, Rothermel (1984) specifically states that:

*There is no definitive research on the problem of flame attachment. It appears from both lab work and discussions with users that the flame becomes attached near 50 percent slope with no prevailing wind. It is not known, but it may not be possible to produce a fire of enough intensity to cause flame detachment on steep slopes regardless of the method of ignition.*

In this context, it is of interest to note that a 50 percent slope is equivalent to a slope of  $26.6^\circ$ .

The first scientific investigations into the flame attachment phenomenon were conducted as part of the official investigation into the cause of the disastrous development of an escalator fire in the London Underground (Crossland 1992; Drysdale et al. 1992; Moodie and Jagger 1992; Smith 1992; Wu and Drysdale 1996). A fire that started on an escalator, just below the ticket hall at King's Cross Station, was initially assessed by firefighters as being of only minor concern. However, in an unexpectedly short amount of time the fire spread with extreme ferocity up the escalator trench and into the ticket hall and surrounding areas with tragic consequences. The fire ultimately killed 31 people – it was described by witnesses as a *blowtorch* or an *eruption*. It is interesting to note that the King's Cross Fire occurred in 1987, approximately 3 years after Rothermel's publication in 1984, and that remarkably, the investigation into the King's Cross Fire found that flames would attach to the surface of the escalator trench when it was inclined over about  $26^\circ$  (Simcox et al. 1992; Drysdale and Macmillan 1992; Wu et al. 2000).

The mechanism that drives flame attachment is a dynamic transition from separated to attached flow of the fire's plume. The interaction between the buoyant plume and the atmosphere creates indrafts into the base of the fire. However, when the terrain surface is inclined above a critical, or threshold angle of about  $26^\circ$ , the entrainment into the plume from below the fire cannot be matched by the entrainment from above the fire. This results in a pressure deficit near the surface directly upslope from the location of the fire. At this point the flow associated with the fire's plume encounters a bifurcation, which results in the plume attaching to the surface. This in turn causes enhanced preheating of the fuels above the fire, as they are



**Figure 2.** Plots of combustion wave speed versus time ( $Le = 8$ ). (a) Constant speed propagation when  $\beta = 7.5$ , (b) periodic combustion wave speed when  $\beta = 7.6$ , (c) period-2 variation in wave speed when  $\beta = 7.9$ , (d) chaotic wave speed when  $\beta = 7.95$ .

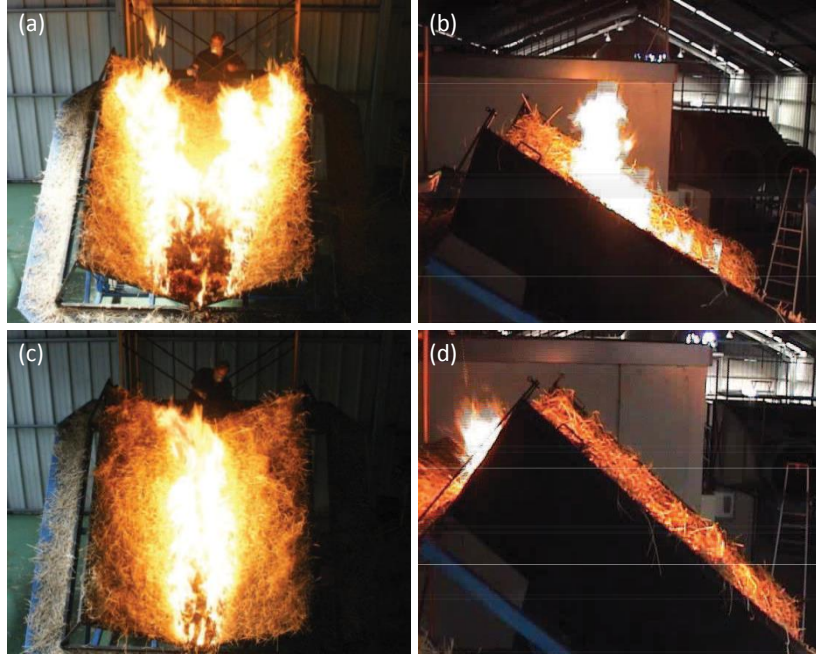
bathed in the hot plume of the fire moving along the surface. This enhanced preheating then results in enhanced rates of spread. Indeed, Dold and Zinoviev (2009) indicate that there is no obvious upper limit to the speed at which an attached flame can move over a surface<sup>1</sup>.

Research into flame attachment has focused on two cases: that of an inclined planar surface; and that of an inclined rectangular trench. While such cases are of interest, particularly in a structural firefighting context, they do not tend to correlate well with the elements of terrain encountered in the landscape. For example, canyons or gullies within a landscape tend to be somewhat V-shaped in profile, rather than rectangular like an escalator trench. Moreover, due to the effects of erosion, most gullies or canyons have a layer of sediment along their waterline, which tends to smooth the V-shaped profile.

Experimental fires set in steep V-shaped canyons indicated that the threshold angle of inclination for such a configuration is in the range of  $30^\circ - 40^\circ$ . Examples of the observed fire behaviour can be seen in Figure 3. In Figure 3a the canyon is inclined at  $30^\circ$  and the fire spreads up the canyon as two distinct head fires that follow the lines of maximum slope. Figure 3b shows clearly that for this case the fire's plume is not attached to the terrain surface. Figure 3c shows that when the canyon is inclined at  $40^\circ$  the resultant pattern of fire spread is markedly different to the  $30^\circ$  inclination case. In Figure 3c the fire can be seen propagating as a single head fire straight up the waterline of the canyon. Moreover, Figure 3d shows that the fire's plume is now attached to the surface – the flames are only visible from the side view as they erupt from the top of the canyon.

The flame attachment phenomenon therefore serves as another example of dynamic fire propagation, which is subject to threshold behaviour. In this instance the threshold relates to the conditions of the terrain. Investigations to date indicate that the threshold angle of inclination, above which flames will attach to a surface, is dependent upon the geometric profile of the canyon. This is being investigated in further research funded through the Australian Research Council.

<sup>1</sup> Of course, one would not expect flames to exceed the speed of sound!



**Figure 3.** Photographs of experimental fire behaviour in V-shaped canyons. In panels (a) and (b) the canyon is inclined at 30°, while in panels (c) and (d) the canyon is inclined at 40°.

## THRESHOLDS TO VORTICITY-DRIVEN LATERAL SPREAD

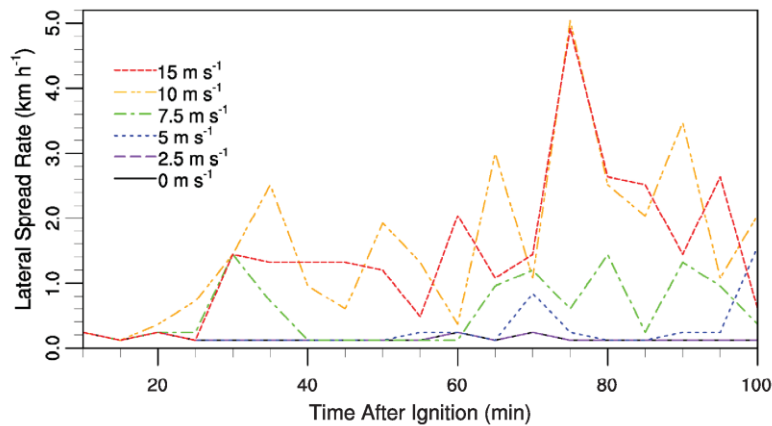
Vorticity-driven lateral spread (VLS) is a dynamic mode of wildfire propagation that has been linked to the rapid development of bushfires (Sharples et al. 2012; Simpson et al. 2013; Simpson et al. 2014). Initial work aimed at understanding the processes underlying the VLS phenomenon identified topographic slope and aspect conditions that were conducive to VLS occurrence. Specifically, it was found that a necessary condition for VLS occurrence was given by  $\chi(\sigma, \delta) = 1$ , where

$$\chi(\sigma, \delta) = \begin{cases} 1, & \text{if } \gamma_s \geq \sigma \text{ and } |\theta_w - \gamma_a| \leq \delta, \\ 0, & \text{otherwise.} \end{cases} \quad (3)$$

In equation (3),  $\gamma_s$  and  $\gamma_a$  are the topographic slope and aspect angles, respectively, and  $\theta_w$  is the wind direction angle (i.e. the way the wind is heading). The model (3) is defined by the model parameters  $\sigma$  and  $\delta$ , which are termed the *slope threshold* and *aspect discrepancy threshold*, respectively. Sharples et al. (2012) found that for VLS events observed during the 2003 Canberra fires, the model parameters could be estimated as  $\sigma \approx 25^\circ$  and  $\delta \approx 40^\circ$ . This model has also been successfully applied to several other notable fires, though these studies are yet to be published.

Sharples et al. (2013) examined the effect of variable prevailing wind speed on VLS occurrence. They considered an idealised triangular ridge with an apex line oriented orthogonally to the prevailing wind directions. Further details of the simulations are provided by Simpson et al. (2013) and Sharples et al. (2013). For wind speeds below about  $5 \text{ ms}^{-1}$  it was found that VLS did not occur. The reason for this is that under such low wind speeds the flow does not possess enough momentum to separate from the surface in the lee of the ridge line. As a consequence, there is no source of ambient vorticity and the fire cannot produce the interaction that drives VLS. On the other hand, for wind speeds of  $7.5 \text{ ms}^{-1}$  or greater the simulations all exhibited VLS (see Figure 4).

Simpson et al. (submitted) extended the study described above, by systematically altering the inclination of the leeward slope while holding the prevailing wind speed at a constant  $15 \text{ ms}^{-1}$ . They found that for slopes below  $20^\circ$  the spread of a simulated fire ignited on the leeward slope was dominated by spread in a downslope direction. This again reflects the nature of the wind flow driving the fire – in these low slope



**Figure 4.** Lateral spread rates arising from coupled fire-atmosphere simulations of fires burning on leeward slopes under different prevailing wind speeds.

cases, the lee slope is not sufficiently steep to drive the flow separation required to create the ambient horizontal vorticity required for VLS. Instead the wind simply flows over the ridge line and drives the fire as a downslope wind. For leeward slopes of  $25^\circ$  the pattern of fire spread is indicative of a transitional stage between the quasi-steady behaviour in the shallower slope cases and the dynamic behaviour for steeper leeward slopes. Indeed, for leeward slopes of  $25^\circ$  or more the pattern of fire spread is markedly different, with the evolution of the fire's perimeter dominated by rapid lateral spread across the top of the leeward slopes. This transition to dynamic fire propagation as the leeward slope angle is increased is illustrated in Figure 5.

Ongoing research is examining environmental thresholds relating to topographic aspect and properties of the fuel, as well as the interdependence of these thresholds as environmental factors are varied in combination.

## DISCUSSION AND CONCLUSIONS

Thresholds to dynamic behaviour are inherent in combustion systems, even in their most elementary realisations. Dynamic instabilities in combustion systems can give rise to variable propagation speed (e.g. oscillatory) that result in undesirable consequences for industrial processes (e.g. impurities, thermal runaway). We have demonstrated that dynamic fire behaviour can also arise in wildfire situations, but that its occurrence can depend critically on a number of environmental factors; for example, in V-shaped canyons there is a slope threshold above which flames will attach to the surface. Flame attachment can result in significantly enhanced (and accelerating) rates of fire spread and may have played a role in a number of wildfire incidents in which firefighters were injured or killed (Sharples et al. 2010).

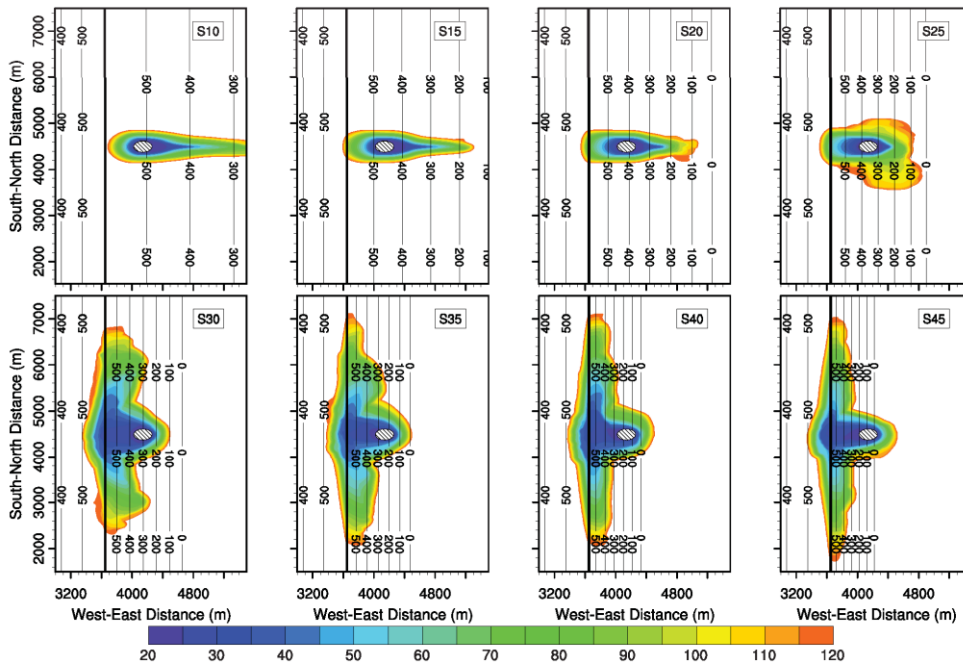
Investigation of flame attachment in the types of terrain geometries found in the landscape is still in its initial stages. A number of challenges remain. For example: How does the threshold inclination for flame attachment change in response to variations in the geometric profile of the canyon?; and How does the presence of an ambient wind affect the threshold inclination? These issues will be addressed in ongoing research.

Most significantly, at least in the context of extreme wildfire development, is the VLS phenomenon and its associated environmental thresholds. The ability of wildfires to exhibit rapid lateral spread across steep, lee-facing slopes, poses a significant challenge to the management of fires in rugged terrain. The interaction between the terrain-modified winds and the fire's plume transforms the ambient horizontal vorticity into a pair of counter-rotating vertical vortices, or fire-whirls, which drive the fire laterally across the slope. As demonstrated above, VLS is subject to a number of environmental thresholds, including those relating to wind speed, topographic slope and aspect and fuel properties.





The wind speed threshold for VLS, as determined using couple fire-atmosphere simulations, is approximately  $5 \text{ ms}^{-1}$  ( $18 \text{ km h}^{-1}$ ), which is in general agreement with the value of  $20 \text{ km h}^{-1}$  suggested by Sharples et al. (2012). This threshold relates to the nature of the wind flow over the leeward slope - the wind must



**Figure 5.** Coupled fire-atmosphere simulations of fires burning on leeward slopes with different inclinations. Slope values are indicated in the figure panels, for example 'S35' indicates a leeward slope angle of  $35^\circ$ .

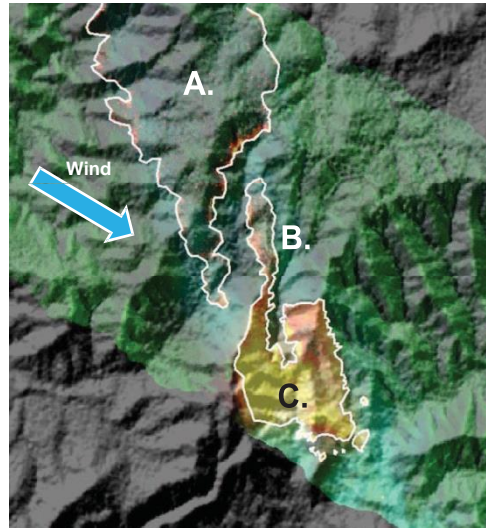
be sufficiently strong to separate from the surface and produce horizontal vorticity, which is a key element of the VLS mechanism. The coupled simulations also indicated a topographic slope threshold for VLS of approximately  $25^\circ$ , which is in good agreement with the slope threshold determined empirically by Sharples et al. (2012). Again this threshold relates to the nature of the flow on the leeward slope. For leeward slopes inclined at an angle less than  $25^\circ$  the wind manifests essentially as a (non-separated) laminar flow and drives the fire downslope. On leeward slopes greater than  $25^\circ$  the leeward wind regime is dominated by turbulent eddies (which manifest as an upslope time-averaged flow). In such cases horizontal vorticity is present to drive the VLS phenomenon.

We have also considered thresholds relating to topographic aspect and fuel properties. Although this work is still under formal peer-review, we can report that the coupled simulations indicated a topographic aspect discrepancy threshold of approximately  $10 - 20^\circ$ . This means that the wind direction and topographic aspect direction must align to within  $10 - 20^\circ$  of each other for VLS to occur. This is much less than the value reported by Sharples et al. (2012) of  $40^\circ$ . The reasons for this difference are not presently understood, though our suspicion is that it is due to the variable nature of environmental conditions in real situations, as opposed to the precise conditions that are set in the coupled simulations. VLS has also been found to be sensitive to fuel properties, as defined in the fuel classification framework of Anderson (1982). The most important fuel-related variables determining VLS occurrence appear to be wind speed reduction factor, initial fuel mass loading, mass loss rate and packing ratio. Essentially all of these variables affect the heat output from the fire. If the heat output is insufficient then VLS will not occur (Simpson et al. 2013).

The existence of environmental thresholds to dynamic fire propagation has a number of operational and safety implications. Indeed, they imply that small changes in environmental conditions can result in significant changes in the nature of fire spread, not to mention the associated fire behaviour characteristics. For example, with a slight change in topographic aspect, firefighters working on leeward slopes could suddenly encounter an abrupt and distinct change in fire behaviour: Figure 6 shows exactly this situation.



The fire near point A is propagating in a typical fashion, as is evident by the relatively thin flaming zone (yellow) around the fire perimeter. Similarly the fire at point B is progressing downslope towards the west (and the fire at point A) in a typical fashion. This fire behaviour has all the hallmarks of a well-executed back-burn, ignited to head-off the main fire at point A. Note that a fire trail runs along the ridge line evident in



**Figure 6.** Multispectral linescan of a wildfire (point A) and a back-burn (points B and C).

the figure. The fire at point C exhibits a markedly different and far more alarming pattern of spread. The fire at this point appears to be in a state of *deep flaming*, where a large area of the landscape has been ignited in rapid succession. The fire at point C now dominates the fire propagation, and the associated pyro-convection, in what amounts to a phenomenological coup d'etat.

In fact the fire behaviour at point C is consistent with the VLS phenomenon, and demonstrates the topographic aspect threshold effect. The terrain at point B has an approximately northeasterly aspect that does not sufficiently align with the wind direction (wind blowing towards the southeast) to drive any dynamic fire spread. However, upwind of point C (and downwind of the fire trail along the ridge line) the topographic aspect is approximately southeasterly and aligns with the wind in a way that is highly conducive to VLS occurrence. The apparent lateral spread, the downwind extension of the flaming zone and the abundance of spot fires evident in the linescan near point C are all consistent with VLS. Indeed, it is difficult to account for the significant differences in fire behaviour, under meteorological and vegetation conditions that were more or less uniform over the region, without invoking some form of dynamic threshold behaviour.

Some may view the exacerbation of the fire near point C in Figure 6 as a failure of the fire crews involved or the strategic decisions that were made surrounding the ignition of the back-burn. However, in our opinion, the real failure was in the inadequacy of our collective understanding of how fires burn under extreme conditions in rugged terrain. Bushfires burning in rugged terrain under extreme weather conditions are distinctly dynamic phenomena that are influenced by a range of mechanisms that we are only beginning to properly understand. Incorporating new findings into training programs and increasing the general awareness of processes such as VLS, which have been shown to dramatically influence fire development, appear to be the best options for improving matters, at least in the immediate future.

## ACKNOWLEDGEMENT

This work is supported by an Australian Research Council (ARC) Discovery Indigenous Award (IN130100038) and an ARC Future Fellowship (FT110100576). WRF-Fire model runs were performed using the facilities at NCI. Experimental studies of fires in V-shaped canyons were conducted at the Centre for the Study of Forest Fires, University of Coimbra, Portugal. The authors are extremely grateful for the collaboration of Prof. Domingos Viegas and his team.





## REFERENCES

- Anderson, H. (1982). *Aids to determining fuel models for estimating fire behaviour*. USDA Forest Service, Intermountain Forest and Range Experiment Station INT-122.
- Crossland, B. (1992) The Kings Cross Underground Fire and the setting up of the investigation. *Fire Safety Journal* 18, 3-11.
- Dold, J. W., Zinoviev, A. (2009). Fire eruption through intensity and spread rate interaction mediated by flow attachment. *Combustion Theory and Modelling* 13, 763793.
- Drysdale, D.D., Macmillan, A.J.R., Shilitto, D. (1992) The Kings Cross Fire: Experimental verification of the trench effect. *Fire Safety Journal* 18, 75-82.
- Drysdale, D.D., Macmillan, A.J.R. (1992) Flame spread on inclined surfaces. *Fire Safety Journal* 18, 245-254.
- Gubernov, V.V., Mercer, G.N., Sidhu, H.S., Weber, R.O. (2003) Evans function stability of combustion waves. *SIAM Journal on Applied Mathematics* 63, 1259-1275.
- Makino, A. (2000) Initiation of SHS flame induced by another SHS flame evaluation of the ignition energy. *Journal of Energy Resources Technology* 123, 70-75.
- Merzhanov, A.G., Rumanov, E.N. (1999) Physics of reaction waves. *Reviews of Modern Physics* 71, 1173-1211.
- Moodie, K, Jagger, S.F. (1992) The Kings Cross Fire: Results and analysis from the scale model tests. *Fire Safety Journal* 18, 83-103.
- Rothermel, R.C. (1984) Fire behavior consideration of aerial ignition, in Mutch, R.W., *Prescribed Fire by Aerial Ignition: Proceedings of a Workshop*. Missoula, MT. Intermountain Fire Council, Missoula, MT. p. 143-158
- Sharples, J., McRae, R., Wilkes, S. (2012). Wind-terrain effects on the propagation of large wildfires in rugged terrain: fire channelling. *International Journal of Wildland Fire* 21, 599614.
- Sharples, J.J., Gubernov, V.V., Sidhu, H.S., Towers, I.N., Kolobov, A.V., Polezhaev, A.A. (2009) Behaviour of combustion waves in one-step and two-step models. *Proceedings 18th World IMACS/MODSIM Congress*, Cairns, Australia 13-17 July 2009.
- Sharples, J.J., Gill, A.M., Dold, J.W. (2010) The trench effect and eruptive wildfires: lessons from the King's Cross Underground disaster. *Proceedings of AFAC 2010 Conference*, Darwin. Sept. 2010.
- Sharples et al., (2013) Threshold behaviour in dynamic fire propagation
- Simpson, C., Sharples, J., Evans, J., McCabe, M. (2013). Large eddy simulation of atypical wildland fire spread on leeward slopes. *International Journal of Wildland Fire* 22, 282296.
- Simpson, C.C., Sharples, J.J., Evans, J.P. (2014) Resolving vorticity-driven lateral fire spread using the WRF-Fire coupled atmosphere-fire numerical model. *Natural Hazards and Earth Systems Science Discussions* 2, 3499-3531.
- Simpson, C.C., Sharples, J.J., Evans, J.P. (submitted) Sensitivity of vorticity-driven lateral fire spread to ambient wind and leeward slope using WRF-Fire. *Geophysical Research Letters*.
- Simcox, S., Wilkes, N.S., Jones, I.P. (1992) Computer simulation of the flows of hot gases from the fire at Kings Cross Underground Station. *Fire Safety Journal* 18, 49-73.
- Smith, D.A. (1992) Measurements of flame length and flame angle in an inclined trench. *Fire Safety Journal* 18, 231-244.



Viegas, D.X. (2005) A mathematical model for forest fires blow-up. *Combustion Science and Technology* 177, 27-51.

Viegas, D.X., Raposo, J., Davim, D., Rossa, C. (2012). Study of the jump fire produced by the interaction of two oblique fire fronts. Part 1: Analytical model and validation with no-slope laboratory experiments. *International Journal of Wildland Fire* 21, 843856.

Weber, R., G. Mercer, H. Sidhu, and B. Gray (1997). Combustion waves for gases ( $Le = 1$ ) and solids ( $Le \rightarrow \infty$ ). *Proceedings of the Royal Society of London Series A* 453, 11051118.

Wu, Y., Drysdale, D.D. (1996) *Study of upward flame spread on inclined surfaces*. HSE Contract Research Report No. 122/1996.

Wu, Y., Xing, H.J., Atkinson, G. (2000) Interaction of fire plume with inclined surface. *Fire Safety Journal* 35, 391-403.

Zeldovich, Y.B., Barenblatt, G.I., Librovich, V.B., Makhviladze, G.M. (1985) *The Mathematical Theory of Combustion and Explosion*. Consultants Bureau, New York.



# A PRE-DISASTER MULTI-HAZARD DAMAGE AND ECONOMIC LOSS ESTIMATION MODEL FOR AUSTRALIA

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

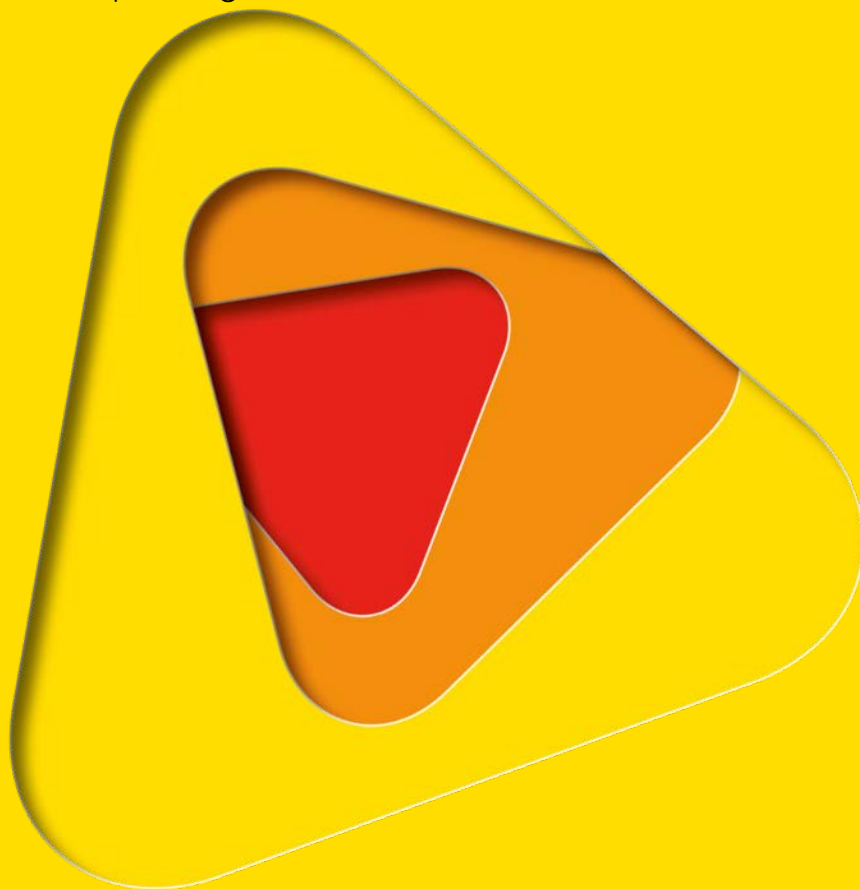
Abbas Rajabifard<sup>1,3</sup>, Mehmet Ulubasoglu<sup>2,3</sup>, Katie Elizabeth Potts<sup>1,3</sup>, Muhamman  
Habibur Rahman<sup>2,3</sup>, Mohsen Kalantari<sup>1,3</sup> and Prasad Bhattacharya<sup>2,3</sup>

<sup>1</sup>The University of Melbourne

<sup>2</sup>Deakin University

<sup>3</sup>Bushfire and Natural Hazards CRC

Corresponding author: [abbas.r@unimelb.edu.au](mailto:abbas.r@unimelb.edu.au)





## ABSTRACT

Australia has witnessed a series of natural disasters throughout history that significantly affects its development trajectory. Examples include: cyclones Mahina (1899) in northern Queensland and Tracy (1974) in Darwin; floods in New South Wales (1955) and South-east Queensland (1974; 2011; 2012); earthquake in Newcastle (1989); landslide in Thredbo (1997); and bushfires in Victoria, South Australia, Tasmania and Australia Capital Territory (Black Saturday 2009; Canberra Fires 2003; Ash Wednesday 1983; Black Tuesday 1967; and Black Friday 1939). The resulting economic impact of these natural disasters is estimated to cost an average of AU\$1.14 billion annually (BTE, 2001). This alarming statistic alone, along with its ever growing vulnerability due to rapid economic expansion in Australia, makes natural disasters a high priority issue for policy makers. In recent catastrophic natural disaster events, the emergency response of Australia has proven to be very effective at saving human lives. However the mitigation and preparedness of disaster risk reduction (DRR) appear to be less successful in avoiding the adverse economic impacts of natural disasters. One of the significant problems observed in this connection is the lack of effort to estimate the full economic impact of natural hazards, taking into account all the affected sections of the economy. This effort should consider not only the primary effects of the natural disasters, but also its secondary effects due to losses propagated through the economy arising out of possible inter-sectoral linkages. In order to achieve a paradigm shift from reactive response to a proactive risk reduction culture, disaster risk reduction measures need to be integrated into the economic development process. With this in mind, this paper discusses the shortcomings of current approaches and identifies the steps required for developing a system for increasing the disaster risk resilience of Australia.

## INTRODUCTION

History portrays numerous natural disasters that not only reshaped topographical settings but also have bearings on the economic structures of many countries, including Australia. The economic impacts are often overlooked in management planning as they are not immediately felt and focus is put onto emergency response systems. In Australia, the disaster management arrangements across all stages (mitigation, preparedness, response and recovery) have proven to be very successful at saving lives and property. However, in terms of the adverse economic impacts of the natural disasters, less attention and resources have been allocated.

In Australia, natural disasters are estimated to cost an average of AU\$1.14 billion annually (BTE, 2001). This statistic, which includes the costs carried by individuals, governments, businesses etc., along with the rapid economic growth in Australia, makes natural disasters a significant issue for policy makers. One of the substantial issues identified in this connection is the inability to estimate the full economic impact of natural hazards, considering all the affected sections of the economy. This effort should take into account not only the *primary effects* of the natural disasters, but also its lingering, all-important *secondary effects* due to the pervasive losses throughout the economy emanating from various sectors within the economy.

In this paper, we identify at least two major requirements that seek immediate attention to bridge the related gap. Firstly, a disaster risk assessment system needs to be developed which provides adequately quantifiable potential damages as a result of different types of disasters for regions of Australia. Secondly, a framework needs to be established to estimate the indirect economic losses. With the identification of the disaster-specific potential damage and losses, policymakers at different levels will be able to formulate disaster risk reduction-inclusive development policies to mainstream disaster



resilience practices. Hence, modelling the potential impacts of a full range of natural disasters remains highly critical towards designing more informed national economic policies. The overarching aim is to increase the level of the disaster risk resilience of the Australian economy. To summarise, in order to move from reactive response to a proactive risk reduction culture, a pioneering effort in mainstreaming disaster risk reduction (DRR) measures into the economic development process is required.

## **THE TRUE COST OF DISASTERS – CALCULATING THE ECONOMIC IMPACTS**

Until the 1990s, the economic impact of natural disasters received relatively little attention from both the academic as well as the practitioner communities. A series of disasters in the mid-1990s, such as the Northridge Earthquake in 1994 and the Kobe Earthquake in 1995, which occurred in developed urban areas and resulted in considerable damage and impact to the society, demonstrated how vulnerable modern industrialised cities are to severe natural hazards.

Substantial progress has been made in recent years in the economic analysis of disasters, especially in the field of economic modelling of disaster impact analysis in a regional context. Since the pioneering work by Dacy and Kunreuther (1969), various generalised frameworks for the economic analyses of natural disasters have been proposed. The recent advancements have been more toward empirical analyses and the strategies for modelling extensions and modifications to fit them to different disaster situations. The method proposed in this paper aims to formulate a macro-econometric model for Australia that would not only quantify the potential losses in various economic sectors, but would also prescribe optimal policy mix for ensuring effective reallocation of available resources in the economy.

## **ASSESSING CURRENT APPROACHES AND METHODS AVAILABLE**

As outlined in this introduction, the approach that this research will be taking is firstly developing a disaster risk assessment system, secondly modelling economic impact analysis and finally visualising the results of the first two stages to enable more informed national economic policies (figure 1).

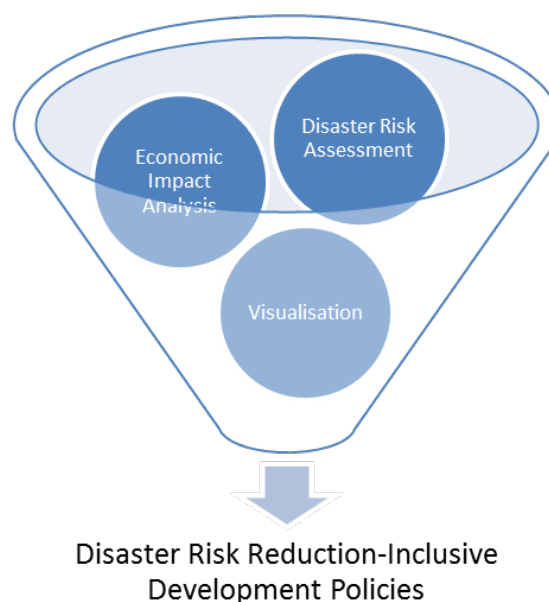


Figure 1: The research approach and outcomes



A number of different approaches and methods have been identified for developing a disaster risk assessment system and an economic impact assessment model. Below the identified approaches and methods have been summarised and their limitations identified.

Three key methodologies for developing a disaster risk assessment system have been identified in this research: HAZUS (Hazard in the US); Advanced Component Method (ACM); and CAPRA.

HAZUS was developed by the National Institute of Building Sciences for the Federal Emergency Management Agency (FEMA) in the United States and is one of the major efforts worldwide to develop a methodology for disaster risk assessment. HAZUS contains extensive databases and default values for methodology parameters, thus, making it possible to estimate potential damage and losses. However, its estimates on economic losses are *not accurate*, as it considers only linear growth patterns in economic activities.

ACM was developed by AIR Worldwide Corporation and is more advanced than HAZUS in a number of ways. With ACM, an objective and scientific methodology largely replaces the subjective measures and opinions of experts about how building damage relates to different level of disaster (i.e. earthquake) intensities. ACM assesses both physical and monetary damage at the component level (e.g., damage to beams, columns and partitions of buildings). Estimates of component damage are subsequently combined to achieve an estimate of total damage to the building. However, like HAZUS it *does not estimate indirect economic losses* associated with physical damage due to natural disasters.

CAPRA is a disaster risk information platform for assessing and estimating disaster risks. It consolidates hazard and risk assessment methodologies providing potential loss estimation with regard to different natural hazards. However, CAPRA is not *technically feasible* to adopt in the context of bushfire hazard. Further, CAPRA does not take into account broader sections of the economy given its emphasis on cost-benefit analysis.

The disaster risk assessment component for the model developed to be applied to Australia will leverage off these identified models and will aim to address some of the shortcomings which make these above models unsuitable for the proposed application. For the economic impact analysis component of the model a number of current methods and models have also been identified.

Various economic techniques have been employed to estimate the higher order effects of a disaster. One methodology developed for this purpose is the Damage and Loss Assessment (DaLA) methodology. This methodology was introduced by the Economic Commission for Latin America and the Caribbean (UN ECLAC) and has been considered as the internationally accepted standard methodology for assessing the economic impact of natural disasters. It quantifies both direct damages and indirect losses due to natural hazards in a sector-by-sector context. However, the economy is by nature very complex since all of the sectors are inter-linked simultaneously. This imposes a downward bias in the estimates of DaLA, since it ignores *inter-sectoral* relationships in assessing the overall impact of natural disasters.

Another widely used modelling framework is the Input-Output model (c.f. Cochrane 1974, 1997; Wilson 1982; Kawashima et al. 1991; Boisvert 1992; Gordon and Richardson 1996; and Okuyama et al. 1999). The application of this model to disasters dates back to strategic bombing studies during the Second World War (Rose 2004). The popularity of this modelling approach for disaster-related research is primarily based on the ability to reflect the interdependencies within a regional economy in detail for deriving higher-order effects, and partly on its simplicity - the model creates a set of limitations including



its linearity, its rigid structure with respect to input and import substitutions, a lack of explicit resource constraints, and a lack of responses to price changes (Rose, 2004).

An alternative to the Input-Output model is the Computable General Equilibrium (CGE) model (c.f. Boisvert 1992; Brookshire and McKee 1992; Rose and Guha 2004; and Rose and Liao 2005). Unlike the Input-Output approach, CGE models are nonlinear, can respond to price changes, can incorporate input and import substitutions, and can explicitly handle supply constraints. However, Rose and Liao (2005) claim that most CGE models are intended for long-run equilibrium analysis and hence, in contrast with the rigidity of the Input-Output model, a CGE model generally leads to the underestimation of economic impacts due to its flexible adjustment feature. Another limitation of CGE models is that the assumption of optimising behaviour can be considered questionable under disaster situations where increased uncertainties arise in the near and distant future. In addition, a more extensive data requirement for CGE modelling presents another major disadvantage for empirical analysis of disasters.

## **FLESHING IT OUT – THE STEPS TO DEVELOP A PRE-DISASTER MULTI-HAZARD DAMAGE AND ECONOMIC LOSS ESTIMATION MODEL FOR AUSTRALIA**

As has been discussed above, a number of different approaches exist for modelling and estimating damage and economic loss as a result of disasters, however none of these approaches are comprehensive when applied to the country of Australia.

Given its multi-disciplinary nature, this research borrows scientific methods from both the engineering and economics disciplines. Initially, it takes a geographic information system (GIS) as a tool to develop a multi-hazard risk assessment map, and following that it uses empirical economic techniques to estimate overall effects of natural disasters. The method utilised will involve the steps of compiling available multi-hazards maps, consulting and collecting data from a number of expert organisations within Australia. This data will then be integrated to create a geographic database of exposed elements. This data will then be verified through random but systematic ground-truthing activities. Following this a vulnerability assessment will then be conducted on a selected case area, and the information will be fed through an intelligent visualisation platform to create a comprehensive multi-hazard risk map. The result will be a presentation of the risk in terms of physical and direct monetary damage pertaining to the administration units of the case study area.

Once the potential physical *damage* of natural disasters is estimated, this research will focus on integrating different scenarios of disaster risks in a macroeconomic model in not only quantifying the potential economic *losses* but also prescribing optimal policy mix for ensuring effective reallocation of available resources in the economy. First, the economists will identify an ideal macroeconomic model for incorporating disaster risks that will enable estimating the sector-specific potential economic losses, and secondly, the possible effects of various policy options for identifying the best alternative economic policy package that will maximally minimise disaster risks are forecast.

To visualise the results the research will utilise an existing geospatial platform – the Intelligent Disaster Decision Support System (IDDSS). The platform adds value to end users by enabling them to access and make use of the results of the system. The IDDSS system can store, update, analyse, and visualise data including hazard perception and vulnerability maps for bushfires, floods, storms and earthquakes in order to obtain a multi-hazard vulnerability map for Australia, which will provide estimates on potential





physical damage against a set of possible disaster scenarios. This platform is also capable of displaying the indirect economic losses that would be derived from a macroeconomic model.

## EXPECTED OUTCOMES OF THE RESEARCH

Given that the main objective of this research is to build a scenario-based pre-disaster multi-hazard damage and economic loss estimation model to support decision makers in reducing disaster risks, it is expected that this initiative estimates the impact of different types of natural disasters on Australian economic growth at the national as well as state level. In particular, the expected outcomes of this research are fourfold. First, it uncovers the causal impact of natural disasters—such as bushfires, floods, storms and earthquakes—on sector-specific economic growth in Australia. Second, it develops a spatially enabled multi-hazard (i.e., bushfires, floods, and earthquakes) risk assessment map for Victoria to quantify *potential damage*. After that, such damage scenarios are expected to be subsumed as a ‘shock’ in a macroeconomic model for forecasting the *potential economic losses* under a set of possible scenarios. Finally, a possible set of economic policies are expected to be identified to reduce the estimated effects of disaster risks.

## CONCLUSION

Measuring the economic effects of natural disasters remains traditionally challenging. The method proposed in this paper of bringing engineering and economics tools together to pin down the true impacts opens a window of opportunity for the policy makers to comprehend both direct (i.e. damage) and indirect (i.e. losses) effects of natural disasters in more detail. The identified process also takes into account the specific hazards and economic environment of Australia to enable effective policy development within the Australian context. The resulting system developed through this process will enable stakeholders to estimate the full economic impact of natural hazards, taking into account all the affected sections of the economy.

## ACKNOWLEDGEMENTS

The support of the Commonwealth of Australia through the Cooperative Research Centre program is acknowledged.

## REFERENCES

- Boisvert, R. (1992) Indirect losses from a catastrophic earthquake and local, regional, and national interest, in: *Indirect Economic Consequences of a Catastrophic Earthquake*, pp. 207–265 (Washington, DC: National Earthquake Hazards Reduction Program, Federal Emergency Management Agency).
- Brookshire, D. and McKee, M. (1992) Other indirect costs and losses from earthquakes: issues and estimation, in: *Indirect Economic Consequences of a Catastrophic Earthquake*, pp. 267–325 (Washington, DC: National Earthquake Hazards Reduction Program, Federal Emergency Management Agency).
- Bureau of Transport Economics (2001) *Economic costs of natural disasters in Australia*, Report 103, Bureau of Transport Economics, Commonwealth of Australia, Canberra.



- Cochrane, H.C. (1974) Predicting the economic impacts of earthquakes, in: H.C. Cochrane, J.E. Haas and R.W. Kates (Eds) *Social Science Perspectives on the Coming San Francisco Earthquakes—Economic Impact, Prediction, and Reconstruction*, Natural Hazard Working Paper No.25 (Boulder, CO: University of Colorado, Institute of Behavioral Sciences).
- Cochrane, H.C. (1997) Forecasting the economic impact of a Midwest earthquake, in: B.G. Jones (Ed.) *Economic Consequences of Earthquakes: Preparing for the Unexpected*, pp. 223–247 (Buffalo, NY: National Center for Earthquake Engineering Research).
- Dacy, Douglas C., and Howard Kunreuther. (1969) *The Economics of Natural Disasters: Implications for Federal Policy*, New York, NY; The Free Press.
- Gordon, P. and Richardson, H.W. (1996) *The Business Interruption Effects of the Northridge Earthquake* (Lusk Center Research Institute, University of Southern California, Los Angeles, CA).
- Kawashima, K., Sugita, H. and Kanoh, T. (1991) Estimation of earthquake induced economic damage, Report of Public Works Research Institute, 186, pp. 1–57 (in Japanese).
- Okuyama, Y., Hewings, G.J.D. and Sonis, M. (1999) Economic impacts of an unscheduled, disruptive event: a Miyazawa multiplier analysis, in: G.J.D. Hewings, M. Sonis, M. Madden and Y. Kimura (Eds) *Understanding and Interpreting Economic Structure*, pp. 113–144 (Berlin: Springer).
- Rose, A. and Guha, G.S. (2004) Computable general equilibrium modeling of electric utility lifeline losses from earthquakes, in: Y. Okuyama and S.E. Chang (Eds) *Modeling Spatial and Economic Impacts of Disasters*, pp. 119–141 (New York: Springer).
- Rose, A. and Liao, S.Y. (2005) Modeling regional economic resilience to disasters: a computable general equilibrium analysis of water service disruptions, *Journal of Regional Science*, 45, pp. 75–112.
- Rose, A. (2004) Economic principles, issues, and research priorities in hazard loss estimation, in: Y. Okuyama and S.E. Chang (Eds) *Modeling Spatial and Economic Impacts of Disasters*, pp. 13–36 (New York: Springer).
- Wilson, R. (1982) *Earthquake Vulnerability Analysis for Economic Impact Assessment* (Washington, DC: Information Resources Management Office, Federal Emergency Management Agency).



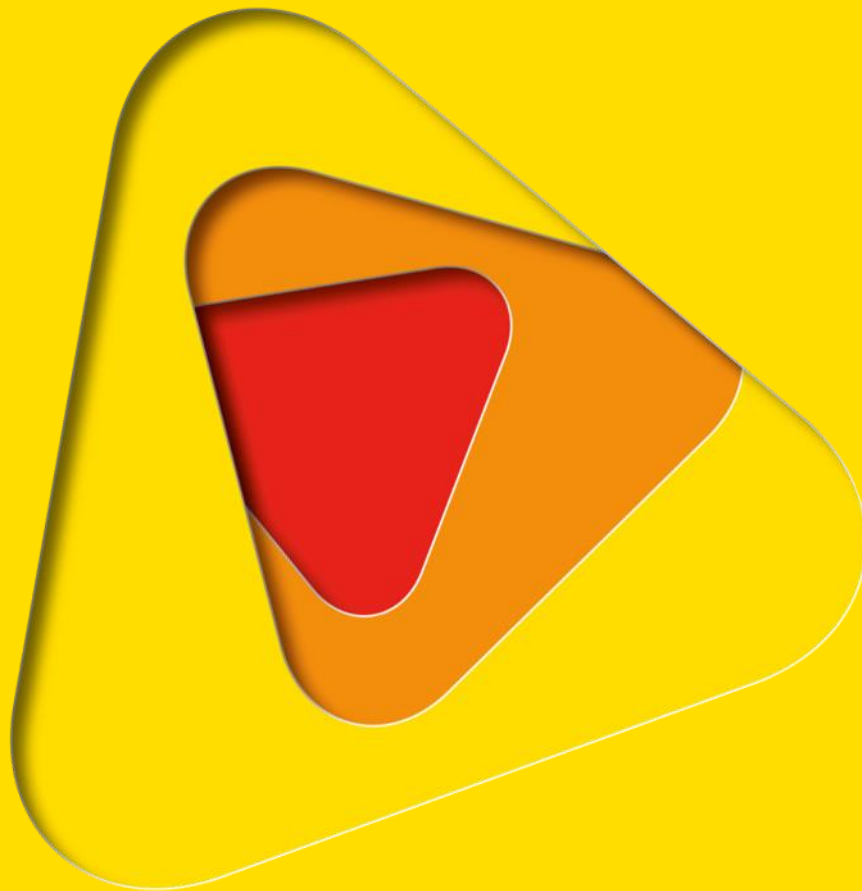
# DISCOVERING FUTURE DISASTER MANAGEMENT CAPABILITY NEEDS USING SCENARIO PLANNING

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**Paul Barnes**

Queensland University of Technology  
Bushfire and Natural Hazards CRC

Corresponding author: [p.barnes@qut.edu.au](mailto:p.barnes@qut.edu.au)





## ABSTRACT

In recent years disaster risk reduction efforts have focussed on disturbances ranging from climate variability, seismic hazards, geo-political instability and public and animal health crises. These factors combined with uncertainty derived from inter-dependencies within and across systems of critical infrastructure create significant problems of governance for the private and public sector alike. The potential for rapid spread of impacts, geographically and virtually, can render a comprehensive understanding of disaster response and recovery needs and risk mitigation issues beyond the grasp of competent authority. Because of such cascading effects communities and governments at local and state-levels are unlikely to face single incidents but rather series of systemic impacts: often appearing concurrently.

A further point to note is that both natural and technological hazards can act directly on socio-technical systems as well as being propagated by them: as network events. Such events have been categorised as 'outside of the box,' 'too fast,' and 'too strange' (Lagadec, 2004). Emergent complexities in linked systems can make disaster effects difficult to anticipate and recovery efforts difficult to plan for. Beyond the uncertainties of real world disasters, that might be called familiar or even regular, can we safely assume that the generic capability we use now will suit future disaster contexts?

This paper presents initial scoping of research funded by the Bushfire and Natural Hazards Cooperative Research Centre seeking to define future capability needs of disaster management organisations. It explores challenges to anticipating the needs of representative agencies and groups active in before, during and after phases of emergency and disaster situations using capability deficit assessments and scenario assessment.

## INTRODUCTION

Emergent risk-related phenomena such as climate change; public and animal health crises; destabilised nations; the increasing hyper-complexity of embedded information-communications-technology (ICT); and emergent inter-dependencies within and across systems of infrastructure, create significant problems of governance for the private and public sector alike. Unmitigated disturbances from such sources are likely to generate cascading impacts propagated along unexpected pathways and fault lines throughout commercial and institutional segments of established and establishing economies. The potential for rapid spread of consequences, geographically and virtually, can render a comprehensive understanding of a crisis's context beyond the grasp of competent authority.

Because of these cascading phenomena, response and recovery agencies would be unlikely to face single incidents but rather series of systemic failures: often appearing concurrently. A further point to note is that both natural and technological hazards can impact directly on socio-technical systems as well as being propagated by them: as network events. Such events have been categorised as 'outside of the box,' 'too fast,' and 'too strange' (Lagadec, 2004). Emergent complexities in linked systems often make moving impacts of emergencies difficult to anticipate and consequences difficult to plan for. Further, under emergency conditions the pressure on senior decision-takers to 'make-sense' of multiple lines of information (for both crisis and consequence modes) is significant.

An issue of some importance to both public and private sector alike relates to whether increased awareness, derived from involvement (direct or in-direct) in such failures, can actually reduce the likelihood of future failure or at least attenuate consequent impacts.



A further question of possibly greater importance is whether such enhanced awareness or experience of past disasters can be used to plan future capability need.

This paper presents initial scoping of research funded by the Bushfire & Natural Hazards Cooperative Research Centre (BNHCRC) seeking to define future capability needs of disaster management organisations. It explores challenges to anticipating the needs of representative agencies and groups active in all phases of emergency and disaster situations using capability deficit assessments and scenario planning.

## **ANTICIPATION NOT PREDICTION**

### **THE NEED FOR FUTURES-THINKING IN DISASTER MANAGEMENT**

Surprise has always had an egalitarian affect in society. To be surprised in a pleasant fashion is preferable to the alternative. Unfortunately, the alternative state has been present more often than not in many organizational crises through time and arguably recent natural disasters affecting Australia. Over the past decade the many natural disasters have triggered significant government assessments of the readiness status and efforts of first response and supporting services either via Royal Commissions or other formal investigations.

Critical incidents (or multiple concurrent incidents) may be triggered at any time in large highly complex systems. Such incidents might manifest suddenly and unexpectedly or may 'cook' slowly (without recognition) until some triggering event or process precipitates them. In either case incidents can be surprising and/or unexpected. The wider literature on complex socio-technical systems failure suggests that for many situations evidence is discoverable that confirms there had been 'signs' that a crisis was emerging from organisation's normal functional 'noise' (Perrow, 1984; Turner & Pidgeon 1997; Boin & Lagadec, 2000; Comfort *et. al.*, 2001, Rijpma, 1997).

Furthermore evidence in support of the idea that failure patterns may repeat is found in the cybernetic research of Stafford Beer in 1966 who suggested that while it was not possible to predict events *per se*, the pattern of interaction between *systemic* components (within organisations) is predictable. It has also been suggested that many organisational crises emerge in a number of common ways, yet never manifesting in exactly the same manner (Anderson, 1991).

Consideration that significant organisational emergencies manifest in repeatable and recognisable stages in major socio-technical failure (like fractals) is compelling and is supported by a substantial literature grounded in the analysis of industrial and organisational settings over a number of years. Stead & Smallman (1999) summarise key findings from a selection of this literature that identify specific stages in organisational failure, namely:

- *Pre-conditions* (sets of operational activity where 'signs' were buried or ignored in background noise);
- *Trigger* (an escalation factor either internal or external to an organisation or setting);
- *Crisis* (an emergent process exhibiting uncertainty and potential for loss and/disruption);
- *Recovery* (systems recovery and normalisation of functions);
- *Learning* (identification and changes to functional capacities of organisation/systems).

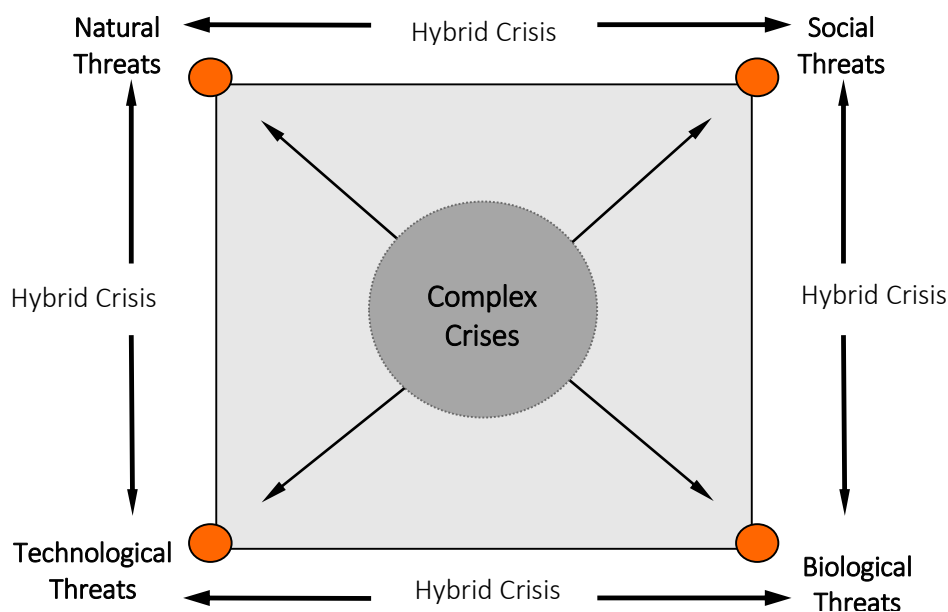
It is arguable that in natural disasters common effects inherent to the events themselves require degrees of repetitiveness in response and recovery actions.



So with a presumption that causal and conditional evidence about such failures always awaits discovery, normally afterwards, and that humans and human systems do 'learn' in such circumstances, the benefits of trying to anticipate future disturbances seems obvious. So apart from being professionally competent emergency and disaster response agencies, must also at times unlearn established practices (retain a capacity to adapt) in order to survive when the signs of imminent chaos are detected (Nystrom & Starbuck, 1984:53).

A practical reality in many larger natural disasters is that initial threat conditions rapidly morph into social, technical and biological impacts: facilitated by the socio-technical interdependencies of modern infrastructure systems (Parker & Tapsell, 1995). Figure 1 depicts this complex relationship. Response and recovery efforts for different aspects of such 'Complex' crises are normally coordinated by different agencies: as are prevention/planning and preparation efforts.

Figure 1: Complex Crises



With the assumption that a degree of familiarity exists amongst agencies with responsibilities for emergency and disaster management an appreciation that the cascading sub-category impacts would normally be present during large protracted events suggests a deeper understanding of the standard stages of the conventional (prevention, preparation, response, recovery) disaster continuum. The extensions<sup>1</sup> of the continuum are:

- **Prevention** – vulnerability reduction and recognition capability for emergent events and impacts;
- **Preparation** - for the both expected and unknown;
- **Response** - making effective decisions and having them implemented; and
- **Recovery** - restoring normality and learning.

However, both *preventing* and *preparing* for emergency situations presumes a deep and effective understanding of the manner in which the 'unknown' factors and conditions can manifest and how they might directly or indirectly exploit organizational and institutional vulnerabilities.

<sup>1</sup> Derived from Rhinard, M. et al. (2004).



*Responding* and *recovering* from crises also assumes an effective appreciation of mitigation and consequence factors. These levels of understanding presume planning, advice and that response agencies retain tacit knowledge of past disasters and can make-sense of confusing and at times conflicting information flows: a presumption that many iconic disasters have shown to be unsupported.

While the relative importance of these skills and the benefits of pursuing them are self-evident, in practice, they are not always present in a sustainable manner even in wealthy economies. There is also generally little said in major post-disaster inquiries about how to develop and sustain organisational capabilities that could form the basis of providing assurances to governments that institutions can apply response and recovery efforts efficiently and effectively.

A parallel issue to the notion that emergencies and related disruptions seem to manifest in familiar ways is the repetitive findings of many boards of inquiry into disasters and their impacts. Like the idea of failure fractals it is arguable that institutional capability and interoperability deficits may also exist. A 2011 review and analysis of recent Australian disaster inquiries by the Monash University Injury Research Institute (Goode et. al., 2011) identified common strategic issues and themes of significance that warranted addressing in order to enhance disaster management arrangements. These included:

- Critical infrastructure resilience
- State Emergency Management arrangements
- Shared responsibilities between Emergency Management agencies
- Professionalising Emergency Management workforce
- Research & databases
- Implementation of gaps and opportunities from (post-disaster evaluations)

Pollock (2013) identified similar findings in a review of deficiencies in large-scale disaster operations in 32 recent major disasters in the United Kingdom. Common factors include:

- Poor working practices and organisational planning;
- Inadequate training;
- Ineffective communication;
- No system to ensure that lessons were learned and staff taught;
- Failure to learn lessons;
- No monitoring/audit mechanism;
- Previous lessons/reports not acted upon.

Donahue & Tuohy (2006) provide evidence of similar deficiencies in United States responses to a number of iconic disasters: Hurricane Andrew; the Oklahoma City bombing; the September 11 attack; and Hurricane Katrina. Convergent findings suggest further familiar issues:

- The need to radically improve the way we train and exercise;
- The need for a comprehensive, nation-wide capability to gather and validate the information we learn from incidents, develop and vet corrective actions, and disseminate them to those who must inculcate the changes;
- The need for incentives to institutionalize lessons-learning processes at all levels of government.

In light of these findings it may be prudent to consider the benefit of a means to better understand how deficits in these areas might be better addressed. One particular organisational strategy relevant to enhanced understanding is the application of 'foresight' techniques.





**Table 1:** General Classes of Foresight Methods

Criteria	Methods
(1) Methods that are based on eliciting expert knowledge to develop long-term strategies.	<ul style="list-style-type: none"><li>• Delphi method</li><li>• Expert panels</li><li>• Brainstorming</li><li>• Mind-mapping</li><li>• Scenario analysis workshops</li><li>• SWOT analysis</li></ul>
(2) Quantitative methods that make use of statistics and other data	<ul style="list-style-type: none"><li>• Trend extrapolation</li><li>• Simulation modelling</li><li>• Cross impact analysis</li><li>• System dynamics</li></ul>
(3) Methods to identify key points of action to determine planning strategies	<ul style="list-style-type: none"><li>• Critical/key technologies</li><li>• Relevance trees</li><li>• Morphological analysis</li></ul>

Foresight is a systematic, participatory process, involving gathering intelligence and building visions for the medium-to-long-term future and aimed at informing present-day decisions and mobilising joint actions targeting future need (European Communities, 2001).

As shown of Table 1, scenario analyses are one of a number of strategic tools within a wider method-base of Foresight practice. Scenario making and analysis is a systemic method for thinking creatively about possible, complex and uncertain futures (Peterson et al. 1993).

The most effective use of scenarios with emergency management professionals would derive from avoiding the most likely event(s) and include a variety of disruptions and unanticipated situations, thus seeking to create a more reliable emergency response when confronted with a novel emergency (Bañuls et al., 2013).

The opportunity that this research seeks to take advantage of is the combination of the availability of many sources for ‘lessons not-learned’ from previous inquiries into disaster response, in combination with projections of weather variability, demographic change, and increased reliance on systems of critical infrastructure to create plausible future scenarios for the assessment of capability needs.

## THE RESEARCH STRUCTURE

The Capability Needs for Emergency & Disaster Management project examined here combines approaches from futures thinking generally and scenario planning in particular in an all-hazards/all-agencies context to develop processes for engaging public and private sector organisations in examining a range of capabilities likely to be needed individually and collectively for managing near term and future disasters. It seeks to provide an approach for the development and testing of strategies, policies and capabilities in plausible future disaster contexts.

The research will engage with state and federal response agencies, as well as those supporting response and recovery, and local government, to examine in-depth lessons learnt from historical emergencies and disasters on a case study basis and via analysis of capability and capacity deficits. From this it will examine options for defining agile and sustained skills sets across the full cycle of disaster management. This study will also seek to enhance planning mechanisms to inform the delivery of effective disaster response and efficient recovery strategies for future emergencies.



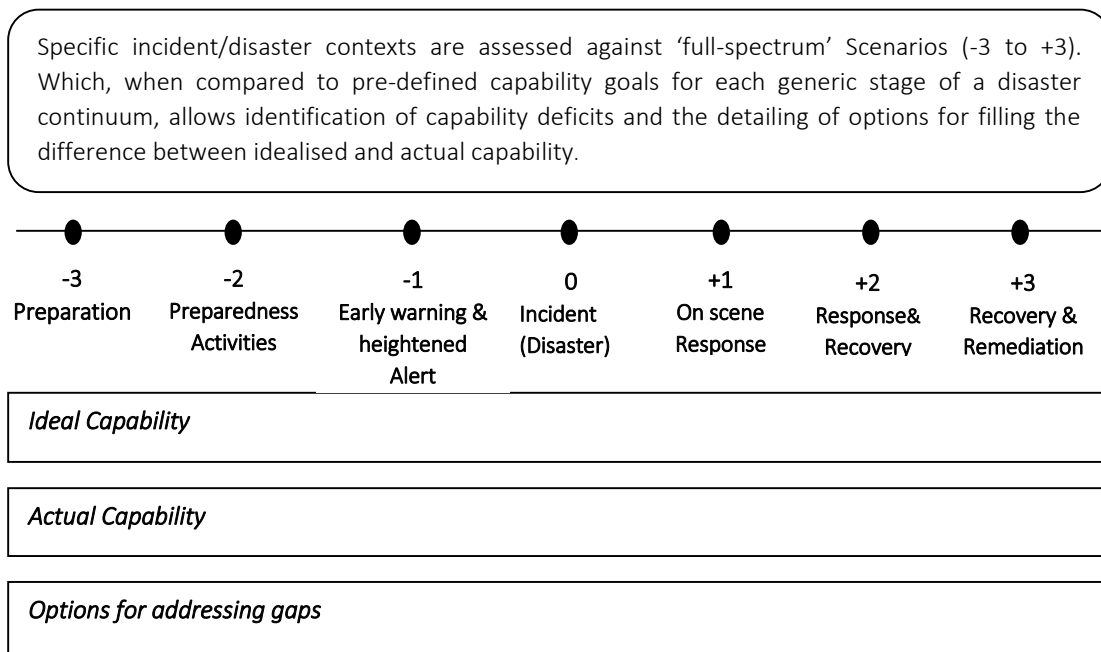
The combination of capability gap analysis and scenario based futures-based thinking will allow the formation of scaled descriptions of capability along a continuum of increasing effectiveness, adaptability and sophistication to contribute to strengthening community resilience.

The work is separated into three stages. **Stage one** will be exploratory with a number of reports planned to document initial findings related to interoperable capability needs relevant to response, recovery and other groups as well as incident scenarios (normal, infrequent and complex) and, the challenges of addressing certain types of capability needs assessments. It will also include the final design and testing of a capability gap assessment tool against three disaster scenarios in-concert with non-Government Organisations (NGO's), local government and state-based disaster management organisations across two state jurisdictions.

In addition to testing the tool, assistance from end-user representatives (above) will be sought to inform design and content of three disaster scenarios emphasising detailed descriptions of a range of consequences. The first scenario will be derived from recent disaster experiences in Australia and include aspects of the lessons not learned (from sources referenced above). The second scenario will be projected into the future and include the effects of expected climatic variability and socio/demographic changes to create a suite of plausible consequences maps against which capability gap assessment tool will be applied. The third scenario will projected further into the future and, like the second scenario, be made relevant to individual state jurisdictions and more broadly operational needs at a national level.

**Stage 2** of the work will apply an accepted version of the Capability Gap Assessment (CGA) Framework (Figure 2 below) to detail initial assessments of capability deficits by engaging representatives from selected State-based agencies to document and contrast comparisons of idealised with actual capability to plan and prepare for, as well as respond to and recover from the impacts detailed in the disaster scenarios.

**Figure 2:** Scenario-based Capability Gap Analysis



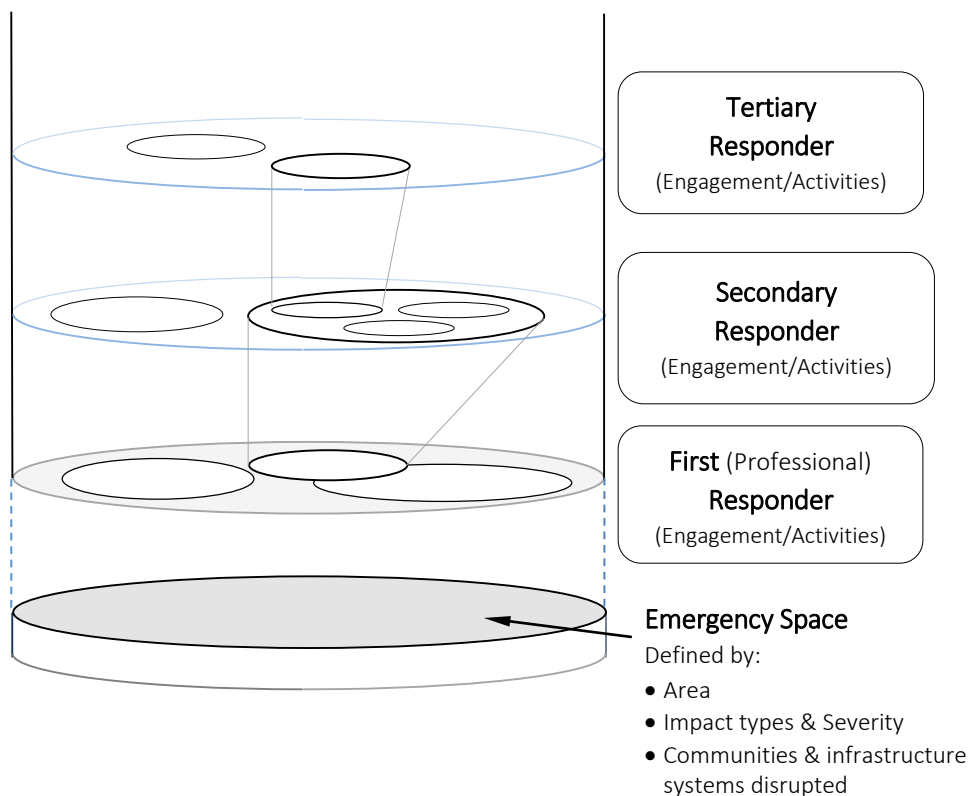


The first scenario will be grounded in recent experience of natural disasters (generic to most Australian state jurisdictions) and will be used to determine current gaps between idealised suite of capability descriptions and actual capability. The two other disaster scenarios mentioned above will be set at ten and twenty years ahead of current time. These projections will be reflective of current projections of climatic and environmental conditions expected to exacerbate the consequences of damage and disruptions from disasters.

**Stage 3** of the work will apply the insight and findings derived from stage 1 and 2 to consider operational dependencies and interdependencies between agencies involved in disaster management. The viability of this endeavour is that an actual “all hazards/all agencies” response effort will entail planning and coordination across multiple groups within and outside government and a real-time, multi-location response. Pressure testing the vertical integration of the agencies is a likely to be a useful in the provision of disaster resilience at a state level.

Figure 3 below displays a representation of a vertically integrated capability map applied to an ‘emergency space’ that identifies certain key interdependent relationships needed to effect a comprehensive and sustained response and recovery effort. As detailed earlier the capability maps that this project seeks to create will entail defining key relational elements that embody the interdependencies of effective response recovery and remediation of essential services.

**Figure 3: Vertically Integrated Emergency Response Capability**



Critical relationships between responder agencies as groupings depicted in Figure 3 are central to the evaluative focus in this research. It is hypothesised that the effectiveness of disaster response will be level support entity.



The staged engagement of each layer of response into the emergency space will typically involve first Responders, and across secondary and tertiary stages, state Government Departments and Agencies, local government, as well as volunteer groups and welfare groups. Examining these relationships will address a major gap in the understanding and integration requirements across influenced by degrees of dependency extending vertically through the full response effort. In figure 3 for example a first response group is supported by the efforts of a cluster of secondary groups: one of which relies in turn, upon a tertiary and within disaster management organisations (Turoff et al. 2009).

The third stage of the work will also involve specifying a scaled continuum of possible levels of capability elements, from lower to more complete, that seeks to enhance planning and carrying out agile and effective disaster management at local, regional, state and Federal levels.

This will lead to a definition of a high-level prototype Maturity Model (MM) incorporating capability assessments for Industry consideration and comment. From this work individual candidate MM's will be prepared for consideration by state-based organisations. While these MM's will include specific details relevant to different organisations, an emphasis will be on whole-of-state considerations. This is important given variation in agency responsibilities across the States.

A central strategy in the delivery of value in this project is ensuring utilisation of findings and entails a range of knowledge sharing opportunities of varying formats both internal and external to the CRC End-user group. Close links with end-users is a central design feature of the work and cooperation in planning of objectives and timelines for delivery of findings will be explicit as will where viable, joint participation the analysis of findings. From this engagement we will seek to maximize fit of both what is investigated, and from this, the relevance to practitioners of what is discovered. The inclusion of end-users in the final design of investigative and analytical frameworks is strategically important, as this will enhance the uptake and usefulness of findings.

It is envisaged that representatives from selected end-user groups will be embedded or closely associated with the research team for agreed periods to provide advice on the design of the "future" disaster scenarios to be used in the capability gap analyses, exchange expertise, and to facilitate direct transfer of findings and provide feedback to the research team.

## **CONCLUSION**

A critical component of the work is capturing the integration of capabilities of relevant agencies active in 'operational' response and recovery in all hazards contexts. Key aspects of this integration include:

- The exploration of options for how Local, State and Federal agencies, as well as local communities, can collaborate more efficiently and effectively to inform choices for maximising adaptable decision-making under disaster conditions.
- The creation of a sustainable and agile emergency management workforce equipped to meet the needs of future disasters with a detailed understanding of the conditions under which planning, preparedness, response and recovery and remediation of infrastructure systems may need to take place.
- The capability needed by first and second responders, and allied agencies, to match current and future disaster contexts, including the disruptions caused by climate variability and geo-political unrest.

From this it will seek to document options for defining agile and sustained skills sets across the full cycle of disaster management.



This study will also seek to enhance planning mechanisms in support of the provision of effective disaster responses and efficient recovery strategies for future emergencies. The combination of capability gap analysis and scenario-based futures-based thinking will allow the formation of scaled descriptions of capability along a continuum of increasing effectiveness, adaptability and sophistication to contribute to strengthening community resilience.



## REFERENCES

- Anderson A (1991) Making a Success out of a Museum of Failure. *New scientist* 130, p. 54
- Bañuls V.A. et al. (2013) Collaborative scenario modeling in emergency management through cross-impact, in *Technological Forecasting & Social Change* 80 (9), pp. 1756–1774 [quoting H. Linstone]
- Beer, S (1966). *Decision and Control*, Wiley, London
- Boin A, Lagadec, P (2000). Preparing for the Future: Critical Challenges in Crisis Management. the *Journal of Contingencies and Crisis Management*, 8(4): pp. 185-191
- Comfort L. *et al.* (2001) Complex Systems in Crisis: Anticipation and Resilience in Dynamic Environments. *Journal of Contingencies and Crisis Management*, 9(3): pp. 144-157
- Donahue AK, Tuohy RV (2006) Lessons We Don't Learn: A Study of the Lessons of Disasters, Why We Repeat Them, and How We Can Learn Them. *Homeland Security Affairs*, Vol. li, No. 2
- European Communities (2001) A Practical Guide to Regional Foresight, FOREN (Foresight for Regional Development Network). Report EUR 20128 EN
- Goode N, et al. (2011) Review of Recent Australian Disaster Inquiries, Monash University Accident Research Centre  
(<http://www.em.gov.au/AboutAGD/Authorityandaccountability/Committeesandcouncils/Documents/Review%20of%20Recent%20Australian%20Disaster%20Inquiries%20-%20final%20report.PDF>)
- Lagadec P (2004) Crisis: A Watershed From Local, Specific Turbulences, to Global, Inconceivable Crises in Unstable and Torn Environments, Future Crises, in International Workshop, *Future Agendas: An Assessment of International Crisis Research*
- Nystrom PC, Starbuck WH. (1984) To Avoid Organisational Crises, Unlearn. *Organisational Dynamics*, 12(4), pp. 53-65
- Parker D, Tapsell S (1995) Hazard transformation and hazard management issues in the London megacity. *GeoJournal*, 37(3) pp. 313-328
- Peterson GD, Cumming, GS, Carpenter SR (1993) Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology*, 17(2): 358-366
- Pollock K (2013) Review of Persistent Lessons Identified Relating to Interoperability from Emergencies and Major Incidents since 1986, *Emergency Planning College Occasional Papers* New Series Number 6: A report commissioned by the Cabinet Office Civil Contingencies Secretariat



Perrow C (1984). *Normal Accidents: Living with High Risk Technologies*, Basic Books, New York  
Rhinard M, Ekengren M. Boin A (2004) *Functional Security and Crisis Management Capacities in the European Union: Setting the research agenda*. Draft Report. pp. 41-69

Rijpma JA (1997) Complexity, Tight-coupling and Reliability: Connecting Normal Accidents Theory and High Reliability Theory. *Journal of Contingencies and Crisis Management*, (5)1: pp. 15-23.

Stead E, Smallman C (1999) Understanding Business failure: Learning and Un-learning Lessons from Industrial Crises. *Journal of Contingencies and Crisis Management*, 7(1), pp. 1-18.

Turner BA, Pidgeon N (1997). *Man-made Disasters* (2<sup>nd</sup>edn), Butter-worth Heineman, Oxford.

Turoff M, Hiltz SR, White C, Plotnick L, Hendela A, Yoa X (2009) The Past as the Future of Emergency Preparedness and Management. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, 1(1), 12-28.





# PROMOTING CHILD RESILIENCE TO DISASTERS: POLICY, PRACTICE, RESEARCH

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**Kevin Ronan<sup>1,7</sup>, Briony Towers<sup>2,7</sup>, Kate McAuslan<sup>2,7</sup>, Vicki Johnson<sup>3</sup>,  
Eva Alisic<sup>4,7</sup>, Susan Davie<sup>5,7</sup>, John Handmer<sup>2,7</sup>, Katherine Haynes<sup>6,7</sup>,  
Nick Ireland<sup>5,7</sup>, Marla Petal<sup>5,7</sup>, Avianto Amri<sup>6,7</sup> and David Johnston<sup>3,7</sup>**

<sup>1</sup>CQUniversity

<sup>2</sup>RMIT University

<sup>3</sup>Massey University

<sup>4</sup>Monash University

<sup>5</sup>Save the Children

<sup>6</sup>Risk Frontiers, Macquarie University

<sup>7</sup>Bushfire and Natural Hazards CRC

Corresponding author: [k.ronan@cqu.edu.au](mailto:k.ronan@cqu.edu.au)





## ABSTRACT

The recently published Synthesis Report on the Post-2015 Framework on Disaster Risk Reduction (UNISDR, 2013) places children at the centre of successful adaptation to disasters: “In particular children and youth have been singled out as having specific needs in terms of school safety, child-centred risk assessments and risk communication. But, more importantly, if appropriately educated and motivated on disaster risk reduction, they will lead and become the drivers of change.” Equally, here in Australia, the role of disaster education in managing disaster risk has been recognised as a major priority in the National Strategy for Disaster Resilience (Australian Government, 2011). While Child-Centred Disaster Risk Reduction (CC-DRR) is increasingly popular across agencies and organisations around the world, rigorous empirical research on the efficacy of the approach is limited. This three-year program of research is planning a range of projects, unified through various means, and an integrated narrative, to increase the reach and impact of CC-DRR education within communities in Australia and New Zealand. Year 1 (of 3) of this Project is focused on planning and pilot work, a scoping and review exercise to identify what the evidence to date suggests in terms of best practices to date and challenges requiring research. Initial efforts have included pilot work on stakeholder views. Based on scoping and review, it has also included multiple team submissions to the UNISDR Global Assessment Report on Disaster Risk Reduction, 2015 (GAR 15), and refereed publications, with a focus on CC-DRR. These early outputs, along with other collaborative efforts within the team, are directed towards investigating the extent to which CC-DRR influences disaster resilience at individual, household and community levels. It will also investigate how CC-DRR influences children’s (1) pre-hazard resilience and readiness and (2) post-disaster response and recovery. In doing so, it will provide disaster resilience researchers, policy-makers, and practitioners with an evidence-base for development of effective CC-DRR programming, in Australia and internationally. The Conference presentation will provide an update on progress of our systematic review and scoping efforts in Year 1 and pilot data collected to date. A main thrust will be to update Conference attendees on current research issues and gaps linked to the policy-practice-research nexus. Main themes here are that research to date has seen an increase in evaluation of CC-DRR education programs, particularly in the past 15 years. Most of the studies published to date support education program effectiveness on indicators linked to risk reduction and resilience (e.g., knowledge of DRR key messages, risk perceptions, reduced fears; child- and home-based preparedness). Challenges identified, and which are to be the focus of attention in this project, include (1) methodological issues (e.g., more rigour needed), (2) no research to date examining whether these programs reduce risk when most needed (i.e., during a hazard event) or if they are cost effective, (3) research suggests that some education programs may not reduce risk in the way envisaged and, finally, (4) education programs developed will benefit from more explicit evaluation, including whether they include theory-supported elements, whether they include effective teacher training, whether they produce bona fide DRR outcomes including over time, and the effectiveness of mechanisms designed to support sustainable, scaled implementation of education programs.

## INTRODUCTION

Children are the most vulnerable demographic group in disasters, representing 30-50% of deaths according to World Health Organisation estimates. They also represent one of the most vulnerable groups for psychosocial effects according to a large scale systematic review of disaster victims (Norris et al., 2002). At the same time, preliminary research (Johnson, Ronan, Johnston, & Peace, 2014; Ronan, 2014; Ronan & Towers, 2014; Towers, 2014; Webb & Ronan, 2014) points to the active role children can play in communities assuming “shared responsibility” with government (National Strategy for Disaster Resilience, NEMC, 2011) for preparing for and responding to natural, and other, hazard events. In addition, in anticipating the post-2015 Hyogo Framework for Action, not only will children be instrumental in community efforts to reduce current risks, they are also the adults of tomorrow who will be dealing directly with the future risks associated with climate change. This is significant for the future of DRR for two



reasons. First, helping today's children, and their families, learn disaster risk reduction and resiliency skills can contribute to reducing current risk including personal, household, school and community risks in relation to natural hazards. Second, CC-DRR has the potential to equip children and youth with the skills and knowledge required to develop the capacity to solve future risks. For example, learning through DRR and resilience education programs may provide today's children, and tomorrow's adults, with DRR-related problem-solving tools that may assist in helping to address some of the complex policy issues in Australia and many other countries. These problems include those that follow from policies that have been shown not to solve problems but, instead, exacerbate natural disaster risks (Ronan & Davies, 2014).

Over the last decade, the role of child- and youth-focused hazards and disasters education has gained increasing emphasis in the international disaster resilience literature, in relation to both policy and practice (e.g., UNISDR, 2005, Ronan, 2014) and empirical research (Johnson, Ronan, Johnston, & Peace, 2014). The UN International Strategy for Disaster Reduction (UNISDR) and the UNISDR's Hyogo Framework for Action (HFA; UNISDR, 2005) identify disaster education as one of five key priorities for action.<sup>1</sup> In planning for the post-2015 HFA framework (HFA2), education programs will again be made a major priority and there is expected to be an increased focus on children and youth (Ronan, 2014; UNISDR, 2013; UNISDR, 2014). In Australia, the National Strategy for Disaster Resilience (NSDR; NEMC, 2011) advocates for an increase in "shared responsibility" between government and communities for disaster risk reduction (DRR). In reflecting HFA-inspired principles, the NSDR also emphasises education as part of the overall strategy to promote collective responsibility in DRR. Taking the idea of education one step further, in its final report, the 2009 Bushfires Royal Commission explicitly stated that bushfire education for children is important, has been recommended but neglected since the 1930's, and needs more attention:

"Inquiries into bushfires in Australia have repeatedly found that teaching school children about fire is fundamental to improving community bushfire safety. Each new generation must be properly prepared for living in an environment that is hazardous. The Commission is of the view that educating children about the history of fire in Australia and about safety in the event of a bushfire will probably influence not only the children but also their parents, siblings and extended family and community. Despite this, fire education remains an optional inclusion in most Australian school curricula...A concerted education program—the need for which has been noted since as early as 1939— remains the most effective approach to instilling the necessary knowledge in Australian families" (Teague et al., 2010, p.55).

More generally, across a range of hazardous events, a recent Background Chapter (Ronan, 2014) commissioned by UNESCO and UNICEF for the HFA2 planning process and its Global Assessment Report on Disaster Risk Reduction 2015 focuses on one of the "core indicators" for HFA's Priority for Action 3: School curricula, education material and relevant training including disaster risk reduction and recovery concepts and practices (PFA3/Core Indicator 2). In addition to summarising policy developments internationally, including in Australia, it also summarised many DRR education programs being carried out. However, both in Australia and elsewhere internationally, DRR education programs tend to be time-limited or one-off projects carried out through schools or emergency management agencies. Moreover, these programs are rarely subjected to formal evaluation or review. Thus, there is a dearth of evidence-based knowledge about the role of disaster risk reduction and resilience education (DRRRE) programs in producing increased risk reduction and resiliency indicators across the disaster cycle, from prevention and preparedness to response and recovery.

In terms of research conducted to date, a recent systematic review of research in disaster risk reduction and resilience education (DRRRE) (Johnson et al., 2014) shows that the area has grown significantly over

---

<sup>1</sup> HFA, Priority for Action 3: Use knowledge, innovation and education to build a culture of safety and resilience at all levels.



the past 15 years, with 34 studies on DRRRE programs for children and youth being published in the grey or academic literatures.<sup>2</sup> This indicates that these programs clearly have promise, with several quasi-experimental, pre-post studies reporting significant enhancements in risk reduction and resiliency indicators (Johnson et al., 2014). These indicators include increased knowledge of risk and preparedness, reduced fears of hazards and increased levels of child- and home-based preparedness. Thus, preliminary data do support an affirmative response to the question “do DRRE programs improve risk reduction and resiliency indicators during the Prevention and Preparedness phases of the disaster cycle?” However, as pointed out in the review (Johnson et al., 2014), improved design and methodology across studies are crucial in making stronger causal statements and provide a more in-depth understanding of which program elements produce which gains. There is also a need to extend the types of indicators assessed (i.e., most studies rely on knowledge-based indicators) and broaden the range of sources from whom data is obtained (i.e., most studies rely on children as sole sources of information, with only a handful using parents, e.g., Ronan & Johnston, 2003; Webb & Ronan, 2014). In addition, it is critical that future asks the question: do DRRE programs translate into effective Response and Recovery for children and their families? Currently, no study worldwide has examined this question.<sup>3</sup> Pending answers to that question, another problem in this area is the problem of scale (Ronan, 2014). Typically, as indicated earlier, DRRE programs are limited in size, scope and duration. Teacher survey and focus group research (Johnson & Ronan, 2014; see also Johnson, 2014) appears to indicate a number of obstacles preventing large scale uptake of disaster resilience education (see next section for more detail). Large scale review and scoping in this area for the post-2015 Hyogo Framework for Action on Disaster Risk Reduction indicates additional policy-related obstacles: what appears to be goodwill towards DRRRE in Australia and internationally, hasn’t resulted in on-the-ground policy development and large scale implementation practices (Ronan, 2014). Thus, implementation tends towards small scale project-based approaches that are delivered either by teachers or emergency management personnel and are not systematically evaluated, either the curricula itself (i.e., is curricula supported by theory and research?) or outcomes (i.e., is the program producing documented DRR outcomes?). Training of teachers in DRR curricula delivery has also been identified as an issue needing attention (e.g., Johnson & Ronan, 2014; Johnston, Ronan et al., 2014b).

Given this multitude of issues, the problem in this research is “can previous research findings provide clues about next steps necessary in research? As introduced above, one major problem is that bulk of existing research has come from one-off education programs that may or may not have theory-supported elements and that have limited before and after assessment, tending to focus on knowledge-based and immediate outcomes (Johnson, Ronan, Johnston, & Peace, 2014a). Thus, an aim of this study is to focus on an increased array of outcome indicators over extended timeframes for following cohorts to see whether any knowledge and skills gained are sustained over time. This would include, where applicable, in areas where a natural hazard event occurs. Another aim, currently underway, is to systematically evaluate existing programs to see whether elements included are supported by theory and research.

To help define the problem, and the narrative that puts different problems into a coherent context, our programmatic research for Year 1 has commenced with a large scale scoping and review in policy-practice-research areas and pilot research. That is, through scoping and review, we are able to discern the normative context across policy-practice-research in relation to children’s role in disaster risk reduction (DRR) efforts. However, as part of piloting in Year 1, we are also getting the unique views of a wide variety of stakeholder groups (end users, teachers/school personnel, EM/DRR professionals, parents, children and

---

<sup>2</sup> With only one study published prior to 2000 – thus, since 2000, there has been a 34-fold increase in studies published in the grey or academic literatures (Johnson et al., 2014).

<sup>3</sup> It might be added that there has been no study done internationally that has looked at a Prevention and Preparedness phase education/intervention program and systematically followed that same cohort into the Response and Recovery phase of a natural disaster.



youth), through Delphi and survey work.<sup>4</sup> Based on this normative and stakeholder input, Year 2-3 are then aimed at a suite of studies that reflect questions related to an overall “research narrative”, linked to moving knowledge and application forward while also trying to solve problems that have been identified. Each study is intended to contribute to the narrative. Main study projects have not yet been finalised, but main research questions to date are summarised below, following a presentation of the research narrative.

Based on scoping and review, the research narrative thus far is as follows:

The narrative for the program of research continues to be in development in various forms: (1) through compiling various theories related to DRRE, (2) through a flowchart approach and (3) through a written narrative. While the theory- and flowchart-based models are yet completed, the written narrative as currently developed is as follows.

We currently do not have evidence-driven DRR education programs, or activities, that are known to save lives, property, reduce injuries and reduce psychosocial consequences. Related, the current best expert- and consensus-advice (e.g., “key messages”; IFRC, 2013; from important stakeholders<sup>5</sup>) has not been systematically accounted for or infused directly in DRRE programs, starting with basic messages for younger children that emphasise child protection and safety. With basic messages, there is a foundation that can then be added to and built over time to more advanced topics in later years. Further, getting the balance right in terms of child protection and child participation is an area of contention in the field (Ronan, 2014). Internationally, the pendulum has swung in the direction of child-participation/child-led direction when in fact research also strongly supports the role of adults in child-protection-based activities: One that includes in educational setting basic guidance in relation to key Prevention and Preparedness messages. The current view of this team is that there needs to be a balance of both child protection and child participation in DRRE programs.

A basic problem is that development and delivery of school-based DRRE programs tend to be one-off or time-limited and are not systematically infused within the curriculum. Thus, developing evidence-based, expert-endorsed curriculum materials that can be implemented on larger scale and help children learn and practice important key messages through participatory learning, messages that translate directly into effective Response and Recovery behaviours, including those that protect children, families and schools, all represent necessary next steps.

At the same time, analysis suggests that there are significant obstacles preventing the development and systematic uptake of evidence-informed education programs, at both practice and policy levels. At the practice level, New Zealand focus group and survey research with teachers and EM professionals (Johnson & Ronan, 2014; see also Johnson, 2014), indicates some significant obstacles including a lack of teacher training in DRRE curriculum development, resource and time limitations (e.g., overcrowded curriculum in schools), a lack of school/agency support for program implementation and a perception that DRRE programs might scare children reasons (Johnson, 2014; Johnson & Ronan, 2014). However, no research on what Australian teachers and EM Professionals see as obstacles and facilitators has yet been conducted.

---

<sup>4</sup> With possible follow-on focus group research during Year 2-3 if deemed useful.

<sup>5</sup> These include emergency management (EM) professionals, parents/households, teachers/schools and children themselves. In the case of EM professionals, they are aware of local conditions which may impact on key messaging developed by international/national experts. In the case of other stakeholder groups, it is important to see what these groups see as key messages. This would include creating DRR messaging that accounts for widely held myths as well as to amplify widely held messages that are more likely to lead to effective responding.



There is also a lack of policy frameworks or guidance for DRRE curriculum being directly, and systematically, infused in schools. At a more basic level, while anecdotal evidence suggests practitioners and policy-makers support the idea of DRRE in the curriculum, there is a lack of research that documents support. That is, with widespread support for the “aspiration” of DRRE, that can promote next steps in policy development, towards more systematic implementation of DRR curriculum practices. In addition, pending wider support from stakeholder groups, if DRRE program development can also be done with an eye to helping policy-makers and practitioners solve identified problems (e.g., teacher training, curriculum guidance and support), that may also assist in promoting increased implementation.

Moving from aspirational policy to actual implementation would also involve working with important government departments and agencies (e.g., education, emergency management) and help them advance sector-wide mapping, including ‘scoping and sequence’ policy and planning activities that can then be used to produce a K-12 curriculum that (1) meets children’s developmental needs, (2) inculcates key, evidence- or at least consensus-driven DRR activities, (3) produces “ultimate” outcomes (saving lives, property, reducing injuries and psychosocial consequences, and (4) are innovative, including solving various documented problems discussed above (e.g., crowded curriculum).

In addition, more evaluation is necessary. In particular, rigorous evaluation of the following is necessary: (1) program content and delivery (e.g., content analysis; fidelity assessment), (2) program effectiveness in producing important outcomes (including immediate, ultimate and cost effectiveness outcomes) and, finally and critically, (3) teacher/EM professional training and other national capacity building efforts.

In terms of this overall narrative, it is the opinion of this team of researchers that the large scale implementation of programs that are taught by well trained teachers and EM professionals and are effective in promoting risk reduction and resilience requires a different mindset. Moving from more of a one-off/project approach to a longer-term, strategic mentality is necessary - one that starts with and is “fuelled” through the development of key relationships between actors across across policy-practice-research sectors. As the main focus of this project, that longer-term view will benefit substantially from data that speaks to the role of DRRE in producing immediate and longer-term risk reduction benefits for children, families, communities and government.

Summary: Status of project to date and main research questions

Pilot research has begun with Delphi, survey, and focus group research with major stakeholder groups (children, parents, EM professionals and policy-makers, teachers/school personnel) on a variety of issues that are important to know for policy-makers, practitioners and researchers. For example, do children, parents, teachers, EM professionals think DRRE for children and youth (and their families) is a good idea or not? If so, what do the educators think should be the focus of such programs? What do they see as facilitators and obstacles to increased delivery of these programs? What would children and their parents like to see addressed in these programs? What do stakeholder groups currently think are the “key DRR messages” that ensure effective Response and Recovery? These questions have never been systematically asked, and we are asking them and others through surveys that are going out in the second half of 2014 and early 2015.

Starting in 2015, the main study will begin to examine core aspects of the narrative, do DRR education programs produce both immediate and longer-term benefits that promote increased knowledge, behavioural, emotional and household resiliency and risk reduction before, during and after hazard events? If so, are they delivered in a way that has potential for delivery on a larger scale? Do they have address an already crowded curriculum, teacher training problems and other practice- and policy-related obstacles? At the same time, are they packaged in a way that supports theory and that both those who deliver the programs (teachers, EM professionals) and those who participate (i.e., children and youth) find them useful





and engaging? If they produce immediate and longer-term DRR benefits, are they cost effective and, thus, more attractive to policy-makers within a whole-of-community DRR approach? Currently, there are multiple studies being planned that address aspects related to these core questions, including evaluating already developed programs as well as a program that is under development. These include at least two PhD studies and 2-3 other projects. These will be presented in more detail as each study finds its place within the overall research narrative and associated research question. As part of this planning, consultations have been underway with end users soliciting input, ideas and interest in being directly involved in the main study.<sup>6</sup> The team is also active in contributing to current knowledge as it reviews and scopes the most timely research questions in this area. In terms of publications, the team is active in publishing scholarly and other pieces in the academic and UN-related international literatures. This publication list is as follows:

## REFERENCES

- Becker, J. S., Paton, D., Johnston, D. M., & Ronan, K. R. (2014). Societal influences on earthquake information meaning-making and household preparedness. *International Journal of Mass Emergencies and Disasters*: in press.
- Burke, S., Gridley, H., Reser, J., Ronan, K.R., & Kenardy, J. (2014). Natural disaster funding: A submission by the Australian Psychological Society to the Productivity Commission. Australian Psychological Society: Melbourne.
- International Federation of Red Cross and Red Crescent Societies. 2013. *Public awareness and public education for disaster risk reduction: key messages*. Geneva: IFRC.
- Johnson, V. A. (2011). Disaster preparedness education in schools: Recommendations for New Zealand and the United States. Wellington, New Zealand: Fulbright New Zealand. Retrieved from <http://www.fulbright.org.nz/publications/2011-johnson/>
- Johnson, V. A., Johnston, D. M., Ronan, K. R., & Peace, R. (2014). Evaluating children's learning of adaptive response capacities from ShakeOut, an earthquake and tsunami drill in two Washington State school districts. *Journal of Homeland Security and Emergency Management*: in press.
- Johnson, V. A., Peace, R., Ronan, K. R., & Johnston, D. M. (2014). Improving the impact and implementation of disaster education programs for children through theory-based evaluation. Manuscript submitted for publication.
- Johnson, V. A. & Ronan, K. R. (2014). Classroom responses of school teachers following the 2011 Christchurch earthquake. *Natural Hazards*: 72 (2), 1075-1092.
- Johnson, V. A., Ronan, K. R., Johnston, D. M, & Peace, R. (2014a). Evaluations of disaster education programs for children: A methodological review. *International Journal of Disaster Risk Reduction*, 9, 107–123.
- Johnson, V. A., Ronan, K. R., Johnston, D. M, & Peace, R. (2014b). Implementing disaster preparedness education in New Zealand primary schools. *Disaster Prevention and Management*, 23(4), 370-380.
- Johnston, D. M., Ronan, K. R., & Standring, S. (2014). Children's understanding of natural hazards in Christchurch: reflecting on a 2003 study. *Australian Journal of Emergency Management*:

---

<sup>6</sup> End users are also involved in pilot research, both a Delphi study on “key DRR messages” and a larger survey for EM professionals. We are also actively soliciting input around “products” related to this research that would benefit their work. Finally, in addition to consultations done thus far face-to-face, by teleconference and email, we are also consulting with end users about a capacity-building workshop, with input from end users about preferred focus (i.e., what focus might assist them in their work currently or in the future?) and format (e.g., live versus webinar-style).





<http://www.em.gov.au/Publications/Australianjournalofemergencymanagement/Currentissue/Pages/AJEM29ONE/Historicalreflection.aspx>.

Johnston, D., Standing, S., Ronan, K. R., Lindell, M., Wilson, T., Cousins, J., Aldridge, E., Ardagh, M. W., Deely, J. M., Jensen, S., Kirsch, T., & Bissell, R. (2014). The 2010/2011 Canterbury earthquakes: context and cause of injury. *Natural Hazards*, DOI: 10.1007/s11069-014-1094-7, 1-11.

National Emergency Management Committee (2011). National Strategy for Disaster Resilience: Building our nation's resilience to disasters. Authors: Canberra.

Norris, F. H., Friedman, M. J., Watson, P. J., Byrne, C. M., Diaz, E., & Kaniasty, K. (2002). 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981–2001. *Psychiatry: Interpersonal and biological processes*, 65(3), 207-239

Petal, M., Ronan, K.R, Davie, S., Alisic, E., Towers, B., Haynes, K., & Ireland, N. (2014). Building best-practice in child-centred disaster risk reduction: Submission to the International Council for Science/United Nations Science & Technology Major Group. Planning for the Third World Conference on Disaster Risk Reduction, 2015.

Ronan, K. R. (2014). Many advances, continuing challenges towards HFA2 and Post-2015: Policy-practice-research summary and recommendations. Hyogo Framework for Action Thematic Review: Priority for Action (PFA) 3 – Core Indicator (CI) 2: School curricula, education material and relevant training including disaster risk reduction and recovery concepts and practices. Background Chapter prepared for United Nations Office for Disaster Risk Reduction and the Global Assessment Report on Disaster Risk Reduction, 2015. UNESCO/UNICEF: Paris/Geneva. Manuscript in review (final draft due by end of June 2014).

Ronan, K. R. (2014). Solving wicked problems linked to disasters, risk and uncertainty: Children are truly our future. *Australian Journal of Emergency Management*: <http://www.em.gov.au/Publications/Australianjournalofemergencymanagement/Currentissue/Pages/AJEM29ONE/OPINIONSolvingwickedproblems.aspx>.

Ronan, K. R. & Davies, S. (2014). Policy review and scoping: Disasters and children. Manuscript in preparation.

Ronan, K.R. & Johnston, D. M. (2003). Hazards education for youth: A quasi-experimental investigation. *Risk Analysis*, 23, 1009-1020.

Ronan, K. R. LeBlanc, J., Kelly, B., & Burke, S. (2014). Community health and disaster recovery. In E. Mpofu (Ed.), *Community-oriented health services: Practices across the disciplines*. Springer: New York: in press.

Ronan, K. R., Petal, M. Johnson, V.A., Alisic, E., Haynes, K., Johnston, D. M., Handmer, J., Towers, B., Davie, S., Ireland, N. (2014). Hyogo Framework for Action Thematic Review: Priority for Action (PFA) 3 – Core Indicator (CI) 2: School curricula, education material and relevant training including disaster risk reduction and recovery concepts and practices. Input Paper prepared for United Nations Office for Disaster Risk Reduction and the Global Assessment Report on Disaster Risk Reduction, 2015. CQUniversity: Authors.

Ronan, K. R. & Towers, B. (2014). Systems education for a sustainable planet: Preparing children for natural disasters. *Systems*: 2, 1-23; doi:10.3390/systems2010001.

Teague, B., McLeod, R., & Pascoe, S. (2010). Victoria's bushfire safety policy (Ch 1). In Volume II: Fire preparation, response and recovery. 2009 Victorian Bushfires Royal Commission:

Towers, B. (Under review). Children's knowledge of bushfire emergency response. *International Journal of Wildland Fire*.



Towers, B. & Ronan, K. (In preparation for submission 28<sup>th</sup> August). Living With Wildfire: Experiences of Children and Youth. In T. Skelton, N. Klocker & N. Ansell (Eds.) *Geographies of Children and Young People. Geographies of Global Issues*. Springer: London.

Towers, B. & Whybro, M. (2014). *Triple Zero Kid's Challenge Teacher's Guide*. A curriculum based resource produced for Triple Zero Working Group and the Australian Government Attorney General's Department. Available online from the 17<sup>th</sup> September, 2014.

United Nations International Strategy for Disaster Reduction (2005). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters.

<http://www.refworld.org/docid/42b98a704.html>

United Nations Office for Disaster Risk Reduction (UNISDR)\_(2013). Synthesis Report: Consultations on a post-2015 Framework on Disaster Risk Reduction (HFA2). UNISDR: Geneva.

United Nations Office for Disaster Risk Reduction (UNISDR)\_(2014). Implementation of the Hyogo Framework for Action: Summary of Reports, 2007-2013. UNISDR: Geneva.

Webb, M. & Ronan, K.R. (2014). Interactive hazards education program in a low SES community : A quasi-experimental pilot study. Risk Analysis: Risk Analysis: DOI: 10.1111/risa.12217.



# **BUILDING COMMUNITY RESILIENCE THROUGH INFORMAL EMERGENCY VOLUNTEERING**

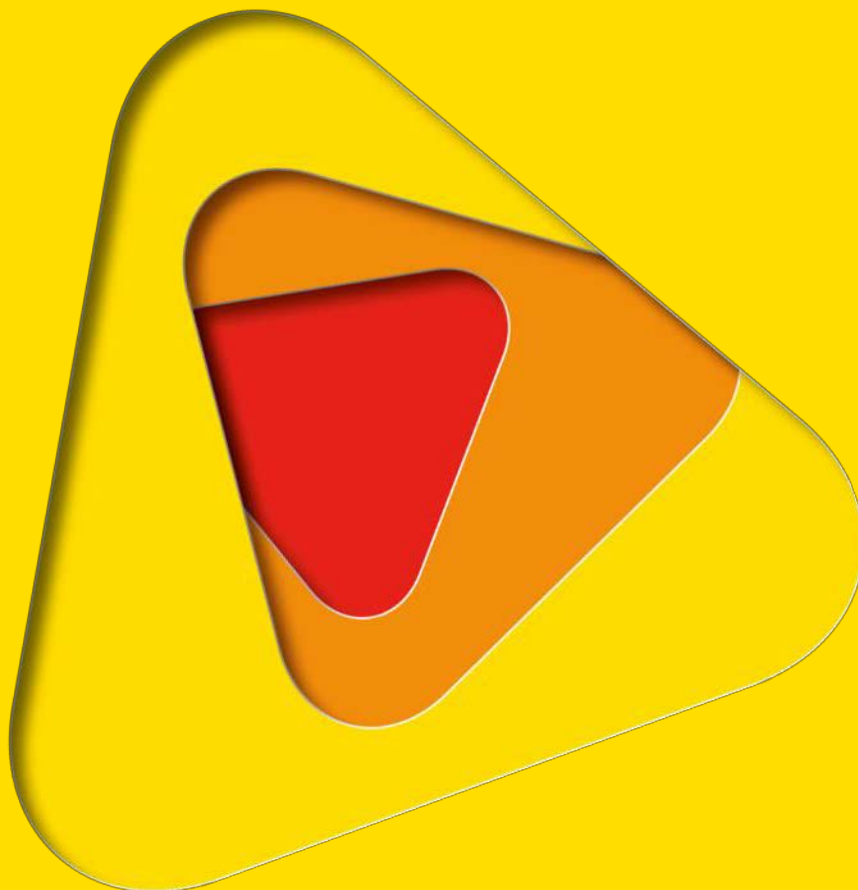
Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**Joshua Whittaker<sup>1,2</sup>, John Handmer<sup>1,2</sup> and Blythe McLennan<sup>1,2</sup>**

<sup>1</sup>RMIT University

<sup>2</sup>Bushfire and Natural Hazards CRC

Corresponding author: [joshua.whittaker@rmit.edu.au](mailto:joshua.whittaker@rmit.edu.au)





## INTRODUCTION

Members of the public are usually first on the scene in an emergency or disaster and remain long after official services have ceased. Research has shown that citizens play important roles in emergency management by helping those who are affected to respond and recover and by assisting emergency services. Such citizen participation is a key principle of disaster risk reduction and resilience building, as outlined in Australia's *National Strategy for Disaster Resilience* (Commonwealth of Australia, 2011; see also UNISDR, 2007). In most developed countries, however, formal emergency and disaster management systems rely largely on a workforce of professionals and, to varying degrees, volunteers affiliated with official agencies. Citizens who work outside of the formal system have often been viewed as a nuisance or liability, and their work is typically undervalued. However, given increasing disaster risk worldwide due to population growth, urban development and climate change (Field et al., 2012), it is likely that these 'informal' volunteers will provide much of the additional surge capacity required to respond to more frequent emergencies and disasters in the future.

This paper considers different types of informal volunteers and their contributions to emergency and disaster management. 'Informal volunteer' is defined in the context of emergencies and disasters, before literature on citizen responses to emergencies and disasters is reviewed. We examine some of the implications of informal volunteerism for emergency and disaster management, including challenges associated with organisational culture and legal liability. We argue that more adaptive and inclusive models of emergency and disaster management are needed to harness the capacities and resilience that exist within and across communities.

## DEFINING INFORMAL VOLUNTEERISM

Volunteering has been defined as 'any activity in which time is given freely to benefit another person, group or organization' (Wilson, 2000, 215). The term is generally used to refer to activities that are non-obligatory (i.e. undertaken without obligation or coercion); undertaken for the benefit of others, society as whole, or an organisation; unpaid; and undertaken in an organised context (Dekker and Halman, 2003; Snyder and Omoto, 2008).

Emergency management agencies tend to adopt more formal, operational definitions of volunteerism. For example, the US Federal Emergency Management Agency (FEMA, 2014) defines a volunteer in the context of the National Incident Management System as: any individual accepted to perform services by the lead agency (which has authority to accept volunteer services) when the individual performs services without promise, expectation, or receipt of compensation for services performed'. In Australia, Emergency Management Australia (EMA, 1998, 114) defines a 'volunteer emergency worker' as someone who 'engages in emergency activity at the request (either directly or indirectly) or with the express or implied consent of the Chief Executive (however designated), or of a person acting with the authority of the Chief Executive of an agency to which either the State emergency response or recovery plan applies'. These definitions place the volunteer firmly within the official emergency management system, with volunteers acting in accordance with the legislation, policies and procedures of the organisations with which they are affiliated. Training and accreditation is often a key requirement of such 'official' volunteering (Britton, 1991).

Although most agencies retain these formal, operational definitions, the participation of 'unofficial', 'unaffiliated', 'informal' and 'spontaneous' volunteers in emergency management is also widely recognised.



For example, the Australian Government's (2010, 5) *Spontaneous Volunteer Management Resource Kit* defines spontaneous volunteers as 'individuals or groups of people who seek or are invited to contribute their assistance during and/or after an event, and who are unaffiliated with any part of the existing official emergency management response and recovery system and may or may not have relevant training, skills or experience'. Similarly, FEMA (2013) distinguishes between affiliated and unaffiliated volunteers, with the latter defined as 'individuals who offer to help or self-deploy to assist in emergency situations without fully coordinating their activities'. FEMA notes that although unaffiliated volunteers can be a significant resource, the lack of pre-established relationships with emergency management agencies can make it difficult to verify their training or credentials and match their skills to appropriate service areas – highlighting that even though the volunteers are informal, they are seen as constituting an agency responsibility.

Essentially, in the context of emergency and disaster management, an 'informal volunteer' is anyone who freely helps those affected by emergencies or disasters by working – at least initially – outside of the established, official emergency management system. This broad definition includes a potentially wide range of volunteer types and activities. However, formal, operational definitions tend to overlook this spectrum, instead conflating the different types of informal volunteers and volunteer groups that may exist under one label. This has implications for the way these volunteers might be integrated with official response and recovery systems. For example, not all volunteers falling within the Australian definition of 'spontaneous volunteers' are necessarily unplanned or impulsive as this label implies. Similarly, even when volunteers are not affiliated with official response and recovery agencies, they may still volunteer in coordinated ways, for example, through their affiliations with other community and interest groups. Thus, a more accurate picture of the range of 'informal volunteers' and their potential contributions is needed in emergency and disaster management.

## **INFORMAL VOLUNTEERS: ROLES AND TYPES**

The important roles played by citizens in emergency and disaster management is widely documented in disaster research. Research challenges the popular perception that disasters unleash chaos and disorganisation, with citizens rendered passive victims, panic-stricken or engaging in antisocial behaviours such as looting. Instead, individuals and groups have generally been found to become more cohesive than in 'normal' times, working together to help those who are affected and to overcome disaster-induced challenges (e.g. Fritz and Mathewson, 1957; Stallings and Quarantelli, 1985; Helsoot and Ruitenber, 2004; Scanlon *et al.*, 2014).

Early disaster studies examined the phenomenon of 'convergence', involving the informal movement of people, messages and equipment into the affected area. An early study by Fritz and Mathewson (1957) noted that contrary to popular images of chaos and disorganisation, survivors tend to be more passive and cooperative than those who converge on the disaster scene from outside. While most citizens are well intentioned, convergence can create problems and challenges for emergency managers. Auf der Heide (2003) notes that hospitals and other emergency response organisations are often inundated by requests for information and offers of donations. Unsolicited donations may be inappropriate or unnecessary, requiring the expenditure of valuable resources to manage or dispose of them (Holguin-Veras *et al.*, 2012). This can impede the work of emergency services, particularly when transportation and communications infrastructure are overloaded. However, as Auf der Heide stresses, convergence is not always detrimental and 'local authorities need to recognize that unsolicited volunteers will show up, and procedures must be developed for processing these volunteers and integrating them into the response' (2003, 465).



Early studies of collective behaviour during crises led to the development of a fourfold typology of organised disaster response (Quarantelli 1966; Dynes, 1970) (Table 1).

Table 1: The DRC typology of organised response to disasters (Dynes, 1970)

		TASKS	
		Regular	Non-regular
STRUCTURE	Old	TYPE I: ESTABLISHED	TYPE III: EXTENDING
	New	TYPE II: EXPANDING	TYPE IV: EMERGENT

The typology identifies four types of organisation based on a classification of tasks (regular and non-regular) and structure (old and new):

- *Type I – Established organisations* involve routine tasks performed through existing structures (e.g. firefighting performed by a state fire agency).
- *Type II – Expanding organisations* undertake regular tasks through new structures (e.g. by recruiting new volunteers). These are typically volunteer associations or groups whose core activities are not emergency-related, but have latent emergency functions (e.g. Salvation Army).
- *Type III – Extending organisations* have established structures but take on new and unexpected functions during the emergency period (e.g. a netball club that uses its members to deliver food and clothing to survivors).
- *Type IV – Emergent organisations* are groups with new structures and new tasks. They emerge when needs are not being met, or are perceived to be unmet, by other organisations. These groups may become involved in a range of activities, such as initial search and rescue, operations such as collecting and distributing food and clothes to survivors, and coordination activities such as citizen committees that resolve disputes and advocate for resolution of community problems (Stallings and Quarantelli 1985).

Extending (Type III) and Emergent (Type IV) groups can pose significant challenges for emergency managers as they do not come under the latter’s control and may not see the ‘bigger picture’ (Dynes, 1970).

This typology highlights that citizens can participate informally in emergency and disaster management in a number of ways. Participation may be anticipated or spontaneous, involve individuals or groups, and may be short to long-term. Informal volunteers therefore include volunteers with ‘Extending’ groups and organisations that take on new emergency or disaster-related tasks (e.g. a sporting club), and ‘Emergent’ groups and organisations that form to meet a need that is (or is perceived to be) not being met (e.g. a search and rescue party). Another type of informal volunteerism has grown recently with the expansion of social media and web-based mapping software: known generally as digital volunteerism. We consider the potential roles of these three types in turn below.



## **SPONTANEOUS/EMERGENT VOLUNTEERISM**

Spontaneous volunteers are ‘those who seek to contribute on impulse – people who offer assistance following a disaster and who are not previously affiliated with recognised volunteer agencies and may or may not have relevant training, skills or experience’ (Cottrell, 2010, 3). Their proximity to the emergency or disaster site means they often play critical roles in first response. For example, many earthquake victims are rescued by uninjured, fellow citizens. In the 1980 Irpinia earthquake in Southern Italy, 90 percent of survivors were rescued by fellow citizens. In the 1976 Tangshan earthquake in China as many as 300,000 people crawled out of the debris, with many going on to form rescue teams that saved 80 percent of those buried under the debris (Noji, 1997). Other examples of spontaneous volunteerism include youths who performed search and rescue operations following the 1985 Mexico City earthquake (Castanos and Lomnitz, 2012) and the one million volunteers from Japan and abroad who came forward in response to the 1995 Kobe earthquake (Shaw and Goda, 2004). Recent groups include the Christchurch “Student Volunteer Army”, and the “Mud army” that emerged after the 2011 Queensland floods.

A key benefit of spontaneous volunteers is their ability to improvise. As discussed earlier, emergent behaviours and groups are more likely to emerge when a specific need of the affected are not being met by formal response organisations. This is not necessarily a failure of the established organisations however, as – particularly for large and unpredictable events – no organisation is able to foresee or meet all the needs of the people affected (Stallings and Quarantelli 1985). Spontaneous volunteers are likely to have a ‘real time’, ‘on-the-ground’ view of the problem and can rapidly configure themselves and their responses to meet specific local needs. Unlike emergency services and other formal response organisations, they are rarely constrained by pre-established rules, strategies and technologies that may inhibit effective local response (Fernandez *et al.*, 2006). However, while they can be more innovative and responsive to local needs than formal responders, they are often unaware of the ‘bigger picture’ and hence can overlook important flow-on impacts of their activities.

According to Fernandez *et al.* (2006) there are two main risks associated with spontaneous volunteers. The first risk involves the failure of emergency managers to effectively utilise volunteers, which creates potential for loss of life, injury and property damage, as well as poor public perception of emergency/disaster response. The second risk is associated with the actions of untrained, uncoordinated volunteers, who may disrupt organised response and reduce the resources available to those who are affected. Examples include the actions of spontaneous volunteers causing traffic jams that prevent emergency services from reaching affected areas, untrained volunteers becoming overwhelmed by their experiences and adding to the work of emergency and other services, and serious injury and death of volunteers (Helsloot and Ruitenberg, 2004; Sauer et al. 2014).

## **EXTENDING VOLUNTEERISM**

Existing groups and organisations within communities often extend their activities to volunteer in times of crisis, and may include local chambers of commerce, sports clubs, religious groups or service organisations. These volunteers often have a good understanding of local problems and needs and can draw on existing networks, skills and resources to meet them. In Australia, volunteers from organisations such as the Country Women’s Association and Rotary International often play an important role in relief and recovery by collecting and distributing donated food, clothes and other domestic goods. Following the Black Saturday bushfires in Victoria, for example, dozens of Four Wheel Drive clubs from across Victoria banded together to deliver caravans to families who lost homes; helped clear debris and damaged trees; re-fenced





farm properties; and delivered supplies to volunteer fire brigades (see also Wositzky, 1998; Apan et al. 2010; and Whittaker et al. 2012 for other Australian examples); . Businesses and corporation are also increasingly involved in emergency and disaster volunteering as part of their corporate social responsibility (CSR) programs (Twigg, 2001; Chong, 2009).

## **DIGITAL VOLUNTEERISM**

Widespread use of social media and the accessibility of free, web-based mapping software have allowed citizens to freely produce and disseminate their own emergency-related information, and to coordinate their activities. This applies to people directly affected by disaster as well as to those who wish to help – either on site or from far away. Examples of social media applications range from use of sites like Facebook to share information ([www.facebook.com/tassiefireswecanhelp](http://www.facebook.com/tassiefireswecanhelp)), through to more complex uses involving data mining and crisis mapping (Meier, 2013). In March 2014, for example, 2.3 million people around the world joined the search for missing Malaysian Airlines flight MH370 by scanning more than 24,000 square kilometres of satellite imagery uploaded to the Tomnod website (Fishwick, 2014).

The strength of ‘volunteered geographic information’ (VGI) lies in the notion that information obtained from a group of many observers is likely to be more accurate than that obtained from a single observer. Goodchild and Glennon (2010, 235) note that despite concerns about the quality of data produced by non-experts free of institutional and legal frameworks, ‘the quality of VGI can approach and even exceed that of authoritative sources’. The rich, contextual information that observers ‘on-the-ground’ can provide, and the speed with which it can be updated, are key advantages. Nevertheless, there are a number of challenges associated with use of VGI in emergency management (Poser and Dansch, 2010). It cannot be known beforehand how much information will be volunteered and where it will come from. As such, it should be treated only as a supplementary source of information when possible. Nor can the quality of data be guaranteed, with the potential for citizens to intentionally or unintentionally contribute erroneous information. There is a possibility that citizens may also be biased toward exceptionally large or severe events, meaning that smaller events go unreported.

Digital volunteerism is likely to become increasingly prevalent in emergency and disaster management in Australia and abroad. A key strength of the crowdsourcing approach is that volunteers do not necessarily have to invest long periods of time in order to participate, nor do they need to be near the emergency or disaster affected area. They can be anywhere in the world.

## **DISCUSSION AND CONCLUSION**

This paper has examined some of the ways citizens participate in emergency and disaster management by informally volunteering their time, knowledge, skills and resources to help others in times of crisis. Research suggests that citizen convergence on emergency and disaster sites is inevitable, so emergency services and other organisations must plan for and manage the participation of these volunteers. As noted earlier, this is necessary to reduce the risk that untrained and uncoordinated volunteers will disrupt organised response and reduce the resources available to those who are affected. However, it is also necessary to maximise the effectiveness of emergency and disaster management by drawing on the immense knowledge, skills, resources and enthusiasm of ordinary citizens.

Informal volunteering is also an important vehicle for building community resilience to disasters. The *Australian National Strategy for Disaster Resilience* (Commonwealth of Australia, 2011, v) recognises that:



*Non-government and community organisations are at the forefront of strengthening disaster resilience in Australia. It is to them that Australians often turn for support or advice and the dedicated work of these agencies and organisations is critical to helping communities to cope with, and recover from, a disaster. Australian governments will continue to partner with these agencies and organisations to spread the disaster resilience message and to find practical ways to strengthen disaster resilience in the communities they serve.*

Other documents explicitly recognise the potential for informal volunteerism to contribute to disaster resilience. The *Victorian Emergency Management Reform White Paper* (Victorian Government, 2012) acknowledges the important role played by spontaneous volunteers and commits the government to work with local government, volunteer organisations and agencies to develop strategies for managing spontaneous volunteers during relief and recovery efforts. A key document guiding the management of volunteers by State and local governments is the *Spontaneous Volunteer Management Resource Kit* developed by the Australian Red Cross and the Department of Families, Housing, Community Services and Indigenous Affairs (Commonwealth of Australia, 2010). It draws a distinction between ‘potential’ and actual spontaneous volunteers, suggesting that ‘people do not become spontaneous volunteers until they have undergone the relevant induction/checks for the role they will be undertaking. Until they do, therefore, they are *potential* spontaneous volunteers’ (Commonwealth of Australia, 2010, 5). A number of agencies and volunteer associations have developed registers to enable people to indicate their willingness to volunteer in emergencies and disasters (eg. <http://emergencyvolunteering.force.com/Register>). However these initiatives may not capture less formal types of volunteer and volunteering. Consideration of the activities and implications of digital volunteerism also appears limited.

Despite increasing recognition of the benefits and inevitability of citizen participation, there appear to be two main barriers to greater integration of informal volunteers into emergency and disaster management arrangements. The first barrier relates to the culture of emergency management and of emergency management organisations. In most developed countries, emergency management is based on bureaucratic, command-and-control approaches (Quarantelli, 1987; Neal and Phillips, 1985). Although these approaches are evolving, they still tend to assume that citizens are recipients of help rather than participants in emergency management (Drabek and McEntire, 2003). An alternative approach, argued for by Quarantelli (1988, 381), involves ‘loosening rather than tightening to the command structure’. Emergencies are viewed as problems that must be solved within the affected community as much as possible (Dynes, 1994). This is the basis of a more flexible ‘problem-solving’ approach that draws on the knowledge, skills and resources that exist within and across communities. Elements of both approaches are necessary; however, it is likely that achieving greater flexibility and involving citizens will require cultural and organisational change for many emergency management organisations.

The second main barrier to greater involvement of informal volunteers in emergency management is concern about safety and legal liability. Sauer et al. (2014) note that despite the ‘universal presence’ of spontaneous volunteers following disasters, few studies have considered issues related to safety and liability. Their study of voluntary organisations active in disasters found that most had encountered spontaneous volunteers during their response activities, yet the majority did not perform background checks on volunteers and only half provided training. Two of the organisations in their study had reported a spontaneous volunteer death, while eight had reported injuries. Although one organisation had been sued



by a volunteer and three had been sued due to the actions of a volunteer, most did not believe they were liable for spontaneous volunteers' actions (Sauer et al. 2014).

While further research into legal liability is needed, the risks associated with informal volunteerism can be minimised. One option is to ensure that volunteers are registered, trained, briefed, credentialed, assigned appropriate tasks, and supervised where possible (Sauer *et al.*, 2014). This is already happening in Australia through the programs and registers of a number of State emergency services and volunteer associations. However, the research reviewed in this paper highlights that many citizens will volunteer in less formal, emergent ways during emergencies and disasters. It is therefore important that emergency managers are attuned to what is happening on the ground and are prepared to engage with a diverse range of informal volunteers.



## REFERENCES

- Apan, A., Keogh, D.U., King, D., Thomas, M., Mushtaq, S. and Baddiley, P. (2010). The 2008 floods in Queensland: a case study of vulnerability, resilience and adaptive capacity. Report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia.
- Auf der Heide, E. (2003) Convergence behavior in disasters. *Annals of Emergency Medicine* 41 (4), 463-466.
- Australian Government (2010). Spontaneous volunteer management resource kit: helping to manage spontaneous volunteers in emergencies. Commonwealth of Australia, Canberra.
- Britton, N.R. (1991). Permanent disaster volunteers: where do they fit? *Nonprofit and Voluntary Sector Quarterly* 20, 395-414.
- Castanos, H. and Lomnitz, C. (2012) *Earthquake disasters in Latin America: a holistic approach*. Dordrecht: Springer.
- Chong, M. (2009) Employee participation in CSR and corporate identify: insights from a disaster-response program in the Asia-Pacific. *Corporate Reputation Review* 12 (2), 106-119.
- Commonwealth of Australia (2010). *Spontaneous volunteer management resource kit*. Available at [http://www.dss.gov.au/sites/default/files/documents/07\\_2012/spontaneous.pdf](http://www.dss.gov.au/sites/default/files/documents/07_2012/spontaneous.pdf) [Verified 15 August 2014]
- Dekker, P. and Halman, L. (2003). Volunteering and values: an introduction. In Dekker, P. and Halman, L. (eds) *The values of volunteering: cross-cultural perspectives*. Kluwer Academic / Plenum Publishers, New York. pp. 1-17.
- Dynes, R.R. (1970) *Organized behavior in disaster*. Lexington Books, Lexington, MA.
- Emergency Management Australia (EMA) (1998). *Australian Emergency Management Glossary*. Manual 03. Attorney-General's Department, Australian Government, Canberra.
- Federal Emergency Management Agency (FEMA) (2013) Volunteer and donations management support annex. Available at: [http://www.fema.gov/media-library-data/20130726-1914-25045-9213/nrf\\_support\\_annex\\_volunteer\\_20130505.pdf](http://www.fema.gov/media-library-data/20130726-1914-25045-9213/nrf_support_annex_volunteer_20130505.pdf), last accessed 6 June 2014.
- Federal Emergency Management Agency (FEMA) (2014). Glossary. Available at: <http://emilms.fema.gov/IS700aNEW/glossary.htm>, last accessed 4 June 2014.
- Fernandez, L.S., Barbera, J.A. and van Dorp, J.R. (2006) Spontaneous volunteer response to disasters: the benefits and consequences of good intentions. *Journal of Emergency Management* 4 (5), 57-68.
- Field, C.B., et al., eds., (2012) *Managing the risks of extreme events and disasters to advance climate change adaptation*. Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge: Cambridge University Press.



Fishwick, C. (2014) Tomnod – the online search party looking for Malaysian Airlines flight MH370. Available at: <http://www.theguardian.com/world/2014/mar/14/tomnod-online-search-malaysian-airlines-flight-mh370> [Verified 1 July 2014]

Fritz, C.E. and Mathewson, J.H. (1957). *Convergence behaviour in disasters: a problem of social control*. Publication 476. Committee on Disaster Studies, National Academy of Sciences – National Research Council, Washington D.C.

Goodchild, M.F. and Glennon, J.A. (2010). Crowdsourcing geographic information for disaster response: a research frontier. *International Journal of Digital Earth* 3 (3), 231-41.

Helsloot, I. and Ruitenbergh, A. (2004). Citizen response to disasters: a survey of literature and some practical implications. *Journal of Contingencies and Crisis Management* 12 (3), pp. 98-111.

Holguin-Veras, J., Jaller, M., Van Wassenhove, L.N., Perez, N. and Wachtendorf, T. (2012). Material convergence: important and understudied disaster phenomenon. *Natural Hazards Review* 15, 1-12.

Meier, P. (2013). Human computation for disaster response. In: Michelucci, P. (Ed.) *Handbook of human computation*. Springer, New York. pp. 95-104.

Neal, D. and Phillips, B. (1995) Effective emergency management: reconsidering the bureaucratic approach. *Disasters* 19, pp. 327-37.

Noji, E.K. (1997) Earthquakes. In Noji, E.K. (Ed.) *The public health consequences of disasters*. New York: Oxford University Press. 135-178.

Quarantelli, E.L. (1966). Organizations under stress. In Britson, R. (Ed.) *Symposium on emergency operations*, Systems Development Corporation, Santa Monica, CA, pp. 3-19.

Shaw, R. and Goda, K. (2004) From disaster to sustainable civil society: the Kobe experience. *Disasters* 28 (1), 16-40.

Sauer, L.M., Catlett, C., Tosatto, R. and Kirsch, T.D. (2014) The utility and risks associated with the use of spontaneous volunteers in disaster response: a survey. *Disaster Medicine and Public Health Preparedness* 8 (1), pp. 65-69.

Scanlon, J., Helsloot, I. and Groenendaal, J. (2014). Putting it all together: integrating ordinary people into emergency response. *International Journal of Mass Emergencies and Disasters* 32 (1), pp. 43-63.

Snyder, M. and Omoto, A.M. (2008). Volunteerism: social issues perspectives and social policy implications. *Social Issues and Policy Review* 2 (1), 1-36.

Stallings, R.A. and Quarantelli, E.L. (1985) Emergent citizen groups and emergency management. *Public Administration Review* 45, 93-100.

Twigg, J. (2001) *Corporate social responsibility and disaster reduction: a global overview*. Available at <http://drr.upeace.org/english/documents/References/Topic%207-Preparedness-%20Early%20Warning,%20Planning,%20Monitoring%20and%20Evaluation/Twigg%2001%20CSR%20and%20disaster%20management.pdf> [verified 23 July 2014]



United Nations International Strategy for Disaster Reduction (UNISDR) (2007) *Hyogo framework for action 2005-2015: building the resilience of nations and communities to disasters*. Available at: [http://www.unisdr.org/files/1037\\_hyogoframeworkforactionenglish.pdf](http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf), [verified 4 July 2014]

Whittaker, J., Handmer, J. and Mercer, D. (2012). Vulnerability to bushfires in rural Australia: a case study from East Gippsland, Victoria. *Journal of Rural Studies* 28 (2), pp. 161-173.

Wilson, J. (2000). Volunteering. *Annual Review of Sociology* 26 (1), pp. 215-240.

Wositzky, H. (1998). Out of the ashes, a community responds: the Dandenong Ranges bushfires, January 1997. *The Australian Journal of Emergency Management* 13 (2), pp. 17-20.



# MANAGING ANIMALS IN DISASTERS (MAID): THE EXPERIENCES OF EMERGENCY SERVICES PERSONNEL IN SUPPORTING ANIMALS AND THEIR OWNERS IN DISASTERS

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

M. Taylor<sup>1,4</sup>, G. Eustace<sup>2</sup>, B. Smith<sup>3,4</sup>, K. Thompson<sup>3,4</sup>, R. Westcott<sup>1,4</sup>  
and P. Burns<sup>1,4</sup>

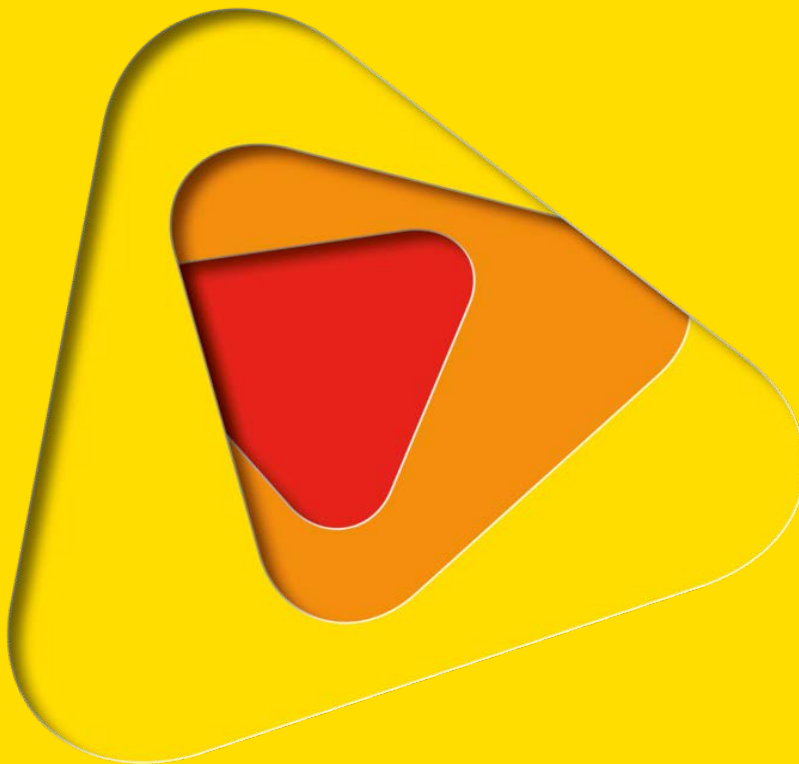
<sup>1</sup>University of Western Sydney

<sup>2</sup>RSPCA Queensland

<sup>3</sup>CQUniversity

<sup>4</sup>Bushfire and Natural Hazards CRC

Corresponding author: [melanie.taylor@uws.edu.au](mailto:melanie.taylor@uws.edu.au)







## ABSTRACT

This paper details an initial exploratory study undertaken as part of the Bushfire and Natural Hazards Cooperative Research Centre (BNHRC) Managing Animals in Disasters (MAiD) project. Data to inform the scoping phase of this project are being collected via a number of small-scale studies with key groups.

The aims of this initial study were to assess attitudes towards operational responsibility for animals and to scope the range and extent of challenges faced by emergency services personnel in their interactions with animals and animal owners in the context of disasters. The goal was to gather the views and experiences of a broad cross-section of emergency services personnel operating across Australia across all hazards.

During the period May-July 2014 data were collected from 117 emergency services personnel. Around one third of responders reported occasional or recurring issues with animals and their owners, and a further 23% felt these issues were significant/frequent or severe. The main issues noted were in the areas of logistics, unclear policy, interaction with owners during response, the physical management and rescue of animals, and inter-agency coordination. Over half the sample reported details of such experiences; these were coded and are discussed in the context of future resilience-enabling emergency management.

## INTRODUCTION

Much of what is known and published on the issues faced by responders, animal owners, and animals in disasters is either anecdotal or based on experiences overseas, most notably North America. Although the published academic literature in this area is growing, it remains relatively scant and heavily framed around animal owners and their failure to evacuate, their risk-taking to save animals, and the emotional impacts of animal loss (Heath et al, 2001a, Heath et al 2001b, Zottarelli, 2010). Limited articles have been published with a focus on emergency management and response in the context of animals in disasters and most are directed towards the logistics of planning for animals and justification of the need to include animals in planning (Leonard and Scammon, 2007; Edmonds and Cutter, 2008; Austin, 2013). Again, the setting for these publications is North America.

Given the differences in culture and operational environments there is a need for more research and access to post-incident reviews to understand the situation for emergency services and other response organisations in Australia and New Zealand. In Australia the National Strategy for Disaster Resilience (COAG, 2011) has shaped the approach being taken to all aspects of emergency management and this strategy has promoted the goal of disaster resilient communities. Given the high rates of companion animal ownership in Australia (63%: Animal Health Alliance, 2013) and the well documented and profound impacts of pet/animal loss on owners (Zottarelli, 2010; Hall et al., 2004; Gosse and Barnes, 1994) it would appear that a fundamental requirement of current emergency management should be consideration of companion and commercial animals in all stages of disaster preparedness and planning.

Recently, the climate in Australia for consideration of animals in disasters has improved with a set of 'National Planning Principles for Animals in Disasters' being endorsed by the Australia-New Zealand Emergency Management Committee (AAWS, 2014). In New Zealand consideration for companion animals in emergency management has also been considered and advanced (Glasse, 2010). These plans and actions indicate a willingness to work towards better integration of animals into emergency management planning and response. In recent years fire agencies in Australia have run advertising campaigns to encourage owners to plan for animals (e.g. *For their sake* campaign, Country Fire Authority, Victoria); and other agencies provide specific advice and fact sheets for pet owners on their websites to encourage



consideration of pets and other animals in disaster preparedness activities (e.g. NSW RFS, 2014; NSW SES, 2014; DFES, 2014). Furthermore, innovative research in Australia is underway to investigate ways to re-frame companion animal ownership from being considered a risk factor to a potential protective factor by using the human-animal bond as a motivating influence to engage owners in disaster preparedness (Thompson, 2013).

However, despite these recent advances in owner-centric activities which appropriately emphasise that responsibility for animals lies with the owners; animal owners continue to fail to prepare or consider their animals in their plans. Anecdotally, and usually in dramatic fashion (via news and social media) owners and animals can find themselves in difficult and potentially dangerous situations. The experiences of emergency response personnel and other animal responders involved in rescue or management of these situations remains largely untold.

To focus on the issues relating to managing animals and their owners in disasters the BNHCRC has funded the Managing Animals in Disasters (MAiD) project (BNHCRC, 2014).

### **THE MAiD PROJECT**

The research reported in this paper forms part of the initial activities being undertaken as part of the '*Managing Animals in Disasters (MAiD): Improving preparedness, response, and resilience through individual and organisational collaboration*' project. The MAiD project is seeking to identify and build best practice approaches to animal welfare emergency management, to enable engagement with animal owners and other stakeholders in disasters/emergencies. The goal of the project is to improve outcomes for public safety and the resilience of responders, animal owners, those with animal-related businesses, and communities.

### **THE EMERGENCY SERVICES AND ANIMALS IN DISASTERS STUDY**

One focus of the MAiD project is to understand and work to improve the interface between responders and the community concerning the planning for, and management of, animals in disaster. This current study, along with a mirror study with stakeholder organisations and studies with animal owner groups, was undertaken to aid our understanding of the breadth and the relative extent of the issues encountered, and the perspectives of a range of different responder groups operating in Australia.

## **METHOD**

### **APPROACH**

A questionnaire was designed to capture the experiences and attitudes of a broad range of responder groups including, but not limited to, emergency services personnel. As this study was part of initial project scoping activities the goal was to gather information from a broad cross-section of responders across Australia and across all hazards. Both opportunistic and targeted snowballing approaches were taken to the recruitment of participants.

A paper version of the questionnaire was used to gather responses from (mostly) NSW RFS personnel attending the Australian Community Engagement and Fire Awareness Conference in May 2014, and later a small number of Emergency Media professionals were recruited at the Emergency Media and Public Affairs Conference in early June 2014. Following this, a link to an online version of the questionnaire was sent to a number of project end-users and other emergency service contacts from within the BNHCRC with an email and a request to approach members of their organisations to invite them to take part in the survey. No requests for follow-up or reminders were issued.



## QUESTIONNAIRE DESIGN

The questionnaire was designed by the research team to collect a broad range of information from responders. It needed to be sufficiently generic to be answered by personnel operating across all jurisdictions and all hazards. To provide structure some questions were 'tick box' multiple choice format, however, to achieve the aim of scoping the area and gaining insight the questionnaire also needed to be balanced with a number of open questions. In total there were 23 questions; 16 structured short answer and multiple choice questions and seven open questions. There was also ample space for supporting comments. None of the questions was mandatory, enabling respondents to provide information freely.

The questionnaire comprised four sections;

1. Respondents' understanding of their organisation's role and responsibility in the area of animal (and animal owner) management and their knowledge of formal emergency management arrangements.
2. Respondents' views of the degree of problems and challenges encountered by their organisations and by themselves and their colleagues. This included a general view as well as responses to a range of specific issues.
3. Respondents' experiences with animal owners, any initiatives they were aware of in the area of animals in disasters, and their ideas for things that would help them to deal with animals/animal owners.
4. A series of demographic questions to enable understanding of the sample composition and context for interpretation of the data.

The questionnaire was reviewed and piloted by project team members before administration. A copy of the full questionnaire can be obtained from the corresponding author.

## RESULTS

### SAMPLE CHARACTERISTICS

Data were collected from a total sample of 165 response personnel, of which 117 were from emergency services agencies; and these have been included in the following analysis. The remainder were collected from other types of responders or emergency managers; such as primary industries personnel, veterinarians, and council officers.

The majority of the emergency services sample comprised personnel from five agencies, see Table 1.

*Table 1. Sample composition.*

<b>Emergency Service Organisation</b>	<b>N</b>	<b>%</b>
New South Wales Rural Fire Service - NSW RFS	48	41.0
Queensland Fire and Emergency Services - QFES	28	23.9
Department of Fire and Emergency Services (Western Australia) - DFES	25	21.4
Country Fire Authority (Victoria) - CFA	9	7.7
New South Wales State Emergency Service - NSW SES	4	3.4
Other (not specified)	3	2.6



The majority of respondents were volunteers (79.1%), 14.8% were salaried personnel, and 6.1% indicated that they had another type of employment status. On further investigation this latter group comprised individuals who were typically members of more than one organisation, e.g. ‘salaried DFES and volunteer SES’. Overall the sample comprised experienced emergency service personnel, with over half (51.3%) having served in their organisation for 11 or more years (34.2% for 11-20 years, and 17.4% for more than 20 years). A fifth (20.0%) had served for five years or less.

The gender of the sample was fairly evenly split; 54.8% male and 45.2% female, and as would be expected from their experience the age of the sample tended to be older, with just under half the sample (49.6%) aged over 50, 26.1% aged 41-50, and 24.3% aged 40 or under.

Respondents were asked about their own pet ownership. Just under three quarters owned household pets (73.5%) and 41.0% owned outdoor animals/pets (e.g. larger animals such as horses, cattle, and/or smaller animals such as chickens).

### RESPONSIBILITY FOR THE MANAGEMENT OF ANIMALS – GENERAL VIEWS

Respondents were asked three initial questions in the survey: What was their organisation’s role or responsibility with regard to the management of animals and/or their owners in disasters? (open question); Did they think their organisation should have responsibility for dealing with animals? and Were they aware of any formal animal response arrangements in their State Emergency Management Plan? Table 2 summarises the responses to these latter two questions.

*Table 2. Respondents’ attitudes towards organisational responsibility for managing animals and their awareness of formal animal response arrangements.*

Question	Yes		Unsure		No	
	N	%	N	%	N	%
Do you think your organisation should have responsibility for dealing with animals?	43	37.1	36	31.0	37	31.9
Are you aware of any formal animal response arrangements in your State Emergency Management Plan?	28	24.3	28	24.3	59	51.3

The open question regarding respondents’ understanding of their organisation’s role and responsibility for the management of animals and their owners generated a wide range of responses. In total 110 respondents answered this question and their responses were coded into themes. The most frequent response (27.8%, n=32) was that the organisation had no direct responsibility to respond to animals. Typically, respondents referred to their role in managing the hazard ‘we fight fires’, ‘protection of life and property’, others commented that they deal with people and that animals are the owner’s responsibility. The next most frequent theme (15.6%, n=18) included some direct indication of responsibility for an aspect of animal response, such as ‘to protect animals’, ‘to deliver food to stranded animals’, and ‘We are responsible for the rescue of animals during flood events. We also assist in the evacuation of animals during floods and fires’.

A number of respondents mentioned that they were responsible for protecting *all* life (13.9%, n=16), but pointed out that human life took priority and animal life was secondary, and that they would do what



they could to keep animals safe from harm. These responses were generally more detailed, and included the following examples.

*'Animals may be considered property but the impact on emergency services is the attachment people have for animals and therefore the agency cannot exclude animals from their charter as excluding animals will put lives at risk as the owners try to save their animals'*

*'Our role is to protect property owners and their family against bush fires. We are now becoming more aware of how animals are extremely important to their owners and putting in place ways to alert and evacuate people and their animals.'*

*'Owner should take full responsibility ensuring their pets are safe and cared for, we will render assistance where possible or undertake rescue if it is too unsafe for owners to do so. We will also rescue animals, wildlife and pets where possible and is safe for rescuers.'*

The fourth most frequent theme (12.9%, n=14) referred to the role emergency services have in helping animal owners plan and prepare for emergencies and disasters and in advising them of their responsibilities, e.g. *'Ensure owners prepare for the safety of their animals (pets/cattle)', 'Provide information or options of where to move animals and when, how to prepare property (e.g. paddocks) prior to fire.'*

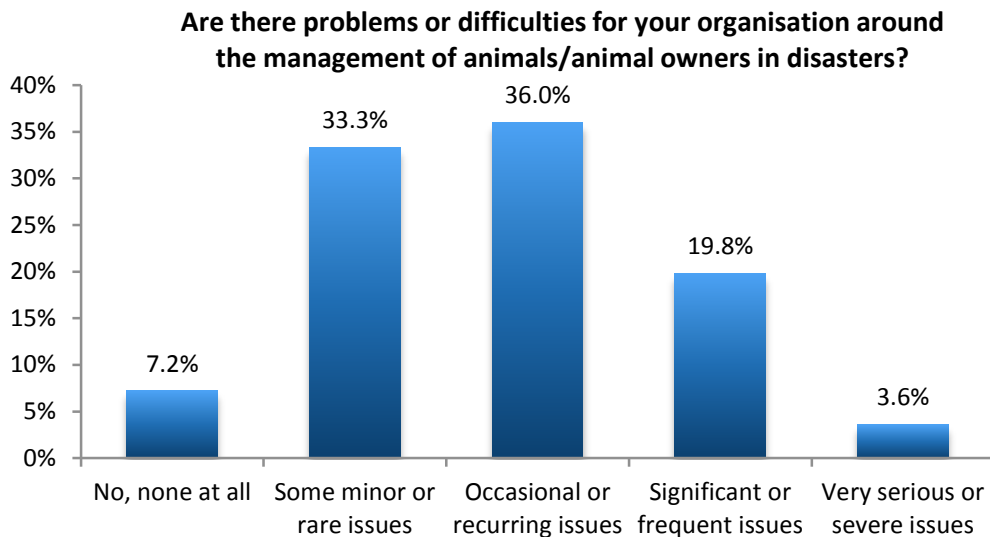
The remaining responses were coded into a further three themes. These included their role in working with other agencies that are responsible for animals, such as councils and primary industries (6%, n=7), and that their responsibility did not include animals, but that animals impacted their response (2.6%, n=3). These responses mentioned issues at evacuation centres and owners' behaviour increasing risk which then impacted/necessitated a change to the response. The final coding category included comments that generally didn't sufficiently address the question (21.7%, n=25), most respondents simply named their organisation or their title, and others mentioned the hazard they responded to – possibly indicating their focus on the hazard but providing too brief a response to interpret fully or code elsewhere.



## SCOPING THE ISSUE: GENERAL PROBLEMS OR DIFFICULTIES

In the main section of the questionnaire respondents were asked a general question; “Are there problems or difficulties for your organisation around the management of animals/animal owners in disasters?” This question was important for gauging the degree of significance of this issue. Figure 1 summarises the response.

Figure 1. Summary indication of the degree of challenge faced by emergency service organisations in managing animals in disasters.



Data shown in Figure 1 indicate that more than two thirds of the sample reports that there are either some *minor or rare issues* or *occasional or recurring issues* in this area for their organisations (69.3%). Just under a quarter of the sample (23.4%) feels that there are *significant or frequent issues* or *very serious or severe issues*. Observations of differences in response patterns across the five main service organisations in the sample suggest that respondents in the CFA were more likely to report more significant or serious issues (66.7%; 6/9 respondents), whereas those in QFES were less likely to report significant or severe issues (14.3%, 4/28 respondents).

## SPECIFIC PROBLEMS AND DIFFICULTIES

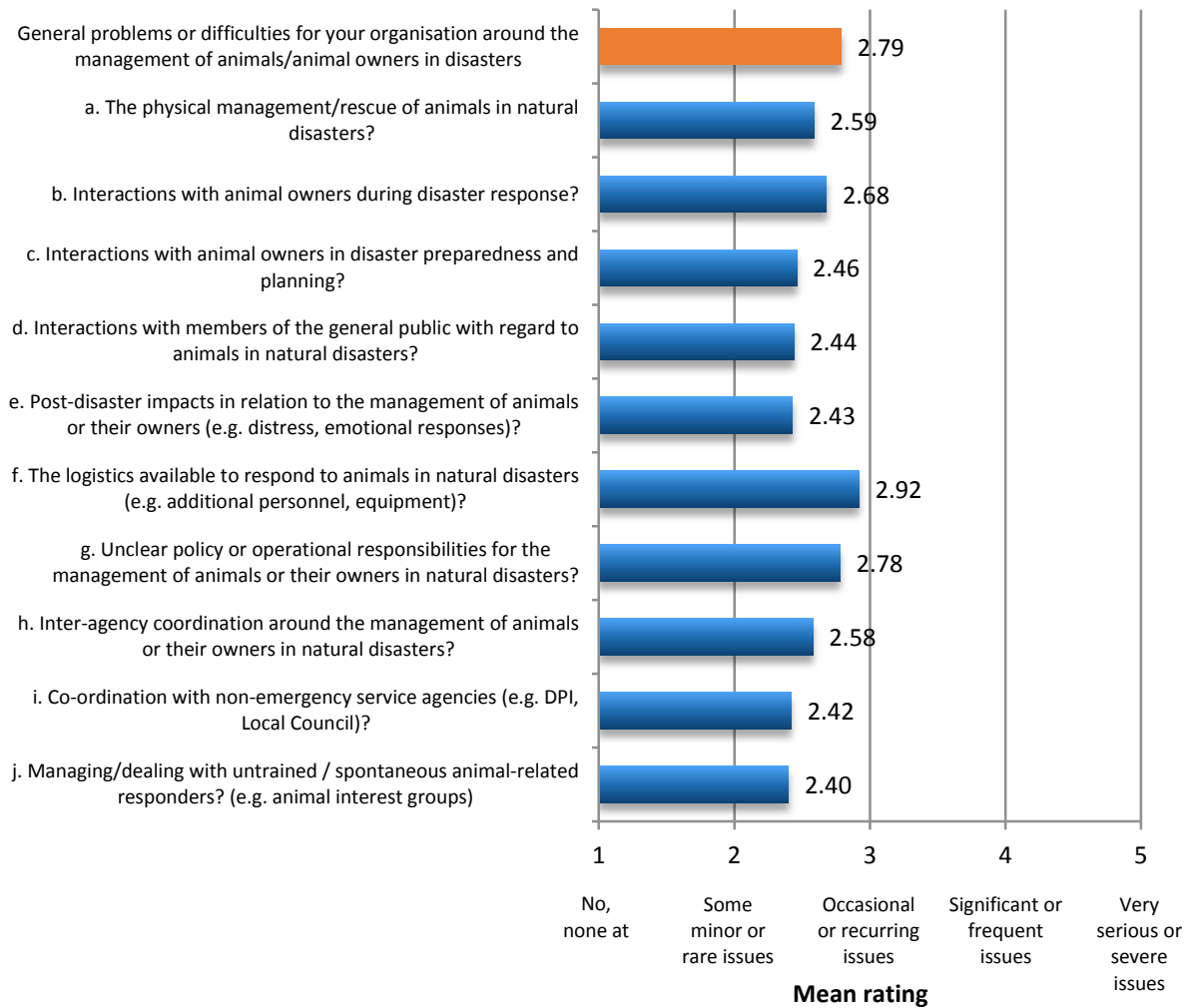
To gain further, more detailed, information about the problems and difficulties encountered by emergency services personnel in this area a further question was asked in relation to a number of potential challenges. Respondents were asked a multi-part question which began “Are there problems or difficulties for you, or your colleagues, in regard to....?” and this was followed by a set of ten specific areas. Respondents were given the same set of response options as those shown in Figure 1.

To summarise the responses to this question in a single figure a mean rating score was assigned to each response level (from 1 to 5), in which 1 = ‘no, none at all’ and 5 = ‘very serious or severe issues’. Therefore, the greater the mean score the more serious or severely the issue was rated by respondents.

Figure 2 summarises these data. The mean rating for the first (general) question shown in Figure 1 is also included in this Figure (in red) for comparison.



Figure 2. Indication of the relative severity of different issues encountered by respondents and their colleagues in relation to the management of animals and their owners in disasters.



As can be seen from Figure 2 there is some variability in the mean ratings for different issues. Issues around the logistics of response and unclear policy or operational responsibilities are rated as being slightly more problematic than the other issues listed. However, interactions with animal owners during response, physical management and rescue of animals, and inter-agency co-ordination are also three of the more highly-rated problems.

In addition to the structured question reported above, respondents were asked about additional challenges they had encountered with animals/animal owners (open comment). In total 31 respondents (26.5%) made further comments, some commented on a general lack of resources including physical equipment and training or agency expertise, others included comments about their experiences, concerns, or examples of how they/their unit responded to animals. Some examples are provided below.

*'I have experienced the following: Roads used for evacuating communities blocked by horse floats... People helping to evacuate friends' horses with no plan or idea of the area and not knowing the roads into or out of the area they have gone into to assist. Non-emergency personnel removing horses/stock from properties without the permission of the owner with no notice of where they have taken the animals and how they can be recovered. Animal/equine Facebook groups becoming*





*immune to the risk as they have got away with doing what they are doing previously, therefore they are taking more risks next time, if that makes sense.'*

*'In this rural area the general consensus is to turn the animals loose and worry about catching them later, however this creates dangerous situations on the roads with cattle and horses bolting from the disaster area.'*

*'Main concern is anticipated slow response from insurance assessors re burnt livestock that need to be euthanased humanely. Have experienced a time when livestock could not be euthanased before assessor has given the OK. Extremely upsetting for stock owner.'*

*'The current system of not being able to tell people where to take their animals is difficult to 'sell'.'*

*'The non-action of pet owners to evacuate when asked and then their anger and distress when animals are not able to be transported in air support (i.e. helicopters).'*

As these example comments indicate, the situations and experiences described by these emergency service personnel can often be emotionally-charged or potentially chaotic and dangerous.

### **DETAILED EXAMPLES AND EXPERIENCES**

In the latter section of the questionnaire respondents were asked to identify and provide details of specific problems or challenges they had previously encountered with animal owners. Just under half of the sample (45.3%, n=53) provided details of their experiences. These comments were coded into themes for reporting to provide an overall indication of their content. Many comments were quite detailed, and therefore some were coded into more than one theme, and themes were sometimes inter-related.

Table 3 summarises the themes identified and the number of respondents making comments that were coded to these themes.

*Table 3. Coding of Emergency Service Personnel's experiences with animals and their owners.*

Themes	N	%
Examples of dangerous/risky behaviour or inappropriate actions	14	26.4
Refusal to leave or be parted from animals	12	22.6
Comments about horses and horse owners as a special case	9	17.0
Details of emotional responses of owners	7	13.2
Experiences with dangerous animals/animal behaviour	7	13.2
Issues around owners returning/wanting to return early or being denied access	6	11.3
Owners' focus solely on animals and ignoring risk to self and others	5	9.4
Owners having unrealistic expectations of the level of help from emergency services	4	7.5
Problems with response co-ordination - with groups/agencies or absent owners	3	5.7

To expand on the themes in Table 3 and provide details of the experiences of emergency service personnel a selection of example comments are shown below.

Comments about risky or inappropriate actions ranged from brief comments, such as *'animals being let free during wild fires'* and *'they [animal owners] try to enter unsafe areas during an incident'* to more lengthy comments like these two below.



*'People ignoring road blocks/ police / RFS to run into dangerous situations to 'rescue' animals that should have been relocated well in advance!'*

*'Animal owners, particularly horse owners, are reluctant, at times, to remove themselves from danger and hand over the control of a rescue to our trained responders. Often their lack of appropriate PPE and their emotional, irrational response to their distressed animal is an added challenge during rescues potentially putting the owner and others involved at greater risk.'*

Issues around road blocks were often mentioned, as were situations in which people put themselves into other dangerous positions to rescue animals and in doing so either risked harm to others (emergency services personnel) or held up the response to the hazard.

As expected, experiences around failure to evacuate and leave animals was mentioned by a number of respondents, comments such as *'not evacuating or leaving high risk areas due to pets - especially horses'* and *'family pets missing - would not evacuate in imminent danger'*.

One respondent commented on a specific event.

*'In Bundaberg 2013 floods, communities were requested to evacuate while roads were still accessible. They relied on their experience with previous floods to ignore the request. They need to understand each event is different. Many people were plucked off their roofs by helicopter and pets had to remain behind. Some people refused to be rescued as their pets were not able to be taken as well.'*

As noted earlier, one aspect that was evident in comments from respondents was the strong and emotionally-charged situations that could occur; this clearly could be quite distressing for responders to manage, as well as potentially dangerous. Simple comments included *'they [animal owners] can get in the way and become very emotional'*, *'very emotional situations in time of large fires endangers staff and public'*, and *'telling people they can't go and get their animals as all ways into area are closed. Very hard to deal with crying angry people'*

With regard to owners abandoning or leaving animals, or generally not planning adequately and then wanting to go back to retrieve animals, the following comment made the point.

*'In the event where owners have been told to evacuate pets/animals are often forgotten, when told they cannot return this causes many problems for emergency crews. Endangering life for animals is a big decision and can stretch already busy emergency crews to the limits. Again owners need to take responsibility for their pets/animals where safe to do so. If they chose to leave them behind they cannot get angry when told for their own safety they cannot return.'*

Finally, the last respondent summed up a wide range of issues in his comment, drawing attention to the range of situations that can arise and touching on issues not mentioned by others, such as misinformation and changes to processes and procedures to react to evolving situations.

*'Volunteers, either spontaneous individuals or emerging groups, self-determining activity to evacuate horses and causing issues at roadblocks, promoting misinformation about animals at risk, etc. Issues at roadblocks generally (people trying to get back to get pets, milk cows, etc.). People turning up with pets to evacuation centres managed by DCPFS who do not normally allow animals in (so dogs in cars outside etc.) and ad-hoc arrangements by local government with variable success (risk of aggression by pets to other people and animals).'*



## DISCUSSION

This study elicited details of emergency service personnel's experiences with animals and their owners in the context of disasters, and provided material to begin scoping the challenges faced in these situations. Overall there was a range of responses regarding the role of service organisations in response to animals, and a variety of responses was gathered from within the same organisations. In addition, half the sample was not aware of formal animal response arrangements. These findings suggest that there is a lack of clarity in this area, even for experienced emergency services personnel, and further education of the workforce in this area might be required.

The sample was equally split when asked about whether their organisation should have responsibility for dealing with animals and this mix of opinion was reflected in comments; with some respondents clearly indicating that their responsibility was firmly hazard-focused, and others having a more flexible view, in which the human life was the priority but rescuing and helping owners with animals would be part of their response if conditions permitted. It is likely that public pressure and adoption of national guidance (such as the National Planning Principles for Animals in Disasters) will drive a greater consideration of animals in emergency planning and response in coming years. This will require a cultural shift within emergency management organisations and therefore there could be merit in early promotion of a clearer position, or direction, now to aid such a shift.

The section of the survey focused on the extent and range of challenges faced by emergency service personnel was useful in starting to quantify this issue in the Australian context. To our knowledge, nothing similar has been published in the open literature. It was quite clear that survey respondents felt there were some significant issues in this general area, and the more detailed question enabled a breakdown of which specific areas were regarded as more significant. Issues of logistics and the need for additional personnel and equipment suggest that responders feel inadequately resourced to manage animals. Anecdotally, response to large numbers of livestock or large numbers of people with pets has been challenging in recent disaster events.

Identification of challenges relating to unclear policy, operational responsibilities, and inter-agency co-ordination further support the need for greater awareness and training at the individual level and may suggest a need for a review of policy or more multi-agency response training in this area.

The finding that interactions with animal owners during response can be challenging concurs with the reported experiences of many emergency services personnel in the survey, and aligns with experiences reported in the literature around evacuation failure in the context disasters in North America (e.g. Heath et al, 2001a). The experiences reported in this study clearly highlight the challenges faced by emergency services personnel in dealing with the differing emotional responses of owners, and the requirement they have for skills to manage such responses in complex and hazardous situations. Literature in this area has typically focused on veterinarians or primary industries personnel in the position of first responders. Often this literature has centred on emergency animal disease response rather than natural disaster response; and the focus has either been on animal welfare or on the psychological impacts of the response on the responders rather than the management of impacted people or recipient communities (e.g. Hall et al, 2004 in the disaster context and Jenner 2007, in Newcastle Disease, and other agricultural responses in Australia). Further attention is required in this area to assist with communication at the responder-animal owner interface.



## LIMITATIONS

As noted, this study was an initial exploratory study, focused on gathering a diversity of responses from Australian emergency service organisations, across all hazards. This study did not set out to gather representative data and relied on a passive self-selection/opt-in administration and used opportunistic and targeted sampling techniques. As such, data presented here do not represent the position of personnel across Australian emergency services organisations, it is only indicative of some of them. It is likely that those who took part in the survey were either more interested or engaged in this area or felt they had a contribution to make to the study. As a point of interest, household pet ownership in this sample was 73.5%, significantly higher than figures for national pet ownership (around 63%) and also underlines the simple fact that many emergency responders are animal owners too. They bring their own views and emotions to this situation, and although they are trained to respond professionally that does not make them immune to the potential emotional and psychological sequelae of difficult operational situations.

Further data collection, additional research with other responder and owner groups and stakeholders, and analysis of the existing dataset are still underway as part of the MAiD project scoping activities. Engagement with a range of project end-users and stakeholders is ongoing and it is expected that review of these scoping data and iterative discussions will lead to the development of a shortlist of target areas for the next phase of the project.

## CONCLUSIONS

This initial study sought to elicit information from a range of emergency services personnel operating across Australia about their experiences with animals and their owners in the context of disasters. Data were collected from more than 100 emergency service personnel and nearly 50 other types of emergency managers and animal responders. Data collection is continuing over the coming months and information will be used to supplement what is already collected to support the requirements of the MAiD project.

The study identified a range of potential priority areas for further discussion and a number of possible recommendations, including clearer communication about the role and responsibilities of emergency service organisations in this area and the need to support responders in their training to manage animals and their interactions with animal owners.

Outcomes of this, and other current scoping studies, will be used to direct future MAiD project activities. In addition, results from these studies will help to guide the development of evidence-informed support tools to assist operational response and community engagement, and the production of professional development resources.

## ACKNOWLEDGEMENTS

The authors would like to acknowledge the funding received from the BNHCRC for the project Managing Animals in Disasters (MAiD): Improving preparedness, response and resilience through individual and organisational collaboration. We would like to thank our project end-users, other BNHCRC partner organisation end users, and emergency service contacts for circulating the survey link to their personnel, and we would like to thank the emergency services and other response organisations' personnel who completed the survey and are contributing to shaping the MAiD project.



## REFERENCES

- AAWS (2014) National Planning Principles for Animals in Disasters. Australian Animal Welfare Strategy. [accessed on 15/08/2014]  
<http://www.australiananimalwelfare.com.au/app/webroot/files/upload/files/PDF/FINAL%20National%20Planning%20Principles%20for%20Animals%20in%20Disasters.pdf>
- Animal Health Alliance (2013) Pet ownership in Australia. [accessed 15/08/2014]  
<http://223.27.22.40/~sh10135/wp-content/uploads/2013/08/Pet-Ownership-in-Australia-2013-Summary-report-2013.pdf>
- Austin JJ (2013) Shelter from the storm: Companion animal emergency planning in nine states. *Journal of Sociology and Social Welfare* 40, 4, 185-210.
- BNHCRC (2014) Managing Animals in Disasters. Bushfire and Natural Hazards Cooperative Research Centre [accessed on 15/08/2014] <http://www.bnhcrc.com.au/research/resilient-people-infrastructure-and-institutions/237>
- COAG (2011) National Strategy for Disaster Resilience: Building Our Nation's Resilience to Disasters, Council of Australian Governments, Canberra, Australia.
- DFES (2014) Pets and other animals. [accessed 15/08/2014]  
<http://www.dfes.wa.gov.au/safetyinformation/animalwelfare/Pages/petsandotheranimals.aspx#1>
- Edmonds AS, Cutter SL (2008) Planning for pet evacuations during disasters. *Journal of Homeland Security and Emergency Management* 5, 1.
- Glasse S (2010) Recommendations to enhance companion animal emergency management in New Zealand. [accessed 15/08/2014] <https://training.fema.gov/EMIWeb/edu/docs/Glasse%20-%20Report-recommendations%20to%20enhance%20companion%20animal%20EM%20in%20NZ.pdf>.
- Hall MJ, Ng A, Ursano RJ, Holloway H, Fullerton C, Casper J (2004) Psychological Impact of the Animal-Human Bond in Disaster Preparedness and Response. *Journal of Psychiatric Practice* 10, 368–374.
- Heath SE, Kass PH, Beck AM, Glickman LT (2001a) Human and Pet-related Risk Factors for Household Evacuation Failure During a Natural Disaster. *American Journal of Epidemiology* 2001, 153, 659–665.
- Heath SE, Voeks SK, Glickman LT (2001b) Epidemiologic features of pet evacuation failure in a rapid-onset disaster. *Journal of the American Veterinary Medical Association* 218, 1898–1904.
- Jenner M (2007) The psychological impact of responding to agricultural emergencies. *Australian Journal of Emergency Management* 22, 2, 25-31.
- Leonard HA, Scammon DL (2007) No Pet Left Behind: Accommodating Pets in Emergency Planning. *Journal of Public Policy and Marketing* 26, 49–53.
- NSW RFS (2014) Fire Safety for your pets. Fact Sheet [accessed 15/08/2014]  
[http://www.rfs.nsw.gov.au/\\_\\_data/assets/pdf\\_file/0006/9429/Fire-Safety-for-your-Pets-Factsheet.pdf](http://www.rfs.nsw.gov.au/__data/assets/pdf_file/0006/9429/Fire-Safety-for-your-Pets-Factsheet.pdf)
- NSW SES (2014) Pet safety in storms. Storm Safe: Pets Fact Sheet. [accessed 15/08/2014]  
<http://www.ses.nsw.gov.au/content/documents/pdf/floodsafe/42153/stormsafepetsfactsheet>



Thompson K (2013) Save me, save my dog: Increasing natural disaster preparedness and survival by addressing human-animal relationships. *Australian Journal of Communication* 40, 123–136.

Zottarelli LK (2010) Broken Bond: An Exploration of Human Factors Associated with Companion Animal Loss During Hurricane Katrina. *Sociological Forum* 25, 110–122.

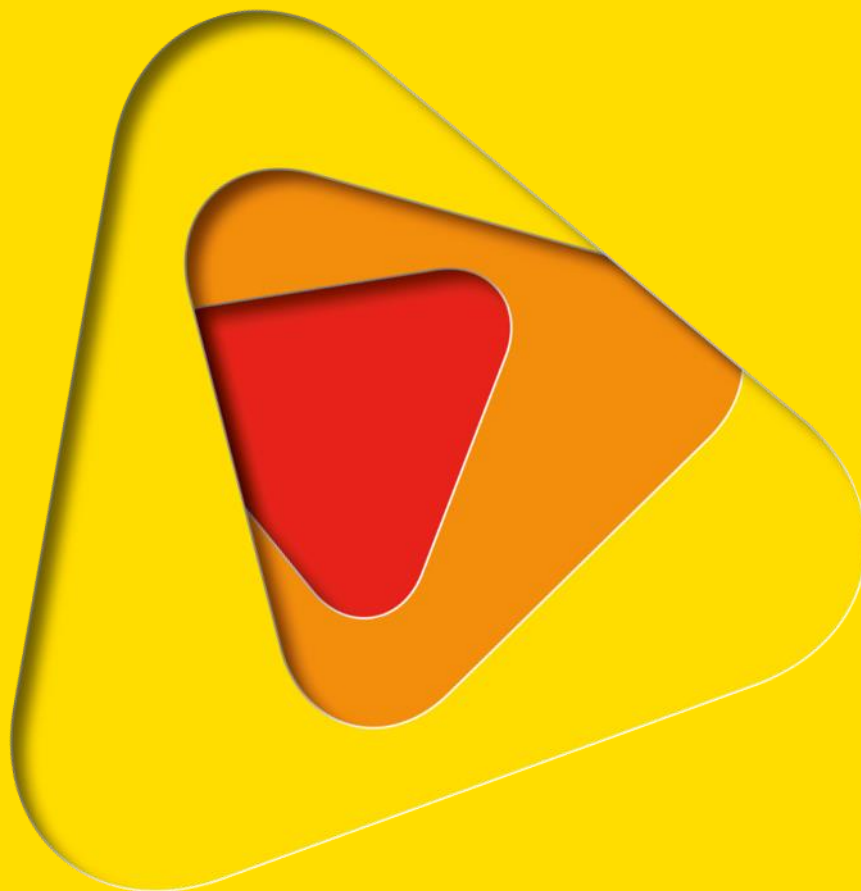


# **SOCIAL MEDIA, CRISIS COMMUNICATION AND COMMUNITY- LED RESPONSE AND RECOVERY: AN AUSTRALIAN CASE STUDY**

**Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014**

**M. Irons, D. Paton, L. Lester, J. Scott and A. Martin**  
University of Tasmania

Corresponding author: [melanie.irons@utas.edu.au](mailto:melanie.irons@utas.edu.au)







## ABSTRACT

This paper discusses research being undertaken to explore and document an Australian case study of a Facebook page, “*Tassie Fires – We Can Help*” (TFWCH), which was created by a community member during a bushfire emergency in 2013. This project represents one of the first and most extensive insights into how a community-led social media page functions in a crisis situation. The page was used as a platform to inform the public and share information, provide a medium for users to ask for help or offer help, and to manage volunteers. This paper discusses the background to the case study.

**Additional keywords:** emergent group, spontaneous volunteer, psychological first aid, social media, crisis communication, community resilience

## INTRODUCTION

Communication plays a pivotal role in effective disaster response. However, due to the heterogeneity of communities, it can be difficult for formal responders to provide a means of getting information from and to affected communities in ways that accommodate their diverse issues, needs and goals. Furthermore, these change over time as people negotiate increasingly varied response and recovery needs. What is needed is a means of communication that engages communities and their members in ways that accommodate this diversity and that complements the official coordination of disaster response and recovery efforts. Social media may represent part of the solution to this problem.

Social media content offers community members and agencies alike access to real-time, first-hand information during the preparation, response and recovery phases of disasters that can be tailored to meet the needs of different groups, and it represents a useful tool for communication and situational-awareness (Cobb et al., 2014; Liu, Palen, Sutton, Hughes, & Vieweg, 2008; Yin, Lampert, Cameron, Robinson, & Power, 2012). An important area of contribution relates to organising the complex management issues created by the surge in volunteers who wish to help in the aftermath of a disaster (Kendra & Wachtendorf, 2001; Paton, Johnston, Mamula-Seadon, & Kenney, 2014) and being able to link the capabilities of this volunteer resource more accurately to community needs.

If, however, social media is to be used effectively for this and other emergency management activities, systematic research into how social media can facilitate cost effective approaches to engaging communities is needed (Sutton, Palen, & Shklovski, 2008). Of particular interest is how these elements combine to potentially enhance community resilience, such as through being operationalised in a theoretically validated model of community resilience (Norris, Stevens, Pfefferbaum, Wyche & Pfefferbaum, 2008). Norris et al. identified four networked resources (objects, conditions, characteristics and energies that are of value) critical for resilience: *economic development, information and communication, social capital* and *community competence*. The model has not been applied in the social media context to date, and thus exploring other potentially important components, such as the leadership of emergent groups, is considered important. Case studies in this area are a critical way of pursuing this goal, and this paper introduces an Australian case study of a social media initiative that was created during a bushfire emergency in 2013.



## THE TASMANIAN BUSHFIRES OF 2013: A SHORT HISTORY

The ensuing information is sourced from the 2013 Tasmanian Bushfires Inquiry report (DPAC, 2013)<sup>1</sup>. In total, there were 103 recommendations put forward by the Inquiry, all of which were accepted or approved-in-principle by the State Government in office at the time.

The bushfires of January 2013 were Tasmania's worst in more than 40 years. As is detailed more specifically in the Bushfire Inquiry, thousands of people were displaced, well over 900 homes, outbuildings, properties and vehicles were damaged or destroyed, and hundreds of square kilometres of bush and farmland were burnt.

Three major fires started in Tasmania in January 2013. A campfire was the 'most likely' cause of one of the three major fires, the Derwent Valley fire, which burned from 4<sup>th</sup> January to the 22<sup>nd</sup> January, with a boundary perimeter of 124.1 kilometres. The Bicheno fire, which began on the 3<sup>rd</sup> January, was ruled to have started from lightning strikes. This fire was contained by the 9<sup>th</sup> January and declared closed by the Tasmania Fire Service on the 22<sup>nd</sup> January. Tasmania Police evacuated approximately 1,000 campers and tourists from the area. The Forcett fire, which began on the 3<sup>rd</sup> January at approximately 2pm, was ruled 'accidental', and likely began from a campfire that had been lit in an old tree stump almost a week earlier; a fire which had not quite been extinguished. This fire was considered closed on the 20<sup>th</sup> March. The fire had burned 25,520 hectares with a perimeter of 309.9 kilometres. This fire was the most destructive of the three major incidents occurring.

Although there were a number of positives in the management of the disaster, several problems arose in regards to the handling of the emergency response, and the subsequent recovery. There was confusion about which individual or groups were in charge of the entire emergency operation (p. 65). The police-appointed road closures were considered by many to be unnecessary, and an inflexible approach to closing the roads was taken that was considered to have hindered the response significantly (p. 111). There was also confusion with when and who to evacuate (p. 114); and overall confusion on the fire grounds with emergency crews being overwhelmed and undermanned (p. 91). Handling information and knowledge in an effective way is paramount for emergency services in a disaster, which is difficult in the turbulent, fast-paced, confusing world that is an emergency (Yates & Paquette, 2011). The findings of the Inquiry suggest that there were critical failures in the flow of information and communication during the disaster.

The Tasmanian Farmers and Grazier's Association stated that there was "no response by Government until the 7<sup>th</sup> January" (p. 135). The Bushfire Recovery Task Force was established on the 11<sup>th</sup> January. As is often the case, the transition from response to recovery was difficult for many reasons, including issues around accessibility, as the fires were burning for quite some time. Furthermore, many of the affected areas remained isolated and dislocated due to the roadblocks that remained in place. There were issues with the evacuation sites, which were well over capacity, such as insufficient staffing, poor leadership, conflicting information, and lack of back-up power generation. There were also issues with spontaneous volunteers and dealing with unnecessary goods being donated by boat (p. 138), to name a few concerns highlighted in the Inquiry.

---

<sup>1</sup> All page number references in this section refer to the 2013 Tasmanian Bushfires Inquiry report



These findings highlight the challenge of communicating with large and diverse groups of people in emergency events whose impacts are geographically distributed and characterized by evolving demands and challenges. Social media offers opportunities to communicate effectively during disasters under these circumstances because it facilitates obtaining real-time information about what is happening from those in situ (Yin et al., 2012). Social media offers many opportunities for emergency management and community groups to engage with and listen to public input and debate and so facilitate comprehensive monitoring and situational awareness during disaster response. In the recovery period, social media can facilitate extending emergency response and management through, for example, crowd-sourcing and collaborative development, and creating social cohesion. While still in its infancy, it is clear that social media represents an area for systematically allowing communities to advance their causes, engage in risk management in ways that more accurately reflect community needs, and enhance research (Alexander, 2013). If it is to realise these benefits, systematic research is essential. This paper outlines some preliminary work in this area that draws on a mix of “participant observation” in the online environment and the analysis of social media use during an event. The fact that this work draws on data obtained during disaster response adds to its validity as a guide to the effective use of this resource.

These findings also provide context and rationale for the founding of a Facebook page, which was created due to seeing gaps in the response and recovery. The page was created by a community member who is the first author of this paper, as after the fires, she analysed the case study as part of a Psychology Doctorate at the University of Tasmania.

## **THE TASSIE FIRES – WE CAN HELP FACEBOOK PAGE: AN ANECDOTAL, AUTO-ETHNOGRAPHIC INTRODUCTION**

On the afternoon after the fires had first begun, January 4<sup>th</sup>, I was at home working while also baby-sitting for a friend. Being 60km away, my property was not under any threat from these particular blazes. I was listening to updates on ABC Local Radio. The ABC (Australian Broadcasting Commission) is a federally and state government funded radio operation around Australia, and since 2010, it is recognised as the predominant emergency broadcaster in the event of any type of crisis. I knew the disaster was serious when the radio coverage was rolling non-stop. I was also monitoring the Tasmania Fire Service (TFS) website. Already, stories were circulating about homes being destroyed, people being evacuated, and other individuals and families being trapped behind the fire front: it was clear a crisis was unfolding.

I had no experience with helping during an emergency. I was anxious to help but was limited by my lack of experience and my immediate situation – stuck at home baby-sitting. I posted a few questions on Facebook through my personal account to my own network of friends and family, and details started to emerge: for example, there was a refuge centre that needed volunteers, people were worried about their pets, people couldn’t get a hold of friends and family who were in the area, and others were offering donations. I had a strong sense that all this information, goodwill, as well as offers and requests for help, needed to be organised. These were only general thoughts, but they were enough to get me started on creating the “*Tassie Fires – We Can Help*” (TFWCH) Facebook page.

I am not a social media expert and I still cannot pinpoint why I actually acted on my desire to help. I know I was emotionally connected to what was happening, as friends of mine either lived in the area or had family in the hardest-hit area of the state. This emergency wasn’t something happening in some



far-off place on a map: it was right around the corner. From my house, I could easily see the thick smoke and the orange glow of the fires.

The fire in the southeast, known as the Forcett fire, was on two peninsulas, which are connected to the rest of the island of Tasmania via the same highway. When the road was cut off due to the fire-front and police blockades, thousands of people were left stranded. Homes lost power and telecommunication services were completely non-operational. A few thousand tourists holidaying in the area were also trapped. There was a tremendous hunger for information – from those trapped on the south east coast, and from those trying to reach them. There were vague reports that the Bicheno fire had also burnt houses; and that the Derwent Valley fire to the northwest was threatening a number of communities in the area.

I set up the Facebook page with the general idea that it could be something of a clearing-house. People could post with requests or problems, and solutions would be found (I hoped). Although I thought it was a long shot, I called my local ABC radio station, and asked if they would put me on air. To my surprise the producer connected me with the news presenter immediately, and we had a live discussion about the page and what I was hoping to achieve. It was an early insight into how social media and traditional media might work together in an emergency situation. Even though the emergency was relatively small, and the state of Tasmania is small, within a few days the page had attracted almost 21,000 followers. People flocked to the page to get information, to ask questions, to give support and to see what was needed. There were updates from police and emergency services provided through the page, information from various charities about what they were doing and how people could contribute, while thousands of volunteers shared information. I was on the laptop and telephone for up to 20 hours a day, posting new content every three to four minutes. This continued for almost a full fortnight. Activity slowed but continued for months, and the page continues to the present day. A locally sponsored website has also been set up to work in tandem with the page in future disasters ([www.tassiefireswecanhelp.com](http://www.tassiefireswecanhelp.com)).

One of the stories which helps illustrate the page's role and impact concerns the plight of an oyster hatchery in Dunalley, Cameron's. The hatchery housed around 60 million baby spat. About 40-45% of the oysters grown in Australia are from spat grown at Cameron's. The hatchery also employs 35 people locally. The hatchery only narrowly escaped the flames but on the day immediately following the worst of the fire-front, another crisis emerged. Power had been lost, and therefore the cooling and feeding systems in the hatchery were non-operational. Baby oysters are very sensitive to temperature; even slight changes will cause stress and will kill the oyster spat in a short space of time.

A distraught local oyster farmer contacted me. He had already seen people using TFWCH and he figured it was his last chance to get some help. On 6<sup>th</sup> January at 1:23pm I posted a message on his behalf. In the post, I explained what was at stake, how we needed to help, and how it could all be done. I was requesting three generators, and some electricians and electrical engineers to get to the area and assist. The message also included the contact details for the hatchery and the emergency services personnel that would be needed as escorts to ensure people were able to access the area safely, if they were going over land rather than by sea. The appeal was a success. Having had ongoing contact with the hatchery, at 3:53pm on the same day I posted again, to say all that was still needed were some big generators, and again at 6:43pm saying one big generator had been sourced, but another was needed. By 9:02pm that night, generators had been delivered, two service stations were back up and running, and two more generators were on the way.



The following morning, having successfully sourced the generators, and more than enough electrical engineers and electricians for the job at hand, I was able to post the following message from the owner of the hatchery:

The screenshot shows a Facebook post from the page 'Tassie Fires - We Can Help', which has 20,232 likes. The post is dated January 7, 2013, at 11:38am. The text of the post reads: 'READ THIS FOR SOME ABSOLUTELY AMAZING NEWS' followed by 'Just speaking to Ben, the owner of Cameron's Oyster Farm. Yesterday I got on to them because they desperately needed some big generators, electricians, and electrical engineers. The word went out here and I rang the ABC too.' It then says 'Here's what he had to say today:' followed by a paragraph: 'We have managed to save an estimated 80% of our livestock at one of our sites - we are thrilled about this. 35 jobs in the local community have been SAVED. We have over 200 customers in other areas in Tassie and in South Australia who rely heavily on us to supply livestock - so we have literally saved dozens of families and family businesses in regional Tas and South Australia.' Another paragraph follows: 'This is all because the word went out and we got generators and sparkies who came out and stayed out for there for hours yesterday.' The post concludes with 'So an enormous thank you to the Hobart community from Ben, the boss of Cameron's Oysters (third generation oyster farmer)' and 'At present - they don't need anything 😊'. Below the text are interaction buttons for 'Like', 'Comment', and 'Share', with a '90' next to 'Share'. A line of small profile pictures and the text 'and 1,099 others like this.' is visible. At the bottom, there is a 'View previous comments' link and a '49 of 58' indicator.

This one example demonstrates how the page helped connect volunteers with those in need, and provide immediate assistance. The owners of the hatchery are certain that help would not have arrived in time if they had attempted to go through the official channels – indeed, they had tried, and these channels had proved to be ineffective. Ben Cameron, the owner of the hatchery, summed up his experiences in an interview for an ABC Australian Story on my role in the fires (ABC, 2013):

*Hour by hour our fish were dying... So we stood to lose all of our all of our livestock, around about \$2.5 million worth of stock, around 100 million individual animals. Our oysters could survive 36 to 48 hours out of water. That's not long enough for a bureaucratic institution to make decisions. So realistically it had to be a private, private venture and that's where Mel came in. It was fantastic. And her being able to deal with all the logistics and coordination from her place meant that I can actually get on with saving our livestock. We asked for something, it just arrived... The Government in this was absent. And that's - I don't necessarily think that is a reflection on their unwillingness to be involved. It was their due process, they have to do this, they've got liability issues, when realistically in an emergency situation like we had, we've just got to act. You can't worry about all that sort of stuff or else the economic losses is going to be tremendous.*

Throughout this crisis, there were hundreds if not thousands of volunteers connecting and contributing. Media coverage of the page was national and international. Some people used the page, while others probably didn't know it existed. But the ones that *did* use it found they could rely on it when they needed to.

My role as Administrator of the page involved channelling, moderating and filtering the information coming in to me via the page, my phone, my emails, or through other media such as local radio,



television and newspaper sources. People were able to contact me directly either through the page or on the telephone. I could post information on their behalf and they could also comment directly on existing posts. I networked and liaised with local media outlets, emergency authorities, charities, agencies, local sources in the affected areas, community groups and individual volunteers as much as possible to ensure to the best of my ability that the information I was sharing was accurate.

## CURRENT RESEARCH

A review of the literature has revealed that scientific, empirical research into the use of social media for driving communication, volunteering and psychological first aid in disasters is limited. Almost all the research to date has explored the use of Twitter in a disaster, rather than Facebook, despite the global uptake of Facebook being substantially higher, and despite Twitter not being used extensively during disasters as yet (De Longueville, Smith, & Luraschi, 2009; Pew Research Centre, 2013; Smith, Bill Halstead, Esposito, & Schlegelmilch, 2013; Starbird & Palen, 2011; Starbird, Palen, Hughes, & Vieweg, 2010; Sutton et al., 2008). There are some impressive crowdsourcing platforms available, such as Ushahidi ([www.ushahidi.com](http://www.ushahidi.com)) and Humanity Road ([www.humanityroad.org](http://www.humanityroad.org)), which has been the subject of a limited amount of research (Starbird & Palen, 2011). One useful case study has been conducted (Taylor, Wells, Howell, & Raphael, 2012), which explored the ability for a community Facebook page to deliver psychological first aid and enhance community resilience. However empirical research on community-driven, structured, emergent volunteering is lacking, as these groups are rare, and are difficult to access for research purposes. Research on co-ordinated emergent volunteers operating in an online environment is practically non-existent.

A social media supported, community-led response and recovery initiative such as TFWCH is yet to be documented comprehensively in the literature. It is important that research is conducted in this area, because the community can improvise and be flexible in disaster situations, and can and do lead vital rescue and relief efforts during emergencies (Kendra & Wachtendorf, 2001; Palen & Liu, 2007; Tierney, 2002). Thus the role of TFWCH in the immediate aftermath of the bushfires is now the subject of a University of Tasmania doctoral thesis, first and foremost to document the case study. The research questions focus heavily on the theoretical models put forward by Norris et al. (2008) and are as follows:

- 1) Does social media influence the ways volunteers can operate, improving their functionality, which in turn can have a positive impact on community resilience?
- 2) What evidence is there that through using social media, an emergent group can contribute to community resilience, specifically as operationalised by Norris et al.'s (2008) models of community resilience?
- 3) Does looking at Norris et al.'s model of community resilience (2008) through the prism of social media reveal a need to complement the social support elements with psychological first aid? Is there evidence for the suggestion that psychological first aid can be delivered in an emergency context by an emergent online group?
- 4) What are the characteristics of online emergent group leadership and management? How does social media influence the development and manifestation of community leadership and how does leadership, in the social media context, influence the resources in Norris et al.'s model (2008) of community resilience?



2,443 Facebook posts have been analysed thematically, to explore the roles and functions of the page. Three different qualitative and quantitative questionnaires administered one-month post-fires have been analysed ( $n = 678$ ). 1,302 comments within these questionnaires relating to the utility of the page and social media have been thematically analysed. A year's worth of Facebook metrics was also analysed to explore the demographic information about the users of the page, and the reach of the page to its audience. The case study is currently being prepared, and will be submitted as part of a Psychology PhD in 2015.





## REFERENCES

- ABC. (2013, July 15). Irons in the Fire [Television series episode transcript]. In D. Fleming [Executive producer], Australian Story, Australia, Australian Broadcasting Corporation. Retrieved August 8, 2014, from <http://www.abc.net.au/austory/content/2012/s3803164.htm>
- Alexander, D. E. (2013b). Social media in disaster risk reduction and crisis management. *Science and Engineering Ethics*, 20(3), 1-17. doi: 10.1007/s11948-013-9502-z
- Cobb, C., McCarthy, T., Perkins, A., Bharadwaj, A., Comis, J., Do, B., & Starbird, K. (2014, February). Designing for the deluge: Understanding & supporting the distributed, collaborative work of crisis volunteers. Paper presented at the 2014 ACM Conference on Computer Supported Cooperative Work & Social Computing, Baltimore, MD, USA.
- De Longueville, B., Smith, R. S., & Luraschi, G. (2009). "OMG, from here, I can see the flames!": A use case of mining Location Based Social Networks to acquire spatio-temporal data on forest fires. Proceedings of the 2009 International Workshop on Location Based Social Networks – Seattle, WA, USA. Retrieved October 28, 2014, from [http://www.cs.rochester.edu/twiki/pub/Main/HarpSeminar/OMG\\_from\\_here\\_I\\_can\\_see\\_the\\_flames-a\\_use\\_case\\_of\\_mining\\_Location\\_Based\\_Social\\_Networks\\_to\\_acquire\\_spatio-temporal\\_data\\_on\\_forest\\_fires.pdf](http://www.cs.rochester.edu/twiki/pub/Main/HarpSeminar/OMG_from_here_I_can_see_the_flames-a_use_case_of_mining_Location_Based_Social_Networks_to_acquire_spatio-temporal_data_on_forest_fires.pdf)
- Department of Premier and Cabinet (2013). 2013 Tasmanian bushfires inquiry report. [Department of Premier and Cabinet Report]. Retrieved June 20, 2014, from [http://www.dpac.tas.gov.au/\\_\\_data/assets/pdf\\_file/0015/208131/1.Tasmanian\\_Bushfires\\_Inquiry\\_Report.pdf](http://www.dpac.tas.gov.au/__data/assets/pdf_file/0015/208131/1.Tasmanian_Bushfires_Inquiry_Report.pdf)
- Kendra, J.M., & Wachtendorf, T. (2001). Rebel food... Renegade Supplies: Convergence after the World Trade Center Attack. Disaster Research Center Preliminary Paper #316, University of Delaware, Newark DE. Retrieved July 6, 2014, from [http://udspace.udel.edu/bitstream/handle/19716/708/PP\\_316.pdf?sequence=5](http://udspace.udel.edu/bitstream/handle/19716/708/PP_316.pdf?sequence=5)
- Liu, S. B., Palen, L., Sutton, J., Hughes, A. L., & Vieweg, S. (2008). In search of the bigger picture: The emergent role of on-line photo sharing in times of disaster. Paper presented at the 2008 Information Systems for Crisis Response and Management Conference (ISCRAM) – Washington, DC, USA.
- Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology*, 41(1-2), 127-150. doi: 10.1007/s10464-007-9156-6
- Palen, L., & Liu, S. B. (2007). Citizen communications in crisis: Anticipating a future of ICT-supported public participation. Proceedings of the 2007 SIGCHI Conference on Human Factors in Computing Systems. Retrieved October 31, 2014, from [https://www.cs.colorado.edu/~palen/palen\\_papers/palen-crisis.pdf](https://www.cs.colorado.edu/~palen/palen_papers/palen-crisis.pdf)
- Paton, D., Johnston, D., Mamula-Seadon, L., & Kenney, C. M. (2014). Recovery and Development: Perspectives from New Zealand and Australia. In Kapucu, N. & Liou, K. T. (Eds). *Disaster & development: Examining global issues and cases*. New York, NY: Springer (pp. 255-272).



- Pew Research Centre. (2013). Social Media Update 2013. Pew Research Centre. <http://www.pewinternet.org/2013/12/30/social-media-update-2013/>, accessed June 30th 2014.
- Smith, A., Halstead, B., Esposito, L., & Schlegelmilch, J. (2013). Social media and virtual platforms: The new situational awareness for emergency management professionals. [Electronic white paper]. Yale New Haven Health System Center for Emergency Preparedness and Disaster Response. Retrieved June 20, 2014, from <http://yalenewhavenhealth.org/emergency/PDFs/SocialMediaandVirtualPlatforms.pdf>
- Starbird, K., & Palen, L. (2011). Voluntweeters: Self-organizing by digital volunteers in times of crisis. Proceedings of the Conference on Human Factors in Computing Systems. Retrieved November 1, 2014, from <https://www.cs.colorado.edu/~palen/voluntweetersStarbirdPalen.pdf>
- Starbird, K., Palen, L., Hughes, A. L., & Vieweg, S. (2010). Chatter on the red: What hazards threat reveals about the social life of microblogged information. Proceedings of the Conference on Computer Supported Cooperative Work. Retrieved November 1, 2014, from [https://www.cs.colorado.edu/~palen/chatter\\_on\\_the\\_red.pdf](https://www.cs.colorado.edu/~palen/chatter_on_the_red.pdf)
- Sutton, J., Palen, L., & Shklovski, I. (2008). Backchannels on the front lines: Emergent uses of social media in the 2007 southern California wildfires. Proceedings of the 2008 Information Systems for Crisis Response and Management Conference (ISCRAM) Conference. Retrieved November 1, 2014, from <https://www.cs.colorado.edu/~palen/Papers/isqram08/BackchannelsISCRAM08.pdf>
- Taylor, M., Wells, G., Howell, G., & Raphael, B. (2012). The role of social media as psychological first aid as a support to community resilience building. *The Australian Journal of Emergency Management*, 27(1), 20-26.
- Tierney, K. (2002). Strength of a city: A disaster research perspective on the World Trade Center attack. [Electronic essay]. Social Science Research Council. Retrieved July 5, 2014, from <http://essays.ssrc.org/sept11/essays/tierney.htm>
- Yates, D., & Paquette, S. (2011). Emergency knowledge management and social media technologies: A case study of the 2010 Haitian earthquake. *International Journal of Information Management*, 31(1), 6-13. doi: 10.1016/j.ijinfomgt.2010.10.001
- Yin, J., Lampert, A., Cameron, M., Robinson, B., & Power, R. (2012). Using social media to enhance emergency situation awareness. *IEEE Intelligent Systems*, 27(6), 52-59. Retrieved November 1, 2014, from <http://www.ict.csiro.au/staff/jie.yin/files/YIN-IS2012.pdf>



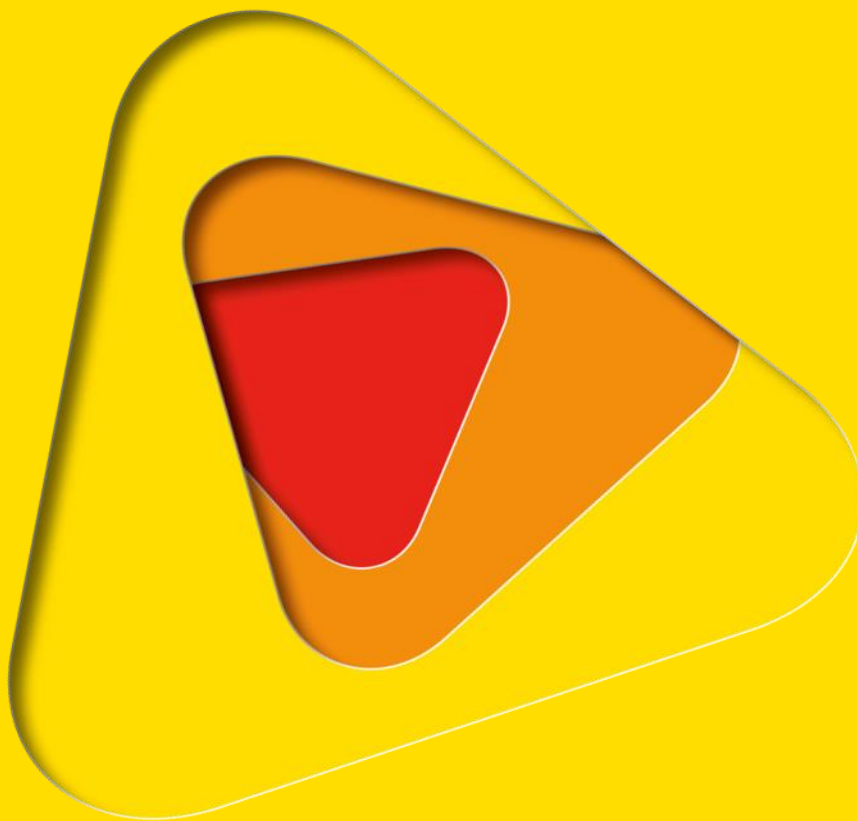
# NSW RFS BUSH FIRE HOUSEHOLD ASSESSMENT TOOL

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**M. O'Halloran**

NSW Rural Fire Service

Corresponding author: [melissa.ohalloran@rfs.nsw.gov.au](mailto:melissa.ohalloran@rfs.nsw.gov.au)





## **ABSTRACT**

The web based NSW Rural Fire Service Bush Fire Household Assessment Tool provides advice to the community to assist with making an informed decision on whether it is safe to stay and defend their property. The new website is based on an extensive body of scientific knowledge and has been developed via a successful partnership between NSW Rural Fire Service and the Centre for Environmental Risk Management of Bushfires at University of Wollongong.

A Bayesian Network has been implemented as the modelling framework to underpin the tool. The first step of the model calculates the Radiant Heat Flux to determine if the location and the structure are adequate to protect people to safely shelter in place. A Bayesian Network is used to assess responses for critical elements of preparedness developed from published expert knowledge. The model also assists NSW Rural Fire Service staff in assessing development applications and adequacy of existing controls for community protection plans.

The complexity of the model is not visible to people using the website. A member of the public will access the website and enter their property address triggering a series of spatial queries to determine the direction of greatest bush fire risk and the characteristics of the risk posed. A series of questions relating to the construction of their house, their personal capacity to defend, the available equipment and the conditions of the grounds of the property are then used to determine their capacity to defend their property. The automated calculations and interactive graphics provide visual assistance with answering critical but often poorly understood questions.

## **INTRODUCTION**

A resident's decision to leave early or stay and defend a well prepared home is complex and may be difficult for an individual to decide without expert advice. The web based NSW Rural Fire Service (NSW RFS) Bush Fire Household Assessment Tool provides specific advice to the community about whether their personal circumstances are adequate for them to safely stay and defend their well-prepared home in the event of a bush fire.

The website provides support to the resident to undertake a self-assessment and determine whether they can satisfy the many criteria required to be able to safely defend their home. The website provides guidance throughout the assessment, and the questions demonstrate the variety of physical as well as personal aspects that need to be considered to defend a home from a bush fire.

The first iteration of a self-assessment website was developed in response to the recommendations from the Victorian Bushfire Royal Commission in 2009. NSW RFS built an initial assessment tool however it was quite simplistic and only considered some of the elements important in preparedness. The informal feedback received suggested it was difficult for the community to interpret and understand. The website statistics indicated that many people that commenced the assessment did not continue to the final page of the assessment. The focus of this project has been to incorporate a wider range of considerations based on contemporary research and expert opinion.

In many cases people do not leave early but wait until a severe threat is realised (McLennan 2012) and those that stay are not adequately prepared. One of the aims of this tool is to demonstrate to the public the many aspects required to preparing your home. The model requires all of the key



areas to meet the criteria to be safe to stay and defend a home, achieving most of the criteria is not an acceptable outcome. House survivability can be increased when residents are present to defend a home (Blanchi 2008) but this should only be considered when the resident is adequately prepared and understands the risk.

## METHOD

The assessment in the Bush Fire Household Assessment Tool has three initial models to determine if a resident is adequately prepared to defend their home. The calculations for the bush fire exposure of the property, the vulnerability of the house construction and the preparedness of the household are then combined for the final outcome. The initial premise of staying to defend a home is that the property needs to be of suitable construction for the bush fire exposure to provide protection for the resident to shelter in place as the fire front passes. The model intentionally prioritises the safety of the resident over the survival of the home.



FIGURE 1 - CONCEPTUAL MODEL FOR DETERMINING WHETHER IT IS SAFE TO STAY AND ATTEMPT TO DEFEND FROM PENMAN ET AL. 2013

The bush fire exposure is determined by calculating the radiant heat flux the property could be exposed to in the event of a bush fire. The calculations for have been redeveloped for this model from AS3959:2009 Construction of Buildings in Bushfire Prone Areas. These calculations are also used by NSW RFS to assess the Bush Fire Attack Level (BAL) for development applications in bush fire prone areas and the Bush Fire Threat areas for the Survival Map of a Community Protection Plan. Any tools developed in the future to support these business processes will use the same model for calculating radiant heat.

The radiant heat flux model is based on a 1 in 50 year fire scenario as defined in Planning for Bushfire Protection 2006. This identifies the relevant fire danger index (FDI) value to input to the model that represents the weather scenario that would be expected in a fire of this scale. The values for the Sydney Region are an FDI of 100, whereas other areas of the State such as the North Coast of NSW have a lower FDI value of 80. On days with a catastrophic fire danger rating (an FDI of over 100) leaving early is the only recommended action for all residents regardless of house construction or



preparation. The site condition inputs to the radiant heat flux model include the distance between the structure and the vegetation, the type of vegetation and the slope under the vegetation. The type of vegetation is used to depict the fuels that may be present in close proximity to the property and provides a description of the fire behaviour that may be experienced.

The Radiant Heat Flux model uses the site specific inputs to determine the bush fire exposure in four categories relating to type of bush fire conditions the house could potentially incur. These are:

- Flame contact
- Radiant heat exposure
- Ember impact
- No fire

To determine if the property is appropriate for the resident to shelter in place as the fire front passes the model requires the bush fire protection construction standard of the house to determine if it is adequate for the bush fire exposure. In NSW, the construction standard AS3959: Construction of Buildings in Bushfire Prone Areas has applied to all new houses been built since 2003 in bush fire prone areas. All houses built prior to 2003 and outside of bush fire prone land are assessed in the model as being built to a low construction standard for bush fire protection and may only provide adequate shelter if the property is exposed to ember impact.

If the property exposure is assessed as being within the flame zone (as described in AS3959-2009) the resident is unable to continue with the online assessment due to unacceptable risk and is only able to access the leave early reporting materials. This trigger is in place to ensure the resident is aware that there are no circumstances where it would be recommended for a resident choose to stay and defend a home.

For areas potentially exposed only to ember impact, the risk of exposure reduces with increased distance from vegetation. A low risk calculation has been applied to the model where the property is at a distance greater than 350m from bush fire prone vegetation. Beyond this distance, the risk to a resident is considered to be sufficiently low that they would be unlikely to experience the impacts of fire. This distance accounts for 99% of all reported historical house losses (Ahern and Chladil 1999, Chen and MacAneney 2010). If a resident in a low fire risk area enters an assessment a message will appear highlighting that the risk is sufficiently low that there are no circumstances where the resident is recommended to leave their property early due to the risk of fire impact. The resident can still continue the assessment to consider elements of preparedness where fire protection can be improved. The model does not consider other reasons why a resident may leave an area impacted by a bush fire early such as concern for health impacts from smoke or risk to travel routes for isolated communities.

Where the model has determined that the property and the bush fire exposure is adequate for the resident to safely stay and defend, the preparedness level is tested. The elements of preparedness were determined by an expert panel selected for their knowledge in specific areas of bush fire preparedness. The elements identified by the panel were based on published and grey literature. The results of the expert workshop that underpins the preparedness model of the Bush Fire Household Assessment Tool have been published in the International Journal of Disaster Risk Reduction (Penman *et al.* 2013).



The model divides the capacity to defend into three categories of preparedness these are personal capacity, equipment required for firefighting and the conditions around the grounds. Each preparedness element within the model were analysed to determine if it was required for all of the bush fire exposure categories. For example personal protective clothing is required for all residents attempting to defend a home from bush fire regardless of the exposure, however having access to multiple water points around a property is only required by the model where the exposure is flame contact or radiant heat. When the bush fire exposure is from embers only the movement around the property to access water points should not be restricted.

Within the model the personal capacity component includes mental and physical capability of the resident, criteria addressing dependents that may influence capacity to defend and elements relating to the planning elements of preparedness.

Equipment required for defending a home includes items of personal protective clothing for each person that would be defending the property, tools to put out fires and a range of items associated with the access and distribution of water. While these items are of primary importance if the resident is likely to stay and defend a property, they may also assist fire fighters or neighbours to defend the home in the absence of the resident.

The landscape conditions immediately around the house are a significant predictor of house loss (Gibbons 2012). The vegetation and other items that may act as fuels are an essential component in considering how fire may transfer from the main fire to vulnerable elements of the house. Heavy fuels adjacent to the house may increase the fire intensity beyond the construction standard the property has been designed for. The potential sources of fuels considered in this model are classified into property maintenance such as clearing gutters of leaves and twigs, landscape elements such as combustible fencing in close proximity to the house and the presence of heavy fuels such as woodpiles or outdoor furniture.

The assessment questions provide defined distances for items relating to the condition of the grounds that pose potential fire risk exposure. These figures have been defined in this research and are not provided in existing NSW RFS community engagement material such as the Bush Fire Survival Plan. The preparedness model treats all elements with equal weighting as there is insufficient evidence to provide accurate probabilities.

## **DISCUSSION**

The Bush Fire Household Assessment Tool website packages the model components into a user friendly site with automated spatial calculations and graphical depiction of all elements of the model. This provides guidance to the resident throughout the assessment process.

The spatial calculation determines the direction and extent of the greatest fire risk by calculating the distance to vegetation, the vegetation type and the slope. These features are often difficult for a resident to quantify therefore the initial spatial calculation provides a valuable starting point. The automated calculation will translate the input values to determine the fuel and topographic features in all directions and distances. The greatest risk may not be posed by the closest vegetation or the direction the resident is most commonly concerned about. The values can be updated by the resident if they are able to provide more accurate property level data. Many of the underlying





datasets have variable spatial accuracy or are not sufficiently detailed to account for small scale variation in data, so it is essential that the calculated figure be reviewed.

Throughout the site, meters reminiscent of the highly recognisable fire danger meter are used to indicate the status of each section of the assessment. The meters identify which elements have a significant effect on the assessment outcome, each step needs to meet the criteria for the final assessment to recommend that a resident can safely stay and defend their home.

All preparedness questions are presented independent of the initial bush fire exposure calculation except where the bush fire exposure has been calculated as flame zone. The results of the assessment questions may not affect the assessment outcome in lower fire exposure areas, however all the elements are triggers for positive actions of preparedness and may provide opportunities for improved preparedness. The assessment process can be used to provide guidance on achievable actions to reduce bush fire exposure and increase the survivability of a home regardless of the intention to stay and attempt to defend a property or leave early.

The household assessment identifies the existing elements of preparedness and can be used to identify areas of weakness in preparedness. Throughout the assessment all questions with achievable preparedness actions ask a follow up question if the resident indicates that the conditions are not currently met. Items such as mental preparedness or access to reliable mains water are elements that are unlikely to be modified prior to the fire season. From the follow up questions, the resident is able to develop an action plan to assist with improving their preparedness regardless of their decision to leave early or stay and defend their property. The list is presented as a 'to do' list for all actions the resident indicated they are willing and able to undertake prior to the fire season such as ensuring there are fresh batteries for the portable radio or activities that need to occur on all high fire danger days such as move combustible outdoor furniture away from the house.

The resident can return to the site via an email link to complete or update existing assessments. The email link or the printed reports can be shared with family members, neighbours or friends as the starting point for developing Bush Fire Survival Plans. The final assessment links to relevant NSW RFS literature on the public website and provides a summary report of responses.

The Bayesian model allows for individual components of the model to be updated and modified as new research and data becomes available. Future enhancements may incorporate data from the post fire Building Impact Assessment programme to provide weightings for the elements of grounds conditions that are most often present when homes are destroyed. The flexible model design will be incorporated into a range of NSW RFS planning functions, the present website interface has been specifically designed to support current NSW RFS community messaging. Residents will be encouraged to revisit the website on an annual basis to ensure the assessment outcomes are still relevant. The model could be modified to provide advice using forecast weather conditions for a specific location, this advice could provide detailed information on the potential fire conditions for that day.

The model will be used by NSW RFS staff and volunteers while undertaking community engagement activities with individuals or groups within the community. The graphics throughout the website can be used to visually demonstrate a bush fire risk scenario. The Bush Fire Danger Assessment can be used iteratively with the Household Construction page to show the relative effect of slope, vegetation type, set back distance and construction standards on the bush fire risk. The online site



assessment process will generate discussion and allow NSW RFS members to provide site specific advice.

## **CONCLUSION**

The self assessment tool provides many prompts for preparedness that highlight to the community the many aspects to being adequately prepared. This tool is best used to start a conversation with family, neighbours, community and NSW RFS members on how best to prepare and what triggers to use for decision making.

The assessment tool reflects evidence from past fires that it often only takes one point of failure for a house to be lost in a bush fire. The relatively small proportion of properties constructed to comply with the Australian Standard 3959-2009 compared with number of properties in bush fire prone area will be the trigger for many well prepared residents to be advised that the only option is to leave early in the event of a bush fire. The outcome of the self assessment is based on a theoretical one in fifty year event, therefore it is potentially a conservative answer and may recommend some people leave early when the actual conditions on the day of a fire in their area may be adequate for them to safely stay and defend.

The Bush Fire Household Assessment tool is presented as part of a range of tools available to the community on the NSW RFS public website. The results of the household assessment will assist the community when completing their Bush Fire Survival Plan and hopefully support better decision making on what actions to take in the event of a fire.

## **ACKNOWLEDGEMENTS**

The Bush Fire Household Assessment tool was conceived and the project initiated by Assistant Commissioner Stuart Midgley and was awarded funding through a NSW National Disaster Resilience Program grant. The model was developed for the NSW RFS via a research contract with Centre for Environmental Risk Management of Bushfires, University of Wollongong under the supervision of Dr Trent Penman. The website component of this project was developed by Owen Woodbury and Steven Mascaro of Bayesian Intelligence. Trent Penman and Bronwyn Horsley provided material for this paper and the presentation.



## REFERENCES

Ahern, A., and Chladil, M., 1999. How far do bushfires penetrate urban areas? In *Proceedings of the 1999 Australian Disaster Conference*, pp. 21-26, Emergency Management of Australia, Canberra.

R. Bianchi, J. Leonard. Property safety: Judging structural safety. in: J Handmer; K Haynes, (Eds.), *Community bushfire safety*. Bushfire Co-operative Research Centre, Melbourne, 2008, pp. 77-85.

Chen, K and McAneney, J 2010 Bushfire Penetration into Urban Areas in Australia: A Spatial Analysis. Bushfire CRC

Gibbons P, van Bommel L, Gill AM, Cary GJ, Driscoll DA, et al. (2012) Land Management Practices Associated with House Loss in Wildfires. *PLoS ONE* 7(1): e29212.

McLennan, J, Elliott, G, Omodei, J. Householder decision-making under imminent wildfire threat: Stay and defend or leave? *International Journal of Wildland Fire*, 21(2012):915-925.

NSW Rural Fire Service 2006 Planning for Bush Fire Protection

Penman, TD, Eriksen, C, Bianchi, RM, Chladil, M, Gill, AM, Haynes, K, Leonard, J, McLennan, J, Bradstock, RA (2013) What does it mean to prepare property for wildfire protection? *International Journal of Disaster Risk Reduction*

Standards Australia. A.S.3959-2009: Construction of buildings in bushfire prone areas. SAI Global Limited, Sydney, Australia, 2009, pp. 129.



# LEARNING FROM ADVERSITY: WHAT HAS 75 YEARS OF BUSHFIRE INQUIRIES (1939-2013) TAUGHT US?

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

Michael Eburn<sup>1,2</sup>, David Hudson<sup>1</sup>, Ignatious Cha<sup>1</sup> and Stephen Dovers<sup>1,2</sup>

<sup>1</sup>Australian National University

<sup>2</sup>Bushfire and Natural Hazards CRC

Corresponding author: [michael.eburn@anu.edu.au](mailto:michael.eburn@anu.edu.au)





## ABSTRACT

This paper reports on preliminary research conducted at the ANU on the effectiveness of formal, public post event inquiries. With a focus on inquiries into bushfires the paper presents a broad overview of the inquiries over time as well as a detailed review of the multiple inquiries into the 2003 Canberra fires to ask what has been learned from these processes.

## INTRODUCTION

Following major natural hazard events, such as the 2009 Victorian ‘Black Saturday’ bushfires and the 2011 Queensland and Victorian floods, Australia usually engages in formal, complex, post-event inquiries to identify how the tragedy occurred and what can be done to prevent future occurrences. Since 1939 there have been over thirty inquiries into wildfires and wildfire management and at least another fourteen into floods, storms, other natural hazards and emergency management arrangements.

Notwithstanding this plethora of inquiries, fires and floods continue to occur, property is damaged and lives are lost. In his report into the 1989 Hillsborough tragedy in the UK, Lord Taylor said:

That it was allowed to happen, despite all the accumulated wisdom of so many previous reports and guidelines must indicate that the lessons of past disasters and the recommendations following them had not been taken sufficiently to heart... there is no point in holding inquiries or publishing guidance unless the recommendations are followed diligently. That must be the first lesson.<sup>1</sup>

Holding a Royal Commission or similar inquiry may give the impression that lessons are being learned and that, by following the recommendations of the last inquiry, the ‘problem’ of fires or disasters will be solved. The fact that catastrophic events continue to recur is evidence either that the community is failing to learn the lessons from the past, or the inquiries fail to identify the true learning – that catastrophic events may be inevitable, or that Royal Commissions are not the most effective way to identify relevant lessons from past events.<sup>2</sup>

This paper is a preliminary review of the recommendations from 51 inquiries into bushfire management and response Service to ask ‘what have we learned?’ The inquiries range from the 1939 Stretton Royal Commission into Victoria’s fires, to 2013 and inquiries into Tasmania’s wildfires, the Auditor General’s performance audit on bushfire readiness in the ACT and the Malone inquiry into the Queensland Rural Fire. The aim of the review was to identify recurrent themes or recurrent ‘lessons identified’ (if not learned).<sup>3</sup> These findings will inform further work being funded by the Bushfire and Natural Hazards CRC that is seeking to identify if there are better ways to identify learning from the impact of natural hazard events.

---

<sup>1</sup> *The Hillsborough Stadium Disaster 15 April 1989; Inquiry by the Rt. Hon. Lord Justice Taylor, Final Report* (London, 1990), [22] and [23].

<sup>2</sup> Neil Dufty, ‘Evaluating emergency management after an event: gaps and suggestions’ (2013) 28(4) *Australian Journal of Emergency Management* 15.

<sup>3</sup> Attorney General’s Department, *Australian Emergency Management Handbook Series, Handbook 8: Lessons Management* (Commonwealth of Australia), p 3.



## METHODOLOGY

The researchers identified some 257 inquiries into the preparation for and response to natural hazard events. From those we identified 51 that were solely related to bushfires and bushfire management and where the recommendations were readily available. The reports the subject of this review include operational reviews (such as the McLeod Inquiry into the Operational Response to the 2013 Canberra fires), Parliamentary inquiries (such as the Parliamentary inquiry into the 2001/2002 Sydney fires), coroner's inquiries, Auditor General's reports on fire management and the operation of fire services, and commissioned inquiries (such as the Malone review of the Queensland Rural Fire Service). A list of the reports the subject of this review can be found in appendix 1, below.

These inquiries produced 1727 recommendations. Having listed the recommendations, two of the researchers, Eburn and Hudson independently coded the recommendations into one of 5 broad themes;

- A – Shared responsibility;
- B – Preparedness;
- C – Response;
- D – Recovery;
- E – Fire agency organisation; and
- F – Research and technology.

Where there was disagreement as to the coding the researchers discussed their differing interpretations and determined the appropriate code by consensus.

At the same time, Cha conducted a review of three inquiries into the 2003 Canberra fires.<sup>4</sup> This event was unique in that it occurred in one small jurisdiction and was the subject of three independent post event reviews. They were:

1. The McLeod *Inquiry into the Operational Response to the January 2003 Bushfires in the ACT* (2003);
2. The inquiry and inquest by Coroner Doogan, (*The Canberra Firestorm: Inquests and Inquiry into Four Deaths and Four Fires between 8 and 18 January 2003* (2006)); and
3. Post-event litigation against the State of New South Wales that was heard in the ACT Supreme Court (*Electro Optic Systems Pty Ltd v New South Wales; West v New South Wales* (2012) 273 FLR 304).

Although not strictly speaking a post event inquiry, the Supreme Court litigation did determine issues of fact that is the Court made findings of what occurred and whether or not the actions of the agencies was, legally, 'reasonable'. In this review the question was asked, if these events present consistent findings as to what occurred and what should have occurred, is there a need to have fact-finding processes that extend for 10 years after the event? If the findings are not consistent 'how can the community and fire agencies learn lessons from multiple processes?'<sup>5</sup>

---

<sup>4</sup> Ignatious Cha, *Learning Lessons from Fires: A study of post-disaster inquiries in the 2003 Canberra fires* (Paper submitted in fulfilment of the requirements for the unit ENV3010 Independent Research Project, The Australian National University, 2014). This research was conducted under the supervision of Eburn and Dovers.

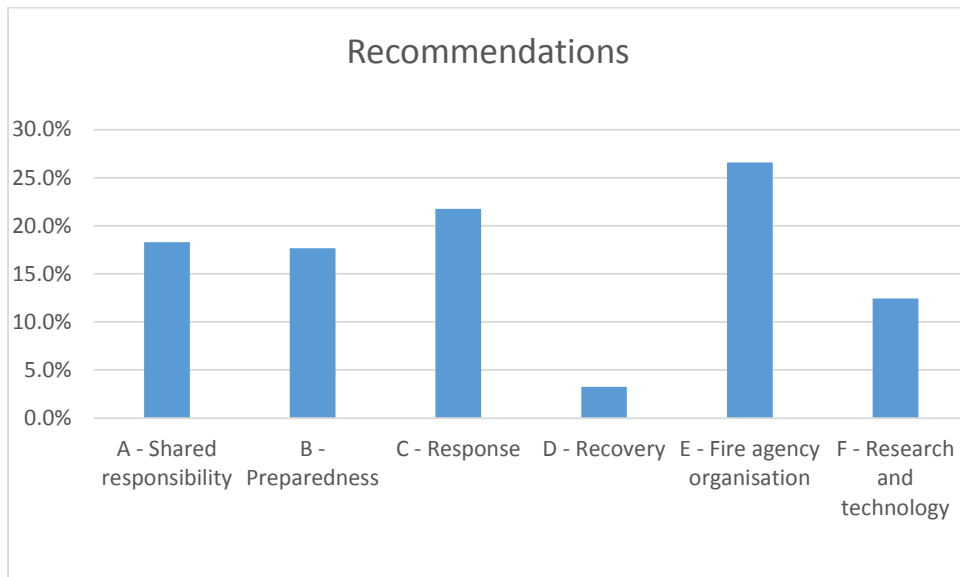
<sup>5</sup> Ibid, 2.



This approach took both a broad view, looking at inquiries over 75 years and across the jurisdictions as well as a narrow focus, three inquiries into one event, to ask ‘What has 75 years of bushfire inquiries (1939-2013) taught us?’

## RESULTS

The distribution of recommendations, across the 6 categories, is shown in Table 1, below.



Recurring themes, across each category, can be identified as the examples in Appendix 2, below, show.

## DISCUSSION

Ideally the product of 51 inquiries and over 1700 recommendations would be that the Australian community would understand and be prepared for catastrophic fire events and losses on the scale of the 2009 Victorian fires will never occur again. History suggests that this is unlikely; so what has been the value of these inquiries?

Answering that question is not easy and not possible here; it may be that recommendations have been made and implemented and that has indeed mitigated the impact of the next fire event but it does not follow that similar issues have recurred and further recommendations are required. Just because an issue recurs does not mean it has not been acted upon. For example, In 1939 Stretton recommended the establishment of a state fire authority that became the Country Fire Authority. The presence of the CFA no doubt has significant impact on Victoria’s resilience to fires today but was never expected to stop all fires. It was beyond the scope of this research to explore if and how recommendations have been implemented but we believe it is still of interest to identify if there are ‘persistent lessons identified’.<sup>6</sup>

Even so, our simple survey shows over time and across jurisdictions, there are recurring themes and issues. That may, or may not, mean that ‘the recommendations are followed diligently’.<sup>7</sup> Perhaps they have not been followed diligently as, over time lessons are learned and then forgotten, or lessons

<sup>6</sup> Kevin Pollock, *Review of Persistent Lessons Identified Relating to Interoperability from Emergencies and Major Incidents since 1986* (Emergency Planning College, York (UK), 2013).

<sup>7</sup> *The Hillsborough Stadium Disaster 15 April 1989; Inquiry by the Rt. Hon. Lord Justice Taylor, Final Report* (London, 1990), [22] and [23].





identified in one jurisdiction are not learned until a similar event occurs in another (but that may have changed given the rush by all Australian jurisdictions to implement the recommendations from the 2009 Victorian Bushfires Royal Commission). It may be that recommendations are being made that just cannot be implemented. Noting that radio communications is a problem during a fire and that work should be done to improve or investigate ways to ensure effective radio coverage does not create the technology, nor the budget to make this happen. Many of the issues identified are ‘wicked problems’:

A wicked problem is one for which each attempt to create a solution changes the understanding of the problem. Wicked problems cannot be solved in a traditional linear fashion, because the problem definition evolves as new possible solutions are considered and/or implemented.<sup>8</sup>

So even if ‘followed diligently’<sup>9</sup> the recommendations may not, and cannot, solve the problem.

It may be that the recommendations are indeed not ‘followed diligently’.<sup>10</sup> The recommendations may be impracticable or rejected by the industry or government due to conflicting priorities, budget constraints or a belief that they are just not appropriate. There is no guarantee that a Royal Commission, whether constituted by a single Commissioner or a team will actually come up with useful and meaningful recommendations.

Another issue may be competing recommendations. Diligently applying the recommendation from one Commission may require action contrary to another, and recommendations change over time. For example, following the 1983 Ash Wednesday fires Victoria amended the State Disasters Act ‘To provide for the appointment of a Minister as Co-ordinator-in-Chief’.<sup>11</sup> The Review Committee took the view that

The concept of a State Disasters Act which makes one Minister responsible for counter-disaster planning, preparedness, co-ordination of participating agencies and welfare relief measures is sound. In this regard, the Committee believes that the same mechanism should be superimposed on the existing structure of the State Disaster Plan by extending the legislation... The result of this modification would be that ... [i]n the event of a declared disaster... the Minister would assume his responsibilities for the implementation and control of all measures to combat the disaster in his capacity as Co-ordinator-in-Chief.<sup>12</sup>

The Committee concluded that:

There is strong justification for a policy, formalised by legislation, under which a Minister is designated as Co-ordinator-in-Chief of disaster affairs and is responsible for direction and control across the whole spectrum of preparedness, combat and relief activities.<sup>13</sup>

---

<sup>8</sup> Above, n 3, p 3.

<sup>9</sup> Above, n 1.

<sup>10</sup> Ibid.

<sup>11</sup> Victoria, *Report of the Bushfire Review Committee on Bushfire Disaster Preparedness and Response in Victoria, Australia, Following the Ash Wednesday Fires 16 February 1983* (1984, Melbourne), p 142.

<sup>12</sup> Ibid, p 146.

<sup>13</sup> Ibid, p 154.



And they recommended that:

There be a close integration of the responsibilities of the Minister under the State Disasters Act and the State Disaster Plan ... [with] Ministerial responsibility for direction and control of counter—disaster preparedness, combat and relief activities.<sup>14</sup>

Come forward to ‘Black Saturday’ where the 2009 Victorian Bushfires Royal Commission said:

The Commission agrees that the designation ‘Coordinator’ and the description of the role as including coordination of agency activities can lead to confusion about the minister’s role. The Commission is clear that it was not intended for the legislation to imply that the minister had any operational responsibilities.<sup>15</sup>

The Royal Commissioners went on to recommend that:

The State consider amending the *Emergency Management Act 1986* and the Emergency Management Manual Victoria in order to achieve the following:

- remove the title of Coordinator in Chief of Emergency Management from the Minister for Police and Emergency Services
- clarify the function and powers of the Minister
- designate the Chief Commissioner of Police as Coordinator in Chief of Emergency Management, who would have primary responsibility for keeping the Minister informed during an emergency.<sup>16</sup>

Diligently implementing the recommendations from 1984 lead to role confusion and lack of clear command in 2009. Inconsistent recommendations may arise over time and as part of the nature of ‘wicked problems’ where ‘which each attempt to create a solution changes the understanding of the problem’.<sup>17</sup> Further experience provides relevant learning so a recommendation is tested but, in light of experience, modified in the next inquiry. Inconsistency can be expected both over time and across jurisdictions. It may also be expected where different inquires, because of their different objectives. To test that hypothesis we can look at the 2003 Canberra fires where a single event, in a single jurisdiction was subject to (at least) three fact-finding inquiries; did they identify the same lessons?

The review of the three reviews post the 2003 Canberra fires revealed both consistency and inconsistency. All three inquiries were of the view that failure to aggressively combat the fires when they first ignited on 8 January represented a lost opportunity and contributed to the eventual firestorm that burned into urban Canberra.<sup>18</sup> In that sense the ‘lesson’ to be identified, that aggressive first attack should be implemented, was identified in 2003, the litigation simply confirmed that view some 10 years later. But there are differences; the McLeod and Doogan inquiries may well have identified that there was a failure to aggressively attack the fires and this allowed the fires to grow and burn into Canberra. What those inquiries could not do, and the Supreme Court litigation could do, was to determine whether or not that failure represented a breach of duty to others with a corresponding obligation to pay damages. All three inquiries could confirm that the action was not taken, only Higgins CJ could determine that, even so, the decision to withhold fire fighters was ‘reasonable’ in the circumstances.

---

<sup>14</sup> Ibid.

<sup>15</sup> Victoria, 2009 Victorian Bushfires Royal Commission, *Final Report* (2011), Vol II, Part A, p 84.

<sup>16</sup> Ibid, Recommendation 11.

<sup>17</sup> Above, n 3, p 3.

<sup>18</sup> Above n 4, p 9.



On the other hand, there were inconsistencies. When the IMT believed that the fire had burned beyond a suitable fire break a decision was made to use the Goodradigbee River as the next line of defence. Both McLeod and Doogan believed that the Goodradigbee River would have been an ineffective containment line in the prevailing conditions. McLeod noted that the severe drought conditions increased the probability for the areas burnt to rekindle and spark, and that ember attack would subsequently cause fires again.<sup>19</sup> Doogan accepted expert evidence that the Goodradigbee River was ridden with abundant fuel load, and was therefore dangerous for it to be used as the Western containment line.<sup>20</sup>

Higgins CJ, on the other hand, took the view that the River would have been an effective fire break. He went further and found that had preventative measures, that he believed were 'feasible', been implemented 'the fire would, in my view, have been unlikely to have crossed to the west of the Goodradigbee River on 17 and 18 January 2003'. His Honour's finding, that the use of the river as the western containment line was defensible [198] and that the fire could have been contained, seems contrary to the views of McLeod and Doogan but further, as a legally binding finding of fact it allowed the judge to conclude that the failure to take steps to prepare the river constituted a breach of a common law duty of care.

Diligently following<sup>21</sup> the findings (the court's rulings are binding, be retrospective findings rather than recommendations for the future, but an agency that wishes to avoid future liability would be expected to distil the lesson from the tribunal's findings for future reference) leads to the conclusion that the use of a river, overgrown and in drought conditions is likely to be futile and dangerous at the same time it is both reasonable, and with proper preparation would have been effective!

## CONCLUSIONS

This has been a brief and introductory review. The question we asked was 'what has 75 years of bushfire inquiries (1939-2013) taught us?' What they have taught us is that there are multiple recurring themes and that may show a problem in the lessons management process. It may be that the inquiries are identifying issues that cannot be solved, making recommendations that cannot be implemented or that their recommendations are sound but ignored or not diligently applied. Further, recommendations both over time and over inquiries, even those that are inquiries into the same event, may produce inconsistent findings and suggestions. It follows that applying Justice Taylor's first lesson, that 'There is no point in holding inquiries or publishing guidance unless the recommendations are followed diligently'<sup>22</sup> is neither easy nor any guarantee that a future disaster will be averted. In the context of natural hazards it is inevitable<sup>23</sup> that there will be future disasters.

It may be that these types of inquiries are useful but they do have their limitations.<sup>24</sup> And if diligently following their recommendations is unlikely to avert future disasters then one has to question their value, given the amount of money that has been spent on the 51 inquiries identified, and they relate to bushfire alone.

---

<sup>19</sup> Ron McLeod, *Inquiry into the Operational Response to the January 2003 Bushfires in the ACT* (2003, ACT Government), p 61.

<sup>20</sup> Maria Doogan, *The Canberra Firestorm: Inquests and Inquiry into Four Deaths and Four Fires between 8 and 18 January 2003* (2006, ACT Coroners Court), p 154.

<sup>21</sup> Above, n 1.

<sup>22</sup> Above, n 1.

<sup>23</sup> *National Strategy on Disaster Resilience-Companion Booklet* (2012, Commonwealth of Australia, Canberra), p 6.

<sup>24</sup> See Michael Eburn and Stephen Dovers, 'Learning lessons from disasters: alternatives to Royal Commissions and other quasi-judicial inquiries', *Australian Journal of Public Administration*, at press.



Worse than having recommendations that are lost, forgotten, rejected or unfunded are recommendations that are inconsistent. Multiple inquiries may reveal multiple aspects of the 'truth' but they, no doubt, cause problems for agencies that are charged with ensuring they are 'followed diligently'.<sup>25</sup> How is industry meant to apply the recommendations if one tribunal says a proposed action would have been ineffective and another takes a contrary view?

We do not have an answer to that question but research we will undertake on behalf of the Bushfire and Natural Hazards CRC seeks to find alternate ways to conduct post event inquiries, particularly after significant high impact events where the community is directly and personally interested in the outcomes, that may produce effective and consistent recommendations and avoid unnecessary duplication.

---

<sup>25</sup> Above, n 1.



## APPENDIX 1: INQUIRIES INCLUDED IN THIS REVIEW (BY YEAR)

1. Stretton, L. (1939). *Report of the Royal Commission to Inquire into the Causes of and Measures Taken to Prevent the Bush Fires of January, 1939, and to Protect Life and Property, and the Measures Taken to Prevent Bush Fires in Victoria and Protect Life and Property in the Event of Future Bush Fires* (Victoria).
2. Stretton, L. (1944). *Report of the Royal Commission to Inquire into the Place of Origin and the Causes of the Fires which Commenced at Yallourn on the 14th of February, 1944 : the Adequacy of the Measures which had been taken to Prevent Damage and the Measures to be taken to Protect the Undertaking and Township at Yallourn* (Victoria).
3. Rodger, G.J. (1961). *Royal Commission appointed to enquire into and report upon the bush fires of December, 1960 and January, February and March, 1961 in Western Australia. The measures necessary or desirable to prevent and control such fires and to protect life and property.* (Western Australia).
4. Barber, E. (1977). *Report of the Board of Inquiry into the Occurrence of Bush and Grass Fires in Victoria.* (Victoria).
5. Miller, S.I et al. (1984). *Report of the Bushfire Review Committee on bushfire preparedness in Victoria, Australia, following the Ash Wednesday fires 16 February 1983.* (Victoria).
6. Milton, P. (Chair), (1984). *House of Representatives Standing Committee on Environment and Conservation, Report: Bushfires and the Australian Environment* (Commonwealth).
7. Hiatt, J.W. (Coroner), (1996) *Inquiry into the cause and origin of the bushfires occurring in New South Wales between 31st December, 1993 and 14th January, 1994 and Inquests into the manner and cause of death of Norman John Anthes, Robert Eglinton Page, William John Roach and Pauline Mary O'Neil.* (New South Wales).
8. NSW Audit Office (1998) *Performance Audit Report: Rural Fire Service - The Coordination of Bushfire Fighting Activities.* (New South Wales).
9. Jones, R. (Chair), (2000). *NSW Legislative Council, General Purpose Standing Committee No 5: Report on Inquiry into the NSW Rural Fire Service.* (New South Wales).
10. Stevenson, J. (Coroner), (2001). *Inquest into the Deaths of Mark Douglas Cupit, Claire Wynne Dean, George Allan Fitzsimmons and Eric Furlan and Inquiry into fire at Mt Kuring-Gai National Park.* (New South Wales).
11. Johnstone, G. (Coroner), (2002). *Report of the Investigation and Inquests into a Wildfire and the Deaths of Five Firefighters at Linton on 2 December 1998.* (Victoria).
12. Price, J. (Chair) (2002). *Joint Select Committee on Bushfires: Report on the Inquiry into the 2001/2002 Bushfires.* (New South Wales).
13. Cameron, J.W. (Auditor General), (2003). *Fire prevention and preparedness.* (Victoria).
14. Esplin, B. (Chair), (2003). *Report of the Inquiry into the 2002-2003 Victorian Bushfires.* (Victoria).
15. McLeod, R. (2003). *Inquiry into the Operational Response to the January 2003 Bushfires in the ACT.* (Australian Capital Territory).
16. Nairn, G. (Chair), (2003). *A Nation Charred: Report on the inquiry into bushfires.* (House of Representatives Select Committee into the recent Australian bushfires, Commonwealth).
17. Pearson, D.D.R. (Auditor-General), (2004). *Performance Examination: Responding to Major Bushfires.* (Western Australia).
18. Brown, M. (Chair) (2004). *Legislative Assembly Public Accounts Committee: Review of Fire Services Funding.* (New South Wales).
19. Ellis, S. et al. (2004). *National Inquiry on Bushfire Mitigation and Management.* (Council of Australian Governments).

- 
20. Hope, A.N. (Coroner), (2005). *Inquest into the death of Judith Lesley Ward and Lorraine Melia ('Albany fires')*. (Western Australia).
  21. Emergency Services Commissioner (2005). *Examination of Prescribed Burning Practices*. (Victoria).
  22. Breuer, L (Presiding Member), (2005). *Parliament of South Australia, Environment, Resources and Development Committee: Eyre Peninsula Bushfire and Native Vegetation*. (South Australia).
  23. Doogan, M. (Coroner), (2006). *Inquests and Inquiry into Four Deaths and Four Fires between 8 and 18 January 2003*. (Australian Capital Territory).
  24. 2007, Monterola, V. (Chair), (2007). *Ministerial Review of Bushfire Management in South Australia*. (South Australia).
  25. Poole, G. (Auditor-General), (2008). *Management of Rural Fire Services in Queensland*. (Queensland).
  26. 2008, Coroner Schapel, A.E. (Coroner) (2008). *Inquest into the Deaths of Star Ellen Borlase, Jack Morley Borlase, Helen Kald Castle, Judith Maud Griffith, Jody Maria Kay, Graham Joseph Russell, Zoe Russell-Kay, Trent Alan Murnane And Neil George Richardson ('Wangary fires')*. (South Australia).
  27. Pandazopoulos, J. (Chair), (2008). *Parliament of Victoria, Environment and Natural Resources Committee: Inquiry into the Impact of Public Land Management Practices on Bushfires in Victoria*. (Victoria).
  28. Fire and Emergency Service Authority of Western Australia (2009). *Post Incident Analysis: Bridgetown Complex Fire 23 (Peninsula), Fire 24 (Hester), Fire 26 (Ferndale), Thursday January 15th 2009 to Tuesday January 20th 2009*. (Western Australia).
  29. Hope, A.N. (Coroner), (2009). *Inquest into the deaths of Trevor George Murley, Lewis Kenneth Bedford and Robert Wayne Taylor ('Boorabin fires')*. (Western Australia).
  30. Department of Premier and Cabinet (2009). *Review of Western Australia's bushfire preparedness*. (Western Australia).
  31. Teague, B et al. (2009). *2009 Victorian Bushfires Royal Commission: Interim Report 1*. (Victoria)
  32. Teague, B et al. (2009). *2009 Victorian Bushfires Royal Commission: Interim Report 2*. (Victoria)
  33. 2010, Ferguson, E. (2010). *A Review of the Ability of the Department of Environment and Conservation Western Australia to Manage Major Fires*. (Western Australia).
  34. Noetic Solutions Pty Limited (2010). *Major Incident Review of Toodyay Fire December 2009* (Western Australia).
  35. 2010, Heffernen, B. (Chair) (2010). *Senate Select Committee on Agricultural and Related Industries: The incidence and severity of bushfires across Australia*. (Commonwealth).
  36. Teague, B et al. (2010). *2009 Victorian Bushfires Royal Commission: Final Report*. (Victoria)
  37. Noetic Solutions Pty Limited (2011). *Post Incident Analysis for Blackwood Fire 11 – Milyeannup-Sollya, 23 November to 5 December 2011*. (Western Australia).
  38. 2011, Blake H.M (Auditor-General), (2011). *Special Report No. 99: Bushfire Management*. (Tasmania).
  39. Ellis, S. (2011). *Major Incident Review: Lake Clifton, Red Hill and Roleystone Fires June 2011*. (Western Australia).
  40. Emergency Services Commissioner (2011). *Review of the Tostaree Fire*. (Victoria).
  41. 2011, Fire Services Commissioner (2011). *Review of Community Bushfire Warnings*. (Victoria).
  42. Keelty M.J. (2011). *Shared Responsibility: The Report of the Perth Hills Bushfire February 2011 Review*. (Western Australia).
  43. Key, S. (Presiding Member), (2011). *Natural Resources Committee Bushfire Inquiry Final Report*. (South Australia).



44. Wendt, W. (Chair), (2011). *Public Accounts and Public Works Committee: Management of Rural Fire Services in Queensland*. (Queensland).
45. O’Gorman, A.P. (Chair), (2011). *Community Development and Justice Standing Committee: Western Australia’s Readiness for the 2011-12 Bushfire Season* (Western Australia).
46. Eldridge, L. (2012). *Review of the Operations of Bushfires NT*. (Northern Territory).
47. Noetic Solutions Pty Limited, (2012). *Post Incident Analysis for Blackwood Fire 8 – Ellensbrook-Gnarabup, 23/24 November 2011*. (Western Australia).
48. Keelty, M.J. (2012). *Appreciating the Risk: Report of the Special Inquiry into the November 2011 Margaret River Bushfire*. (Western Australia).
49. Cooper, M. (Auditor General) (2013). *Performance Audit Report: Bushfire Preparedness*. (Australian Capital Territory).
50. Hyde, M. (2013). *2013 Tasmanian Bushfires Inquiry*. (Tasmania).
51. Malone, T. (2013). *The Malone Review into Rural Fire Services in Queensland 2013*. (Queensland).





## APPENDIX 2: EXAMPLES OF RECURRING THEMES IN EACH CATEGORY

A - Shared responsibility – education.

Stretton 1939	Ellis 2004	Schapel 2008	Wendt 2011
<p>It is suggested that in every school ... fire prevention be made a real part of the curriculum and that the lessons in that behalf be given at the commencement of the summer season. For adult education much of the work now undertaken by the Forests Commissions should be supplemented. Slides and pictures in picture theatres should be shown at the beginning of summer and on the eve of holiday seasons, together with instructions as to the penalties for lighting fires illegally and the fact that fire places are provided at roadsides for picnic fires. It is suggested that at such seasons the newspapers, whose proprietors have always been willing to further this sort of education, should inform the public of the law relating to fires and of the consequences of their breach and of the methods to be adopted to prevent spread of fire ...</p>	<p>The Inquiry recommends that state and territory governments and the Australian Government jointly develop and implement national and regionally relevant education programs about bushfire, to be delivered to all Australian children as a basic life skill.</p>	<p>That the Chief Officer and the Editors of all newspapers and other media outlets develop a Memorandum of Understanding that ensures that all CFS press releases concerning total fire ban days and ongoing bushfire incidents are published in full.</p>	<p>that the Deputy Premier, Attorney-General, Minister for Local Government and Special Minister of State establish with local government a communication strategy to inform all residents about their fire prevention responsibilities.</p>



B – Preparedness – hazard reduction burns.

<b>Stretton 1939</b>	<b>Rodgers 1961</b>	<b>Doogan 2006</b>	<b>Teague 2010</b>
Burning – ... the Forests Commission must recognize the necessity of protective burning in its areas... this method of prevention of outbreak and spread cannot, either in the public or private interest, be ignored.	The Forests Department make every endeavour to improve and extend the practice of control burning to ensure that the forests receive the maximum protection practicable consistent with silvicultural requirements.	That a hazard-reduction program be introduced, involving regular and strategic burning in all areas of the ACT – including the catchment areas – with a view to have fuel-reduced areas in a pattern across the landscape, excluding only small areas of particular ecological or conservation importance.	The State fund and commit to implementing a long-term program of prescribed burning based on an annual rolling target of 5 per cent minimum of public land.

C – Response – improving communication including the use of ‘wireless transmitting sets’ (radio).

<b>Stretton 1939</b>	<b>Hiatt 1996</b>	<b>Nairn 2003</b>	<b>Keelty 2011</b>
Early Detection – Look-Out Towers – Towers so placed that no part of the forest is beyond range of vision of observers, should be placed throughout the forest. These towers should be in communication by telephone with a central body devoted to fire fighting, and as far as possible with each other. Wireless transmitting sets whereby instructions may be given to ground patrols carrying small receiving sets are used in such towers in many parts of the world.	The Court recommends to the Government of New South Wales that it ensures the Government Radio Network is implemented totally to provide an effective radio communications system for the Fire Services of New South Wales, including an efficient fire ground communications system which will enable all fire fighters participating in operations to communicate with each other and the Fire Control Centre.	The Committee recommends that ... an urgent review on a district basis, of the suitability of the current allocated radio spectrum to ensure that as far as possible, fire fighter safety is not being compromised through inadequate communications. Commit to the development, in conjunction with representative bodies of all emergency services, to a National Strategic Radio System.	FESA and local governments jointly review radio communications capability prior to the 2011/12 bushfire season with a view to improving the current delivery of service to firefighters.



D – Recovery – avoiding under-insurance.

Jones 2000	Esplin 2003	Nairn 2003
<p>The Committee views the actions of some property owners who fail to insure, or under-insure, their properties as unsatisfactory, and recommends to the Government that this matter be reviewed.</p>	<p>That CFA, in their education and information packages, encourage appropriate insurance cover, and ensure that insurance becomes a part of the householder’s annual checklist.</p>	<p>The Committee recommends that insurance companies ensure that potential and existing policyholders are aware of the need to regularly review their insurance policies to prevent undervaluing. This could be done through renewal notices and quarterly reminders. This should include a list of bushfire risk reduction measures that policyholders can implement to decrease the cost of their premium.</p>

E - Fire agency organisation – command structure

Stretton 1939	Hiatt 1996	WA Auditor General 2004	Malone 2013
<p>The institution of a State Fire Authority is recommended. ... It is recommended that the functions of this authority should be primarily those of defining a general policy of prevention and suppression of bush fires and protection of life and property; of organizing and recruiting local brigades; of maintaining discipline of local brigades and over local fire authorities; and of acting independently, with or without such advice as it may care to take.</p>	<p>There should be a Rural Fire Service with a command structure from the Board of Commissioners through a commander incorporating Fire Control Officers and voluntary bush fire brigades.</p>	<p>Government should: establish a State-wide command structure across volunteer Bush Fire Brigades for fighting major bushfires, to more effectively manage the coordination of personnel and resources</p>	<p>That the Rural Operations division currently sitting within the Queensland Fire and Rescue Service become an autonomous unit called Rural Fire Service Queensland and be led by a Deputy Chief Officer. Structure and Leadership of the Rural Fire Service</p>



F - Research and technology – spatial awareness

Esplin 2003	Pandazopoulos 2008	Teague 2010	FESA 2012
<p>That DSE: • Provide further training and/or field staff for the routine acquisition and reporting of geographic data (maps of fire extent for prescribed and unplanned fires) and fuel-array data (quantity, type, condition and arrangement before and after fire as in the Overall Fuel Hazard Guide).</p>	<p>That the Department of Sustainability and Environment implement remote sensing imagery as a routine part of its pre-burn and post-burn assessment process for prescribed burning. Maps of every prescribed burn should be produced in a similar format to those used in Western Australia, indicating the boundary of each burn and the varying fire intensities achieved within the burn area. The boundaries of all Fuel Management Zones within each burn should also be indicated. In the case of the CFA the information from the Investigation and Review Unit should be regularly made available to the Board. Each prescribed burn map should be made publicly available on the Department of Sustainability and Environment’s website, together with a map of the same burn area which shows the pre-burn fuel hazard levels and a statement of the total area treated within each Fuel Management Zone by each prescribed burn.</p>	<p>The State identify a central point of responsibility for and expertise in mapping bushfire risk to: ■ review urgently the mapping criteria at present used by the Country Fire Authority to map the Wildfire Management Overlay, to ensure that the mapping used to determine building and planning controls is based on the best available science and takes account of all relevant aspects of bushfire risk; ■ map and designate Bushfire-prone Areas for the purposes of planning and building controls, in consultation with municipal councils and fire agencies; ■ finalise the alignment of site-assessment methods for planning and building purposes, taking into account bushfire risk to human safety as well as to property.</p>	<p>6. Maps prepared for prescribed burns should address the fuel type and burn history of the burn area as well as surrounding areas. Predicted rates of spread under prescribed and other conditions should recognise the complexity of coastal heathlands. 7. Fuel loads on private property need to be identified and included in understanding fire behaviour in determine the contribution they make to the burn risk assessment. 36. Better maps are required for urban/rural interface fires</p>



# THE EFFECT OF HAZARD REDUCTION BURNING ON THE FUEL ARRAY IN NATURE RESERVES AND URBAN PARKS IN THE ACT

Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

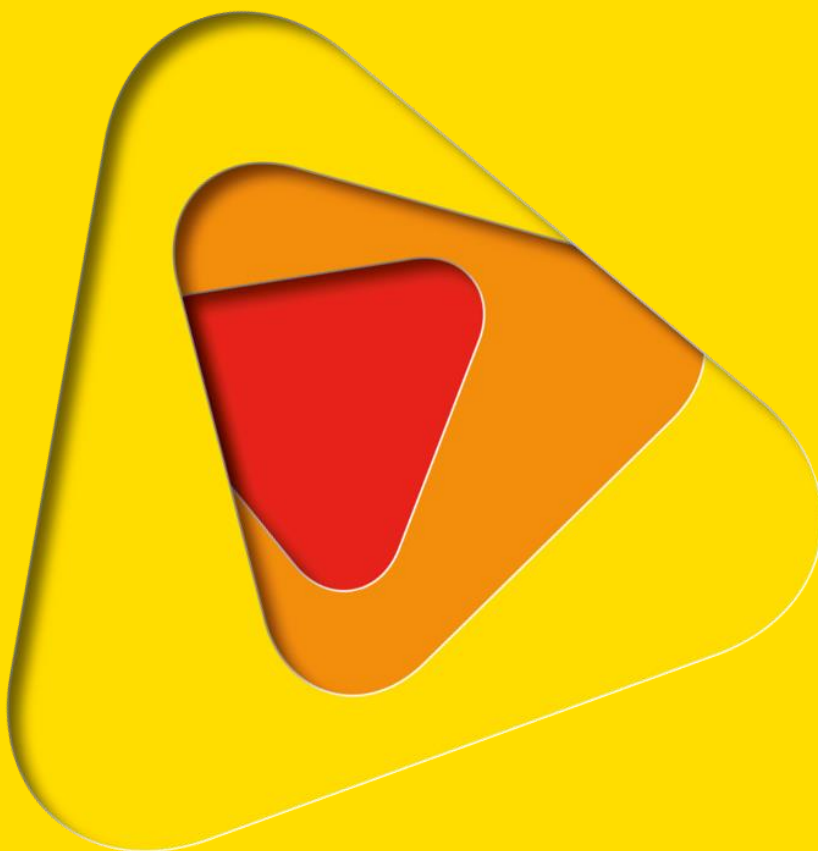
**Adam Leavesley<sup>1</sup>, Jennie Mallela<sup>2</sup>, Julian Seddon<sup>3</sup>, Tony Corrigan<sup>3</sup>,  
Neil Cooper<sup>1</sup> and Brian Levine<sup>1</sup>**

<sup>1</sup>Parks and Conservation Service, ACT Government

<sup>2</sup>Research School of Biology, Australian National University

<sup>3</sup>Conservation Research and Monitoring, ACT Government

Corresponding author: [adam.leavesley@act.gov.au](mailto:adam.leavesley@act.gov.au)





## ABSTRACT

Hazard reduction burning is a key component of the fuel management program in the Australian Capital Territory (ACT). Burning is used in a variety of situations depending on the applicable fuel standard, proximity to property, aims of land management and suitability of alternative methods. The main aim of this study was to characterise the changes in the fuel array due to the ACT hazard reduction burning program. We established 187 plots within 38 hazard reduction burns and adjacent unburnt areas. The fuel in all plots was characterised using the Overall Fuel Hazard Assessment (OFHA) method and then re-assessed following burning. Opportunistic assessments of four unplanned fires were also taken for comparison. The average OFHA prior to burning was High. This reflected the dense grassy fuels, relatively sparse shrub layer and abundance of smooth-barked gum trees in Canberra's nature reserves. Following burning the OFHA was reduced to an average of Moderate. The component of the assessment which exhibited the greatest change was the near-surface fuel which was usually consumed. Changes in bark fuel hazard and elevated fuel hazard were minimal. Surface litter had a minor effect on the OFHA because of the high grass cover in most systems and the incomplete combustion of litter. The sensitivity of the OFHA method to grass means that the OFHA may rapidly return to High – i.e. when the grass cover approaches 50 percent. In contrast, wildfires reduced the OFHA to Low, due to much greater consumption of the elevated, bark and surface litter fuels. We predict that the OFHA at sites burnt by wildfire will increase more slowly because of the slower pace of re-growth of woody vegetation.

## INTRODUCTION

Hazard reduction burning is a key component of bushfire management in the Australian Capital Territory (ACT). The aim of burning is to reduce the fuel load and change the fuel structure so that unplanned fires that may occur in the future are more easily suppressed or mitigated. The aims of each burn are determined according to the standards set out in the ACT Strategic Bushfire Management Plan Version 2 (SBMP; ACT Government, 2009). The fuel standards for forest and shrubland are based on the Overall Fuel Hazard Assessment method (OFHA; Hines *et. al.* 2010). Vegetation in Outer Asset Protection Zones must be maintained at a rating  $\leq$ Moderate and in Strategic Fire Advantage Zones  $\leq$ High. Following each burn the fire ground is visually assessed by the Divisional Commander and a descriptive report of the fuel condition is included in a summary of the incident. The fuel standard achieved by the burn is then audited by the ACT Rural Fire Service.

The aim of this study was to improve understanding of the effects of the ACT Parks and Conservation Service burning program by conducting a systematic assessment. The study had three aims. 1) To investigate whether the fuel characteristics of different vegetation types varied systematically. This information could be used to refine the planning process and improve future outcomes. 2) To demonstrate the effect of the burning program in order to validate the present procedure or to determine what improvements are needed. 3) To characterise the response patterns of the components of the fuel array to understand how each contributed to the outcome.

## METHOD

### STUDY AREA

The study area was the nature reserves and urban parks of the ACT. Data were collected between December 2012 and April 2014. A total of 187 plots were established at 38 burns that were conducted to reduce fuel or meet ecological criteria as part of the ACT Parks and Conservation Service fuel management program.



## EXPERIMENTAL STRATEGY

The preferred experimental procedure was to follow the Before-After-Control-Impact (BACI; Green, 1979) method using matched pairs of treatment and control plots. Sites were matched by proximity to each other, vegetation type, topography and aspect. At sites where matched pairs of plots could not be obtained, plots were surveyed before and after burning. Of the 38 planned burns, 31 proceeded on schedule. Of the 31 completed burns, the BACI method was followed at 25 burns and a before-after method was completed at six burns (Table 1). Twelve plots were surveyed from four wildfires for comparison.

**Table 1. Summary of the number of burns and OFHA plots completed.**

	Pre-burn Assessments	Post-burn Assessments		Wildfire
		Control	Impact	
<b>Plots</b>	187	69	96	12
<b>Burns</b>	38	25	31	4

## OVERALL FUEL HAZARD ASSESSMENT

An OFHA was conducted at each study plot following the method of Hines *et. al.* (2010). The location of the plots within the burn site varied depending on the size of the burn. At small urban reserves, plots were preferentially located in the centre of the largest sectors of the burn. Unburnt control sites were located close-by. At large rural sites, plots were located around the edge of the burn to facilitate matching of treatment and controls. Each plot was classified to one of eight vegetation types: dry sclerophyll forest; Yellow Box (*Eucalyptus melliodora*) grassy woodland; sub-alpine woodland; wet sclerophyll forest, eucalypt plantation; native grassland, exotic grassland and pine plantation (Table 2). Bark fuel hazard was assessed from a plot of 20m radius, classified to one of three types; 'stringybark', 'ribbon bark' or 'other bark' and assigned a bark hazard rating using the OFHA field guide (Hines *et.al.* 2010). Elevated fuel hazard, near-surface fuel hazard and surface litter fuel hazard was assessed from a plot of 10m radius. Elevated fuel hazard was defined as fine fuel (<6mm thick) within the layer of vegetation from 0.5m – 2m in height. Near-surface fuel was defined as fine fuel (<6mm thick) within the layer that was <0.5m in height and attached to the ground but not lying on it. Surface litter fuel was defined as the leaves, twigs, bark and other fine fuel (<6mm thick) lying on the ground (litter layer). To determine the fuel hazard for the elevated and near-surface layers, we estimated the percentage cover of fuel, percentage of the fuel that was dead and fuel height (m). To determine the surface litter fuel hazard, we estimated percentage cover and depth (mm) of the surface litter (Hines *et.al.* 2010). The rating scale for fuel hazard was: Low; Moderate; High; Very High and Extreme. 'Low' represented a light fuel load which was vertically and horizontally discontinuous and with high fuel moisture. 'Extreme' represented a heavy fuel load with excellent vertical and horizontal continuity and little fuel moisture.





**Table 2. The number of plots assessed by treatment and vegetation type.**

<b>Vegetation type</b>	<b>Pre-burn</b>	<b>Control</b>	<b>Impact</b>	<b>Wildfire</b>	<b>Total</b>
Dry Schlerophyll Forest	92	36	56	6	190
Eucalypt Plantation	16	3	1		20
Exotic Grassland	8	3	5	3	19
Native Grassland	4	2	2		8
Pine Plantation	18	6	12		36
Sub-alpine Woodland	4	2	2		8
Wet Schlerophyll Forest	8	4	4		16
Yellow Box Grassy Woodland	37	13	14	3	67
<b>Total</b>	<b>187</b>	<b>69</b>	<b>96</b>	<b>12</b>	<b>364</b>

## STATISTICAL ANALYSIS

Plots were treated as independent because each burn was subject to detailed planning and the effects of fire were largely determined by management decisions and actions. Burn management included: 1) assessment of fuel load to determine whether a burn was required; 2) definition of the aims of each burn in relation to fuel management and conservation outcomes; 3) monitoring of variation in fuel moisture content and changes in it; 4) definition of suitable weather conditions for ignition and continuation of burning; 5) continuous monitoring of the weather prior to and during the burn; 5) pre-burn works to manipulate fuel and establish control lines for lighting and containment; 6) planning of an ignition strategy in relation to topography and pre-determined suitable weather conditions; 7) manipulation of lighting patterns; 8) suppression of fire when behaviour (flame height, rate of spread or intensity) exceeded prescriptions; 9) postponement of burning when fire behaviour failed to meet prescription; 10) monitoring of the fire ground until no smoke had been detected for 48 hours.

The fuel hazard ratings were converted to an ordinal scale for all analyses: Low = 1, Moderate = 2, High = 3, Very High = 4 and Extreme = 5.

## MULTIVARIATE ANALYSES

Multivariate analyses were conducted in CANOCO 4.5 following procedures of Ter Braak (1986) and Ter Braak & Smilauer (2002). Each dataset was subjected to a Detrended Correspondence Analysis (DCA) to determine the lengths of gradient of the first four axes of variation. The DCAs were conducted using untransformed data, no downweighting of rare species and detrending by segment. If the lengths of gradient were <4 then the final analysis was conducted using Principle Components Analysis (PCA). PCAs were conducted using untransformed data, with scaling focussed on inter-species correlations, species scores divided by the standard deviation of the data and with centring by species.

We tested for patterns in the fuel array associated with different vegetation types using all the pre-burn data collected – including from sites that were not burnt during the study. Each plot was classified to a vegetation type with a score for stringybark hazard, ribbon bark hazard, other bark hazard, elevated fuel hazard, near-surface fuel hazard and surface litter fuel hazard. A DCA conducted on the dataset returned gradient lengths <4 so the final ordination was conducted using a PCA. Envelopes were fitted around each classification. The ordination containing all data was dominated by plots from the two most common ecosystem types, so a second ordination was prepared following the same procedure but with these two classes removed.



Analyses comparing the fuel array between burnt and unburnt plots were prepared using data only from the 31 sites that were burnt. The variables tested were bark fuel hazard, elevated fuel hazard, near-surface fuel hazard, surface litter fuel hazard, OFHA and fire severity. The severity classes were defined as: 1) 'burnt' in which fire had burnt across the plot; 2) 'partially burnt' in which less than half the ground fuel in the plot area was burnt; and 3) 'unburnt' in which no ground fuel was burnt and there were no ignitions in the plot. DCAs of the pre-burn and the post-burn data returned gradient lengths <4 so the final ordinations were conducted using PCAs. The pre-burn plots were all classified as unburnt. The post-burn plots were classified as either: 1) unburnt controls; 2) treated by hazard reduction burns or, 3) burnt by wildfires. A second ordination of the post-burn data was prepared in which the classification was modified so that unburnt controls and plots that were within the burn area but did not burn were both classified as unburnt.

## UNIVARIATE ANALYSES

Tests for the effect of burning were conducted using General Linear Models in SPSS 11 (SPSS Inc., 2002). The model was run with two fixed terms. 1) The fixed term 'treatment' represented the effects of burning and consisted of the levels: a) 'pre-burn', including controls and planned treatments; b) 'HR burn', an abbreviation of hazard reduction, including plots that were part of the scheduled burn but may not have actually burnt; c) 'unburnt controls'; and d) 'wildfire'. 2) The fixed term 'burn' represented each incident and these were separated from each other by either space or time. The final model contained the main effect 'treatment' and 'burn'. The dependent variables were bark hazard, elevated fuel hazard, near-surface fuel hazard, surface litter fuel hazard and OFHA. The results were reported using an F-statistic and p-value ( $\alpha = 0.05$ ).

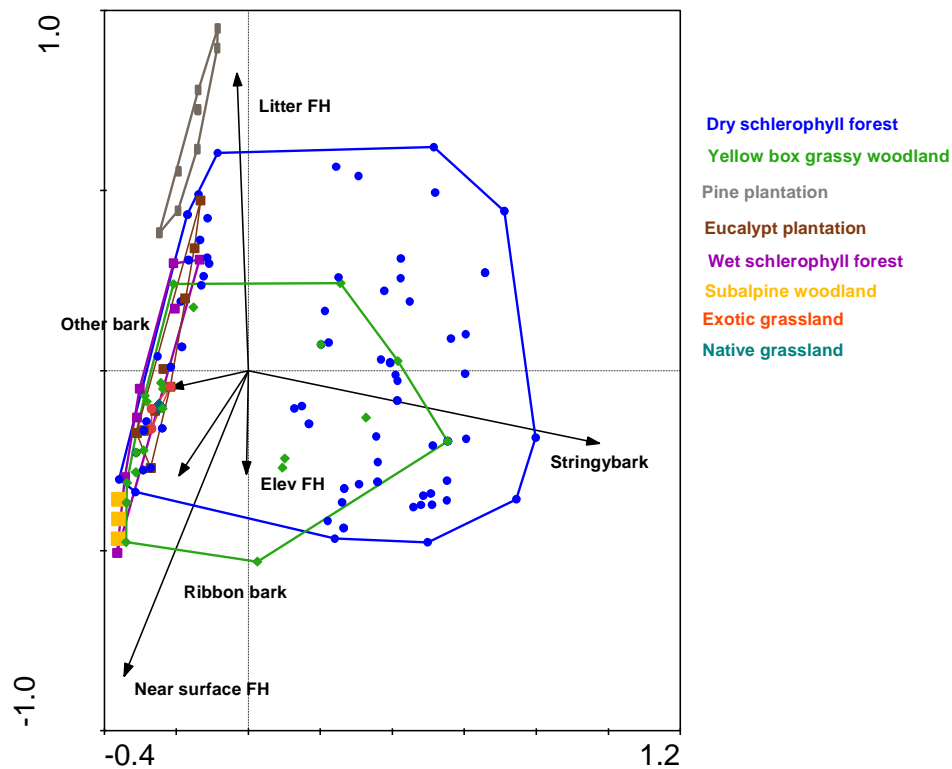
## RESULTS

### VEGETATION TYPES

The fuel array within each vegetation type exhibited distinct patterns (Figures 1, 11, 12). The two main axes of the ordination were stringybark (*Eucalyptus macrorhyncha*) fuel hazard and ground fuels (a combination of the negatively correlated variables, near-surface fuel hazard and surface litter fuel hazard which represent grass and litter). Ordination space was dominated by the vegetation types which were surveyed most frequently; dry sclerophyll forest, and Yellow Box grassy woodland. The prominence of the stringybark fuel hazard variable in the ordination is due to its abundance in the most commonly surveyed fuel type, dry sclerophyll forest. The fuel array in Yellow Box grassy woodland is similar to dry sclerophyll forest except that the bark hazard and surface litter fuel hazard tends to be lower. Eucalypt plantations were similar to the dry sclerophyll forest except they did not contain any stringybark and were therefore distributed along the 'other bark' axis.



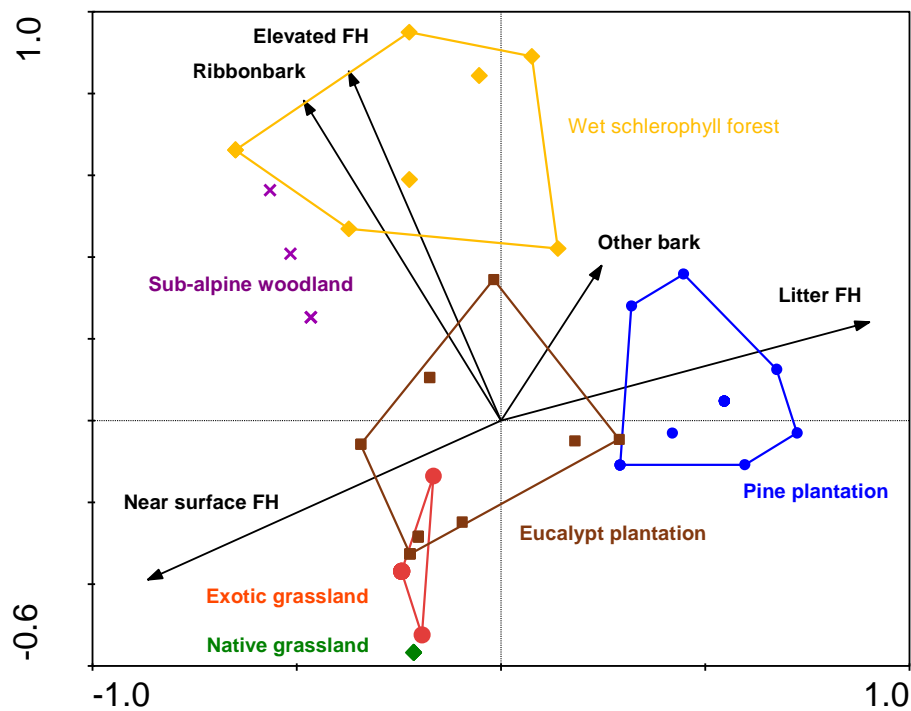
Figure 1. Ordination from a Principle Components Analysis on pre-burn plots using OFHA data with envelopes around plots from different vegetation classes.



The vegetation types that did not support stringybark were concentrated in a small area of ordination space so a second ordination was prepared with the two most common vegetation types removed (Figure 2). The two main axes represent ground fuels and two strongly correlated variables ribbon bark and elevated fuel hazard. Sub-alpine woodland supporting *Eucalyptus dalrympleana* and wet sclerophyll forest supporting *Eucalyptus viminalis* had higher ribbon bark hazard than the other fuel types. These vegetation types also had higher elevated fuel hazard due to dense re-growth of *Bitterpea* (*Daviesia* spp.), *Dogwood* (*Cassinia* spp.) and *Acacias* following the intense wildfires of 2003 (McLeod, 2003). Pine plantations differed from the other fuel types due to a greater coverage of litter fuels. Eucalypt plantations occupied the centre of ordination space indicating that the bark hazard was relatively low while the other variables tended to be at intermediate levels. Grasslands occupied space with higher near-surface fuel hazard values and low elevated fuel and bark hazard values.



Figure 2. The ordination from a Principle Components Analysis performed using OFHA data from pre-burn plots with the two most commonly surveyed vegetation types removed. Envelopes have been placed around plots from each vegetation type.

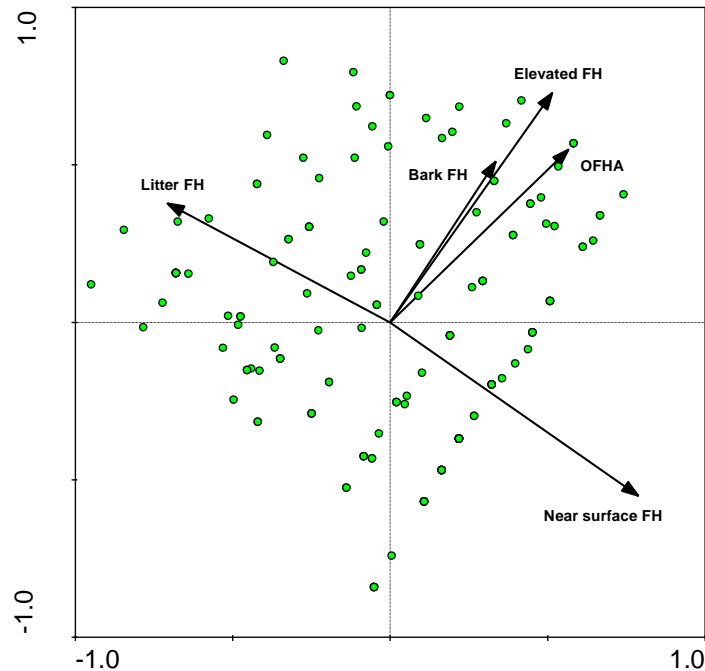


### THE FUEL ARRAY

Unburnt vegetation in the ACT was distributed in ordination space along two main axes of variation (Figure 3). One axis represented ground fuels with two strongly negatively correlated components grass and litter. The other axis represented two strongly correlated variables, bark fuel hazard and elevated fuel hazard. OFHA increased as bark hazard or elevated fuel hazard increased.



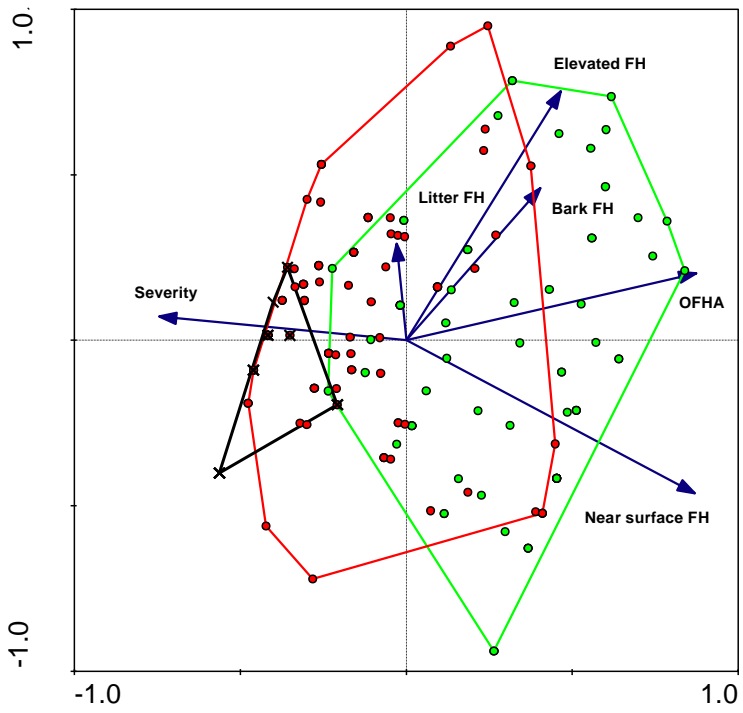
Figure 3. An ordination of a PCA performed on OFHA data from pre-burn plots at locations where burning proceeded. Variables were the inputs to the OFHA, so this ordination is a representation of the fuel array in the ACT at sites prior to burning. The two main axes represent ground fuels and two strongly correlated variables, bark fuel hazard and elevated fuel hazard.



The ACT hazard reduction burning program reduced the OFHA by reducing the grass cover, shrub cover and the amount of combustible bark (Figures 4, 13, 14, 15, 16). Most of the OFHA variables were negatively correlated with fire severity; the strongest relationship was with near-surface fuel hazard which represented grass. Therefore reduction in grass cover was the main driver of the reduction in OFHA. The other main axis of variation represented two strongly correlated fuel hazard parameters, bark fuel hazard and elevated fuel hazard. The wildfire plots were clustered around the axis representing increasing fire severity (Figure 17). Plots treated in hazard reduction burns were also clustered in this region but tended to radiate out into space that was occupied by unburnt control plots. This reflects the incomplete consumption of fuel that occurred during hazard reduction burning and within burn patchiness (some treated plots were only partially burnt or not burnt at all). The ordination represents the change in the fuel array at treated sites due to the ACT hazard reduction burning program.



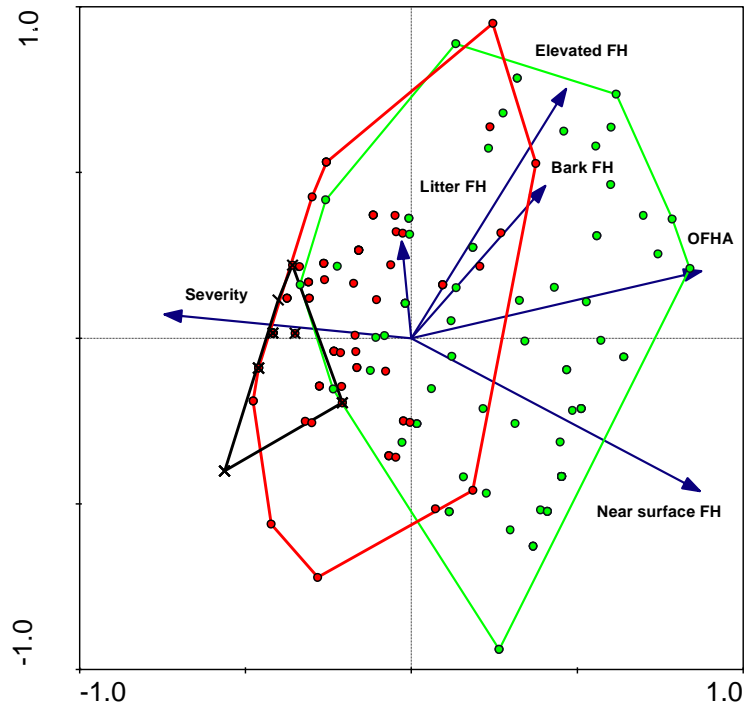
Figure 4. Ordination of a Principle Components Analysis performed using OFHA data and an index of fire severity.



When unburnt plots within treated sites are re-classified as 'unburnt' (Figure 5), the envelope representing OFHA of burnt plots shrinks along the axis of near-surface fuel hazard. The ordination suggests that incomplete combustion of fuel maybe a more important contributor of within burn patchiness than unburnt patches.



Figure 5. Ordination of a Principle Components Analysis performed using OFHA data and an index of fire severity. The ordination was performed using the same data as figure 4, but with a different classification of plots. Plots that were within the treatment area but did not burn have been classified with the unburnt control plots. The ordination therefore represents the effect of fire on the fuel array due to the ACT hazard reduction burning program.



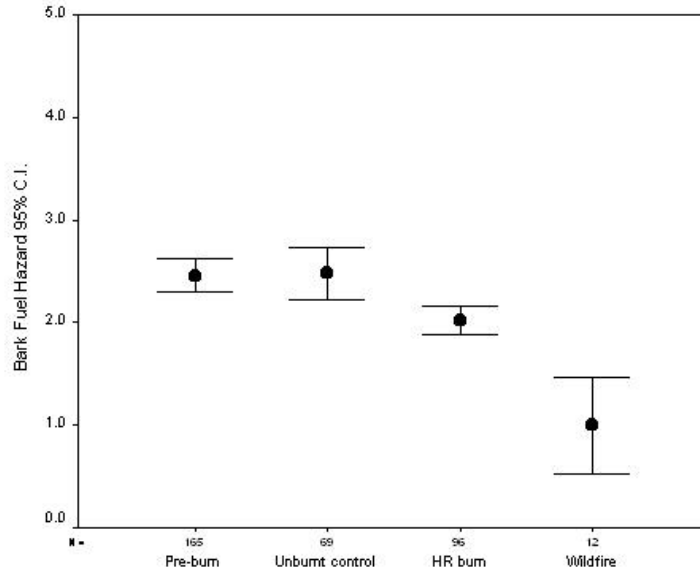




## COMPONENTS OF THE FUEL ARRAY

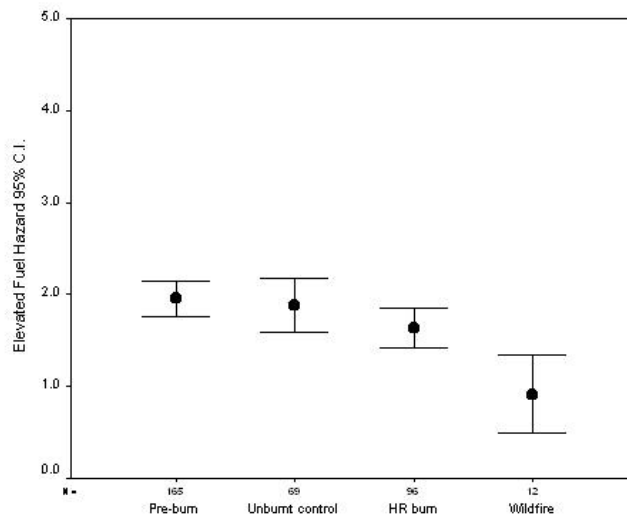
Bark hazard was reduced by hazard reduction burning ( $F = 22.3$ ,  $p < 0.001$ ) but the effect was small such that the pre-burn plots, unburnt controls and fuel reduced sites were all classified to Moderate (Figure 6). Plots burnt by wildfire were reduced to Low.

Figure 6. The effect of hazard reduction burning on bark fuel hazard, showing mean and 95% confidence intervals. Low = 1, Moderate = 2, High = 3, Very high = 4 and Extreme = 5.



Elevated fuel hazard was lower following wildfire than it was in pre-burn plots and unburnt controls ( $F = 4.6$ ,  $p = 0.01$ ; Figure 7). Pre-burn plots, unburnt controls and fuel reduced sites were all classified Moderate, while plots burnt by wildfire were classified Low.

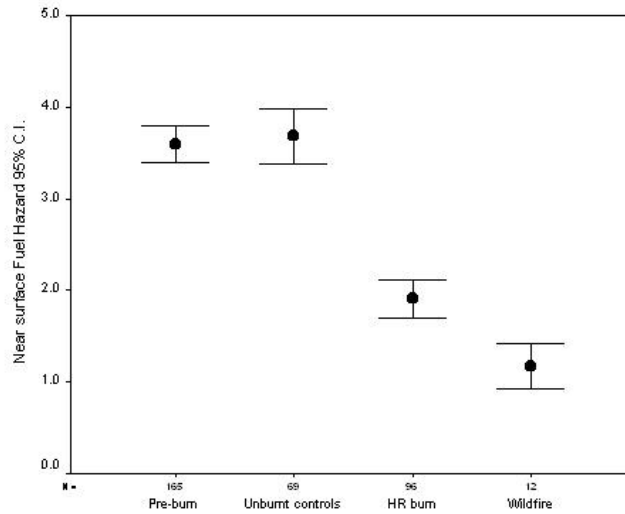
Figure 7. The effect of hazard reduction burning on elevated fuel hazard, showing mean and 95% confidence intervals. Low = 1, Moderate = 2, High = 3, Very high = 4 and Extreme = 5.



Near-surface fuel hazard was reduced from Very high to Moderate following hazard reduction burning ( $F = 132.0$ ,  $p < 0.001$ ; Figure 8). Plots burnt by wildfire were classified Low.

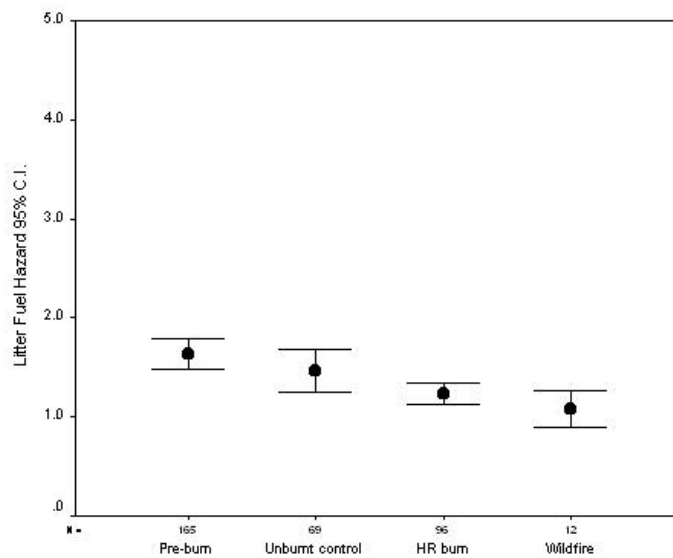


Figure 8. The effect of hazard reduction burning on near-surface fuel hazard, showing mean and 95% confidence intervals. Low = 1, Moderate = 2, High = 3, Very high = 4 and Extreme = 5.



Surface litter fuel hazard was reduced following hazard reduction burning and wildfire ( $F = 14.6.0$ ,  $p < 0.001$ ), but the parameter did not contribute much to the OFHA and the effect was small (Figure 9). Surface litter fuel hazard was classified Low for all treatments.

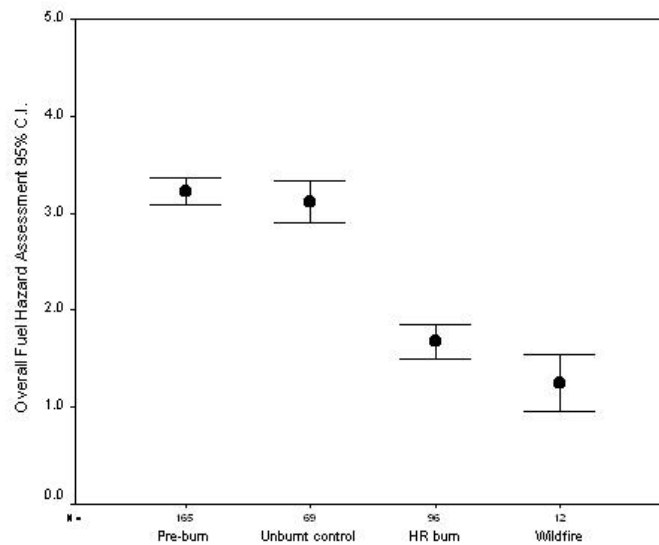
Figure 9. The effect of hazard reduction burning on surface litter fuel hazard, showing mean and 95% confidence intervals. Low = 1, Moderate = 2, High = 3, Very high = 4 and Extreme = 5.



Overall fuel hazard was reduced from High in pre-burn plots and unburnt controls to Moderate following hazard reduction burning ( $F = 149.7$ ,  $p < 0.001$ ; Figure 10). Following wildfire, overall fuel hazard was Low.



Figure 10. The effect of hazard reduction burning on overall fuel hazard, showing mean and 95% confidence intervals. Low = 1, Moderate = 2, High = 3, Very high = 4 and Extreme = 5.



## DISCUSSION

Our results suggest that the ACT hazard reduction burning program is achieving the fuel management standards set out for it by the ACT Government in the SBMP (ACT Government, 2009). The main driver of fuel hazard in the ACT is grass and this is augmented in some places by shrubs and combustible bark. Surface litter appears to be a minor component of the fuel array. The hazard reduction burning program achieves a reduction in the OFHA by removing the grass cover but it is not generally having such a strong effect on the other components of the fuel array.

Different vegetation types in the ACT were characterised by distinct fuel arrays and this information could be used to refine the aims of burning to better meet the objectives of the program. Fuel hazard in the two most commonly burnt vegetation classes, dry sclerophyll forest and Yellow Box grassy woodland was dominated by grass, however stringybark is also an important component where it occurs. Sample sizes of the other vegetation types were small, however the results suggest: 1) dense shrub cover and ribbon bark are key components of the fuel array in sub-alpine woodland and wet sclerophyll forest; 2) pine needle litter is the key component of the fuel array in pine plantations. Burning specifically focussed on reducing these fuel types may improve the fuel management program.

An issue that arises with use of the OFHA in grass-dominated systems is that the near-surface fuel hazard rating is strongly influenced by cover and grass cover usually accumulates more quickly than surface litter following hazard reduction burning (Tolhurst, 1996; Leavesley *et. al.*, 2013). This means that the OFHA may also rapidly increase as the grass coverage returns to 50 percent necessitating more frequent burning than would be required to maintain a given OFHA standard than in surface litter dominated systems.

Red Stringybark trees are a key component of the fuel array in dry sclerophyll forest and some Yellow Box grassy woodland. Following a low intensity hazard reduction burn, charring of stringybark is often restricted to the bottom 1m of tree trunks or if higher to one side of the tree. Previous work has demonstrated that consumption of bark increases with fire intensity (Gill *et. al.* 1986). Further work is needed to better understand bark consumption and charring in low intensity burns.



Figure 11. Dry sclerophyll forest at Googong Nature Reserve prior to burning. The reserve is a water catchment and the site was part of a Bushfire CRC study of the effects of prescribed fire on carbon (Volkova and Weston 2015).



Figure 12. A grass dominated understorey in dry sclerophyll forest at Black Mountain Nature Reserve prior to burning.







Figure 13. A hazard reduction burn at Black Mountain Nature Reserve. The fire is backing down the hill.



Figure 14. After a hazard reduction burn at Black Mountain Nature Reserve. Grass cover is greatly reduced, shrub cover has declined due to flame scorch and charring of stringybark is minimal.





Figure 15. After a hazard reduction burn at Black Mountain Nature Reserve. Grass cover is greatly reduced, eucalypt saplings have received some flame scorch and surface litter consumption is patchy.



Figure 16. Patchy consumption of litter; the Divisional Commander described the progress of this sector of the burn as 'brutally slow'.







Figure 17. The site of a small wild fire in the ACT; charring of bark has carried to the top of the trees, shrub foliage has been consumed in some places and little grass or surface litter remains.







Figure 18. ACT Parks and Conservation fire crews skilfully planned and implemented the burning program.



## **ACKNOWLEDGEMENTS**

We would like to express our gratitude to the staff of Parks Brigade of the ACT Rural Fire Service who skilfully planned and implemented the burning program. They were ably assisted by New South Wales (NSW) Parks and Wildlife Service staff and volunteers from other ACT and NSW volunteer bushfire brigades. Special thanks to Scott Farquhar and Dylan Kendall for accommodating the project within the ACT Parks burning program. The comments of Daniel Iglesias and an anonymous reviewer greatly improved the manuscript.



## REFERENCES

- ACT Government (2009) Strategic Bushfire Management Plan. Justice and Community Services Directorate. <https://esa.act.gov.au/community-information/publications/sbmp/>. Accessed 13 August 2013.
- Green, R. H. (1979) Sampling design and statistical methods for environmental biologists. Wiley-Interscience, New York, New York, USA.
- Gill, A.M., Cheney, P., Walker, J., Tunstall, B.R. (1986) Bark losses from two eucalypt species following fires of different intensities. *Australian Forest Research* **16**: 1-7.
- Hines, F., Tolhurst, K.G., Wilson, A.A.G., McCarthy, G.J. (2010) Overall fuel hazard assessment guide 4<sup>th</sup> edition. Fire and adaptive management report no. 82. Victorian Government Department of Sustainability and Environment, Melbourne July, 2010.
- Leavesley, A.J., Mallela, J. Cooper, N., Kendall, D. (2013) Winter Hazard Reduction Burning Reduces the Fuel Load in *Themeda* and *Phalaris* during Summer. Proceedings of the AFAC and Bushfire CRC conference, Melbourne, September 2-5.
- McLeod, R. (2003) Inquiry into the Operational Response to the January 2003 Bushfires in the ACT. ACT Government, Canberra.
- SPSS Inc. Released 2002. SPSS for Windows, Version 11.5. Chicago, SPSS Inc.
- Ter Braak, C. J. F., (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis, *Ecology*, **67**(5): 1167-1179.
- Ter Braak, C. J. F. and Smilauer, P., (2002) *CANOCO reference manual and CanoDraw for Windows user's guide: Software for Canonical Community Ordination (version 4.5)*, Microcomputer Power, New York.
- Tolhurst, K. (1996) Effects of fuel reduction burning on fuel loads in a dry sclerophyll forest, in Biodiversity and Fire: The effects and effectiveness of fire management, Proceedings of the conference held 8-9 October 1994, Footscray, Melbourne. Biodiversity Series, Paper No. 8
- Volkova, L., Weston, C.J. (2015) Carbon loss from planned fires in southeastern Australian dry *Eucalyptus* forests. *Forest Ecology and Management* **336**, 91-98



# IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS

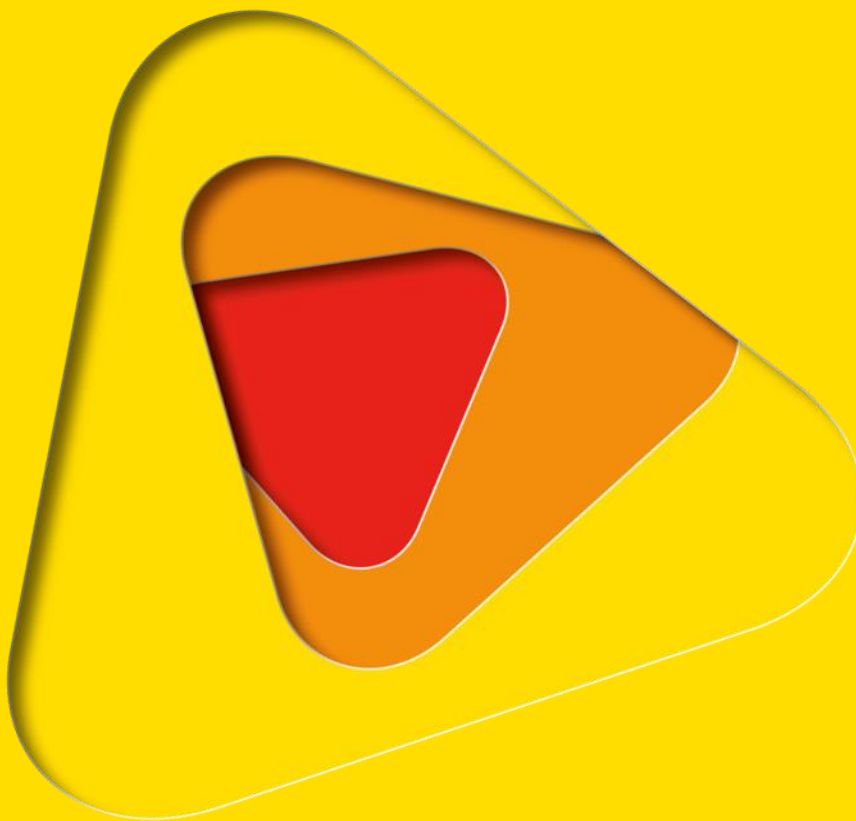
Proceedings of the Research Forum at the Bushfire and Natural  
Hazards CRC & AFAC conference  
Wellington, 2 September 2014

**D.J. Henderson<sup>1,2</sup> and J.D. Ginger<sup>1,2</sup>**

<sup>1</sup>Cyclone Testing Station, James Cook University

<sup>2</sup>Bushfire and Natural Hazards CRC

Corresponding author: david.henderson@jcu.edu.au





## ABSTRACT

Damage investigations carried out by the Cyclone Testing Station (CTS) following severe wind storms have typically shown that Australian houses built prior to the mid-1980s do not offer the same level of performance and protection during windstorms as houses constructed to contemporary building standards. Given that these older houses will represent the bulk of the housing stock for many decades, practical structural upgrading solutions based on the latest research will make a significant improvement to housing performance and to the economic and social well-being of the community.

Some structural retrofitting details exist for some forms of older housing but the take up of these details is limited. There is also evidence that retrofitting details are not being included into houses requiring major repairs following severe storm events, thus missing the opportunity to improve resilience of the house and the community. Hence the issues of retrofitting of older housing including feasibility, and hindrances on take-up etc. must be analysed.

This paper describes a Bushfire and Natural Hazards CRC project whose primary objective is to develop cost-effective strategies for mitigating damage to housing from severe windstorms across Australia. These evidence based strategies will be (a) tailored to both aid policy formulation and decision making in government and industry, and (b) provide guidelines detailing various options and benefits to homeowners and the building community for retrofitting typical at risk older houses in Australian communities.

## INTRODUCTION

Extreme damage to housing resulted from the impact of Tropical Cyclone Tracy in December 1974, especially in the Northern suburbs of Darwin (Walker, 1975). Changes to design and building standards of houses were implemented for the reconstruction.

The Queensland Home Building Code (HBC) was introduced as legislation in 1982 with the realisation of the need to provide adequate strength in housing. By 1984 it is reasonable to consider that houses in the cyclone region of Queensland were being fully designed and built to its requirements.

Damage investigations, conducted by the Cyclone Testing Station (CTS) in NT, QLD and WA, of housing from cyclones over the past fifteen years have shown that the majority of houses designed and constructed to current building regulations have performed well structurally by resisting the wind loads and remaining intact (Reardon et al, 1999; Henderson and Leitch, 2005; Henderson et al, 2006; 2010; Boughton et al 2011). However, these reports also detail failures of contemporary construction at wind speeds below design requirements. The poor performance of these structures resulted from design and construction failings or from degradation of elements such as corroded screws, nails and straps and decayed or insect attacked timber.

This paper describes work on a recently commenced Bushfire and Natural Hazards CRC project and provides an initial review with a focus on cyclonic regions, although the overall project encompasses housing types across the country. The proposed work will;

- Categorise houses into types based on the building features that influence windstorm vulnerability, using survey data collected by Geoscience Australia and CTS-JCU. From these, a suite will be selected representing those contributing most to windstorm risk.

- Involve end-users and stakeholders to assess amendments and provide feedback on practicality and aesthetics of potential upgrading methods for a range of buildings. Strategies will be developed and costed for key house types.
- Develop vulnerability functions for each retrofit strategy, using survey data, author's vulnerability models and NEXIS. Case studies will be used to evaluate effectiveness in risk reduction. Economic assessment using the same case studies will be used to promote uptake of practical retrofit options.

*Figure 1. Removal of roof cladding and battens from wind ward face*



*Figure 2. Part of the roof cladding with battens still attached flipped on to the leeward side*



## **WIND LOADS ON HOUSE AND STRUCTURAL PERFORMANCE**

The wind field within a cyclone is a highly turbulent environment. The dynamic fluctuating winds that impact on the house subjects the building envelope (exterior skin) and structure to a multitude of spatially and temporally varying forces. Generally, the design of the house structure uses the peak gust wind speed in determining the large positive and negative pressures pushing and pulling on the house. The wind duration and temporally varying forces are important in assessing elements of the house envelope and frame, such as roofing, battens, and connections that may suffer degradation from load cycle fatigue.

Figure 3 gives a representation of the pressures acting on a house. The high suction pressures at the leading edge of the roof can be seen. If there is a breach in the building envelope on this windward face, such as from broken window or failed door (Figure 4), the interior of the house is suddenly pressurised. These internal loads act in concert with the external pressures greatly increasing the load on the house cladding elements and structure. Depending on the geometry of the building, the increase in internal pressure caused by this opening can double the load on the structure, thereby increasing the risk of failure especially if the building has not been designed for a dominant opening.





As an aside, houses in cyclonic regions designed in accordance with contemporary design standard AS4055 Wind Loads for housing have the design assumption that a dominant opening can occur. Houses in non-cyclonic regions designed to AS4055 are not required to have the dominant opening pressure case accounted for in their design, resulting in a higher probability of failure if such an opening was to occur.

The National Construction Code (2014) is continually reviewed to ensure that it supports acceptable performance of new housing. However, as only a small fraction of our housing stock is replaced per annum, most Australians will spend the majority of their lives in houses that are already built. Further, from an emergency management, community recovery and an insurance perspective; the majority of the risk is in the housing stock that already exists.

Figure 3. Simple representation of wind pressures acting on building

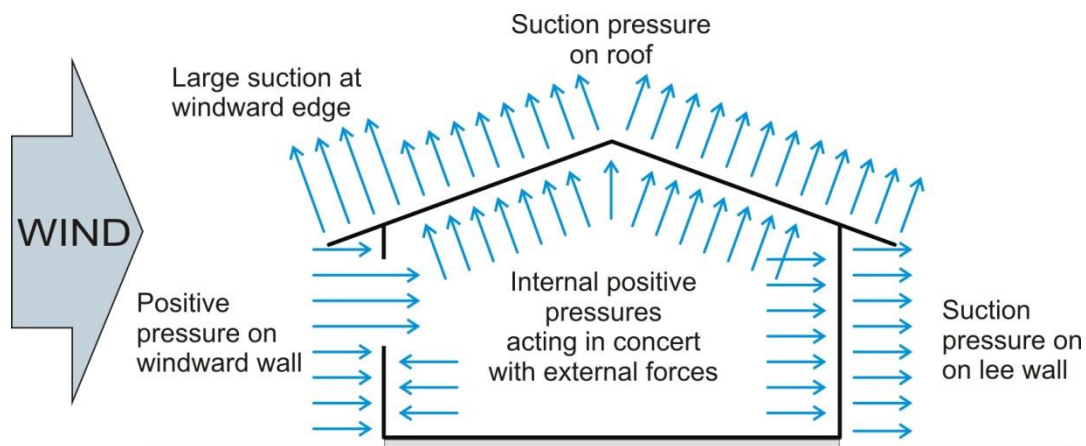
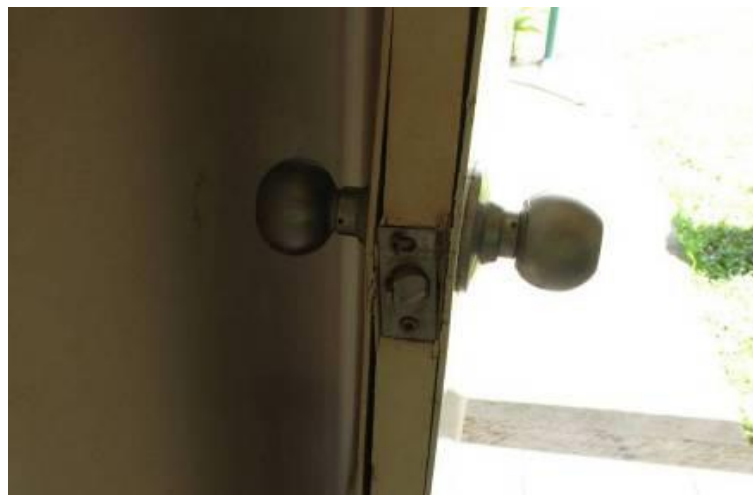


Figure 4. Standard lock and damaged door after being blown inwards during Cyclone Yasi



Houses are complex structures and do not lend themselves to simple design and analysis due to various load paths from multiple elements and connections with many building elements providing load sharing and in some cases redundancy. Different types of house construction will have varying degrees of resilience to wind loads. From a review of building regulations, interviews, house inspections and load testing, the CTS classified the housing stock in the North Queensland region into six basic types (Henderson and Harper, 2003). These types are shown in Table 1.

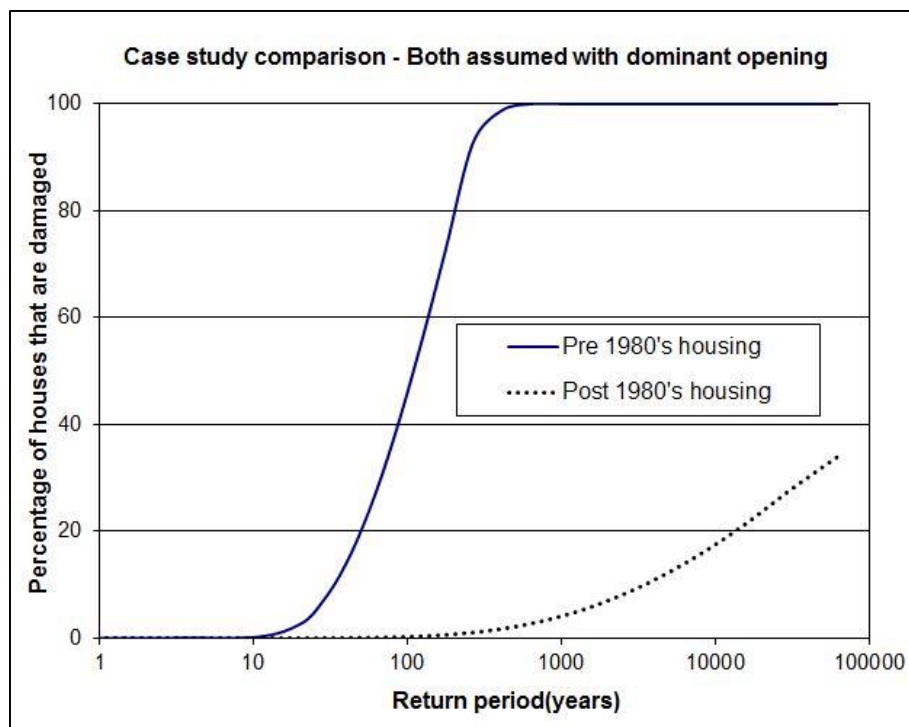


For these six types the CTS developed preliminary housing wind resistance models to give an estimate of the likely failure mode and failure load for a representative proportion of houses. The CTS housing wind resistance models focus on the chain of connections from the roof cladding fixings down to the wall tie-down and incorporate parameters such as a chance of a dominant opening occurring.

The Geoscience Australia NEXIS data base is to be used to generate common housing forms for various regions around the country. Initial groupings for non-cyclonic regions are given in Table 2 (Edwards and Wehner, 2014). Vulnerability models for these types of building systems is to be derived.

AS/NZS 1170.2 provides information for selecting the design wind speed related to the return period. Using vulnerability curves developed by CTS, Figure 5 shows the percentage of housing damaged against the return period for a typical cyclonic region C, suburban site. These curves show the significant decrease in damage to housing that could be achieved if the older Pre-1980s houses were to be upgraded to be as strong as the contemporary Post-1980s houses.

Figure 5. Vulnerability curves for Pre 1980s and Post-1980s houses with increasing return period (King et al, 2013)



## NOT JUST CONSTRUCTION AGE

Damage surveys invariably reveal some failures due to loss of integrity of building components due to aging or durability issues such as corrosion, dry rot or insect attack. The CTS conducted a detailed inspection of over 20 houses built in the 70s and 80s in the tropics. Although the majority of the surveyed houses appeared in an overall sound condition, the majority (all but two) had potential issues such as decay of a timber member, corrosion at a connection, missing/removed structural element, etc. This study highlighted that retrofitting for improved wind resistance is only a part of the process. Ongoing maintenance is an important part of improving our communities resilience in severe weather. In fact, the damage survey after Cyclone Yasi showed substantial corrosion of roof elements in houses less than 10 year old.





## EXISTING UPGRADE PROVISIONS

There are existing guidelines for the upgrading of older houses in the form of handbooks (HB132) published by Standards Australia in 1999. However, the uptake of the prescribed details in the handbooks has not been effective in the light of recurring severe wind damage to older structures. These details and methods will be reviewed to consider reasons for lack of use. It is proposed that this project will access state of the art knowledge to improve the literature detailing general upgrading of structural connections in houses and other similar buildings. Where appropriate, it will also include targeted structural upgrade details for more specific types of housing. This study will provide an opportunity to assess what amendments might be warranted to current literature. The study will also consider the effectiveness of the current literature in supporting upgrading of older houses and consider whether other mechanisms may be needed to support implementation. The involvement of stakeholders including organizations such as professional builders associations, insurers, ABCB and BCQ will be sought for input.

If initial findings from surveys and engagement with stakeholders show that the biggest impediment to upgrading is that the existing HB132 details are all too expensive, excessive and in home owners eyes not aesthetic, then subsequent research should focus on development of new details. However, if the results showed that the details are acceptable, but that there is no incentive to apply them or there is lack of understanding of reasons for upgrading and maintenance, then research should focus on development of information to inform mitigation decisions including dedicated web based strategies to inform and educate home owners, designers and builders.

A major part of this is vulnerability studies combined with cost benefit analysis. This work will include analysis from wind tunnel model studies and load tests, and construction and load testing of “upgraded” representative sections of house for both proof-testing and using resulting video material for education and guides.

## OBJECTIVES

- The uptake of retrofitting and maintenance of house structure will increase community resilience and reduce the needs of response and recovery following severe wind events.
- Promotion of retrofit investment by the home owner is needed.
- Incentives to encourage this action through insurance and government initiatives can be based on the economic modelling from this project.



Table 1. Generalised examples of housing constructions types (King et al, 2013)





Built During	Example of geometry and features	Generalised features
< 1920s		<p>Hip roof, reduced rafter spans, central core, exposed studs, on stumps (low and high)</p>
1920 – 1950s		<p>Hip and gable, VJ lining, reduced rafter spans, on stumps (low and high)</p>
1960s – 1970s		<p>Gable low pitch, vermin proof flooring (studs not mortice and tennon into bearers), panel cladding, on stumps</p>
> early 1980s		<p>Reinforced masonry block, hip and gable, large truss spans, medium roof pitch, slab on ground</p>



Table 2. Example of preliminary schema for house classification in non-cyclonic regions (Edwards and Wehner 2014)

Jurisdiction and Wind Region	Age	AS 4055 Classification	Roof Material	Wall Material					
				Brick Veneer	Reinf'd Masonry	Cavity Double Brick	Timber or Metal Clad	Fibre Cement Clad	
Queensland Region B	1996 to Present	N2	Sheet Metal						
			Tile						
		N3	Sheet Metal						
			Tile						
		N4	Sheet Metal						
			Tile						
	N5	Sheet Metal							
		Tile							
	1980 to 1995	N/A	Sheet Metal						
			Tile and Slate						
	All Other States, Territories Age Groups and Wind Regions	1996 to Present	N1	Sheet Metal					
				Tile					
N2			Sheet Metal						
			Tile						
N3			Sheet Metal						
			Tile						
N4			Sheet Metal						
			Tile						
1980 to 1995			N/A	Sheet Metal					
				Tile and Slate					
1960 to 1979			N/A	Sheet Metal					
				Tile and Slate					
		Fibre Cement							
1914 to 1959		N/A	Sheet Metal						
			Tile and Slate						
			Fibre Cement						
1891 to 1913		N/A	Sheet Metal						
			Tile and Slate						



## REFERENCES

- Boughton G., Henderson D., Ginger J., Holmes J., Walker G., Leitch C., Somerville L., Frye U., Jayasinghe N. and Kim P., (2011) *Tropical Cyclone Yasi: Structural damage to buildings*, Cyclone Testing Station, James Cook University, Report TR57.  
[http://www.jcu.edu.au/cts/research\\_reports/index.htm](http://www.jcu.edu.au/cts/research_reports/index.htm)
- Edwards, M. and Wehner, M. (2014), *Improving the Resilience of Existing Housing to Severe Wind Events - Preliminary Building Schema*, BNHCRC progress report, GEOSCIENCE AUSTRALIA, ACT
- Henderson, D.J. and Ginger, J.D. (2008). *Role of building codes and construction standards in windstorm disaster mitigation*. Australian Journal of Emergency Management, Vol 23 No 2
- Henderson, D., Ginger, J., Leitch, C., Boughton, G. and Falck, D. (2006) *Tropical Cyclone Larry – Damage to buildings in the Innisfail area*. Cyclone Testing Station. Townsville, James Cook University.
- Henderson, D. and Harper, B. (2003). *Climate Change and Tropical Cyclone Impact on Coastal Communities' Vulnerability*. CTS Report TS582 for Dept Emergency Services and Dept Natural Resources and Mines, Queensland Government.  
<http://www.longpaddock.qld.gov.au/about/publications/vulnerabilitytocyclones/stage4.html>
- Henderson, D. & Leitch, C. (2005) *Damage investigation of buildings at Minjilang, Cape Don and Smith Point in NT following Cyclone Ingrid*. Cyclone Testing Station, Townsville, James Cook University.
- Henderson, D. & Somerville, L. (2012) *TIO Housing survey (Built 1975 to 1980)*. TS859, Cyclone Testing Station, Townsville, James Cook University.
- King D, Ginger J, Williams S, Cottrell A, Gurtner Y, Leitch C, Henderson D, Jayasinghe N, Kim P, Booth K, Ewin C, Innes K, Jacobs K, Jago-Bassingthwaighe M & Jackson L (2013) *Planning, building and insuring: Adaptation of built environment to climate change induced increased intensity of natural hazards*. National Climate Change Adaptation Research Facility (NCCARF), 361 pp. ISBN: 978-1-921609-75-6
- Standards Australia (1999). *HB 132.1:1999 Structural upgrading of older houses, Part 1: Non-cyclonic areas*, Standards Australia, Sydney, NSW
- Standards Australia (1999) *HB 132.2:1999 Structural upgrading of older houses - Part 2: Cyclone areas*, Standards Australia, Sydney, NSW
- Standards Australia (2011), *AS/NZS 1170.2:2011 Structural design actions Part 2: Wind actions*, Standards Australia, Sydney NSW, Australia.
- Standards Australia (2011), *AS 4055 Wind Loads for Housing*, Standards Australia, Sydney, NSW.
- Standards Australia (2010), *AS 1684.3:2010 Residential timber-framed construction – Cyclonic areas*, Standards Australia, Sydney, NSW, Australia.
- Walker, G. (1975). *Report on Cyclone Tracy – Effect on buildings – Dec 1974*. Australian Dept of Housing and Construction.



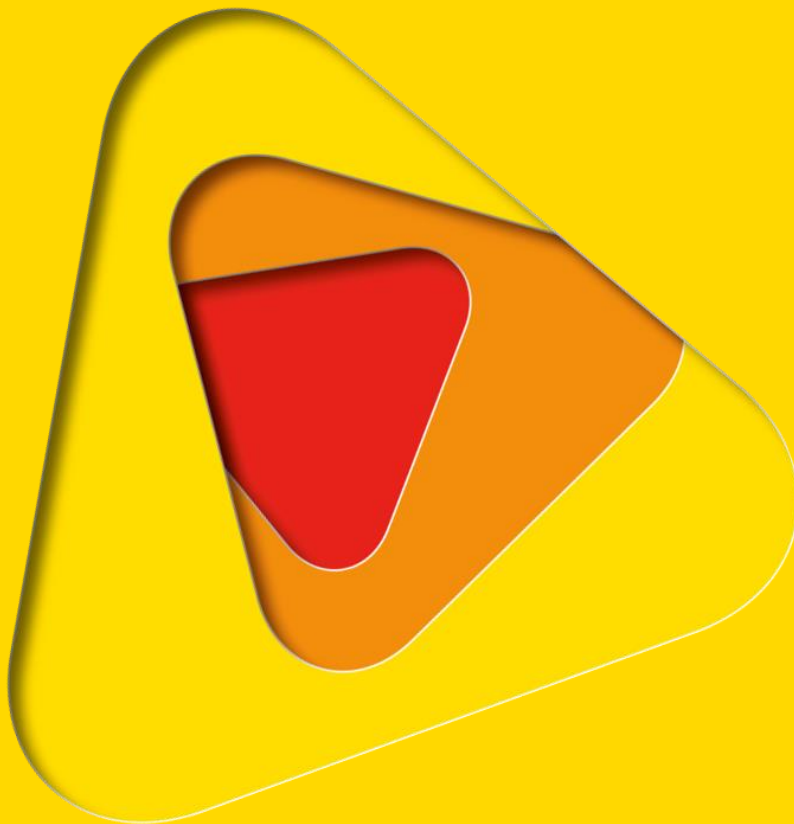
# MODELLING THE FIRE WEATHER OF THE COONABARABRAN FIRE OF 13 JANUARY 2013

Proceedings of the Research Forum at the Bushfire and Natural Hazards CRC  
& AFAC conference  
Wellington, 2 September 2014

Robert J B Fawcett <sup>1 2 3</sup> Claire Yeo <sup>1</sup> William Thurston <sup>1 2 3</sup> Jeffrey D Kepert <sup>1 2 3</sup>  
Kevin J Tory <sup>1 2 3</sup>

1. Bureau of Meteorology/CAWCR
2. Bushfire CRC
3. Bushfire and Natural Hazards CRC

Corresponding author: [r.fawcett@bom.gov.au](mailto:r.fawcett@bom.gov.au)





## ABSTRACT

We will exhibit state-of-the-art high-resolution numerical weather prediction simulations and radar imagery for Sunday 13 January 2013, with a specific focus on the region of the Coonabarabran fire which started at around 1600 Eastern Daylight Time (EDT) on 12 January in the Warrumbungle National Park. The simulations show a complicated range of meteorology including weather features that would affect fire behaviour critical for fire-fighter safety.

Features such as convection outflow gust fronts are displayed in the simulations in the north-westerly wind ahead of the main wind change, together with boundary-layer rolls, and sea-breeze-like wind changes proceeding inland from the coast. In addition, small-scale vortices are modelled on the main change: these lead to hazardous local spikes in the modelled Forest Fire Danger Index. Exceptionally strong north/south temperature gradients were observed over inland New South Wales on the Sunday and these are also seen in the simulations.

Sunday 13 January brought difficult conditions for fire fighting. When the fire was declared “out” on 24 January, it had burnt an area of 55,210 ha west of Coonabarabran, 53 homes, 131 other buildings and 95% of the Warrumbungle National Park.

The simulation has been performed using the Australian Community Climate and Earth-System Simulator (ACCESS), and involves a sequence of nested limited area model runs embedded in the ACCESS global model run, with a finest grid spacing of 550 m. Our analysis will focus on how well the simulations capture the meteorological factors that promote extreme fire behaviour. The ACCESS model is used at the Bureau of Meteorology for operational numerical weather prediction, but is used here in research mode at resolutions much finer than current operational ones.

## INTRODUCTION

A fire started around 1600 Eastern Daylight Time (EDT) on Saturday 12 January 2013 in the Warrumbungle National Park (WNP) in north-east New South Wales. The weather on Sunday 13 January brought difficult conditions for fire fighting (NSW RFS 2013) and exceptionally strong north/south temperature gradients over inland NSW (M Logan pers. comm.). When the fire was declared out on 24 January, it had burnt an area of 55,210 ha west of Coonabarabran (NSW RFS 2013).

In this paper, we exhibit state-of-the-art high-resolution numerical weather prediction simulations and radar imagery for Sunday 13 January 2013, with a specific focus on the region of the Coonabarabran fire. The simulations show a complicated range of meteorology including weather features that would affect fire behaviour critical for fire-fighter safety.

Features such as convection outflow gust fronts are displayed in the simulations in the north-westerly wind ahead of the main wind change, together with boundary-layer rolls, and sea-breeze-like wind changes proceeding inland from the coast. In addition, small-scale vortices are modelled on the main change: these lead to hazardous local spikes in the modelled Forest Fire Danger Index. Exceptionally strong north/south temperature gradients were observed over inland New South Wales on the Sunday and these are also seen in the simulations.

## SYNOPTIC METEOROLOGY

Figure 1 shows the mean sea-level pressure (MSLP) analysis for 1700 EDT on 13 January 2013. The primary meteorological feature is the trough (the dashed line in Figure 1) which moves northeastward through the course of the afternoon on 13 January. This manifests at the surface as a significant wind and temperature change with strong frontal characteristics. At Coonamble for example (Figure 3), the wind direction changes from northerly/northwesterly around to a southerly. The synoptic situation resulted in one of the largest southwest-to-northeast gradients in daily maximum temperature across New South Wales in a hundred years. For example, the average maximum temperature on that day across Rainfall District 52 (containing Mungindi and Walgett) in the northeast was 20°C higher than that for Rainfall District 74 (containing Narrandera, Wagga Wagga and Deniliquin) in the southwest, according to the Bureau of Meteorology's operational daily temperature analyses (Jones et al. 2009).

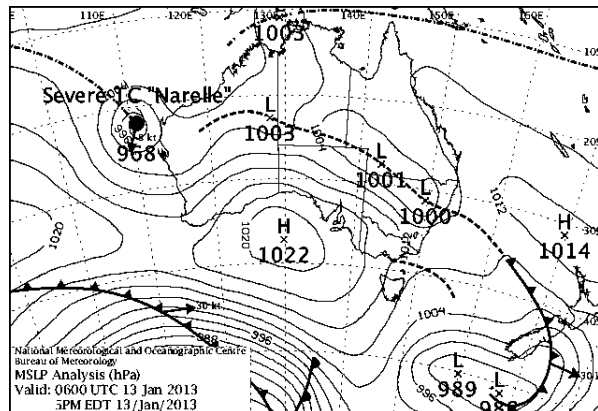


Figure 1: Mean sea-level pressure analysis (in hPa) for 0600 UTC (1700 EDT) on 13 January 2013.

## MODEL DETAILS

To reconstruct the weather conditions across New South Wales on 13 January 2013, a sequence of nested model runs was employed. There were five stages and the nesting was one-way, which means that meteorological information only passed from the coarser resolutions to the higher resolutions. The first stage was a global model run, with a longitude spacing of 0.5625° and a latitude spacing of 0.375°. The second stage had a latitude-longitude grid spacing of 0.11° for a wide region covering Australia and surrounding waters, while maintaining a 20° buffer to the south, 35° to the east and 35° to the north. The third stage (hereafter G36) had a grid spacing of 0.036° (approximately 4.0 km in the north-south direction and 3.4 km in the east-west direction at the latitude of Coonabarabran Airport, 31.333°S). The fourth stage (hereafter G12) had a grid spacing of 0.012° (approximately 1.33 × 1.14 km), with the last stage (hereafter G075) having a grid spacing of 0.0075° (approx. 0.83 × 0.71 km). A parallel version of the last stage was also attempted over the G075 domain, having a finer grid spacing of 0.005° (approximately 0.55 × 0.47 km, hereafter G05). The model boundaries are shown in Figure 2.

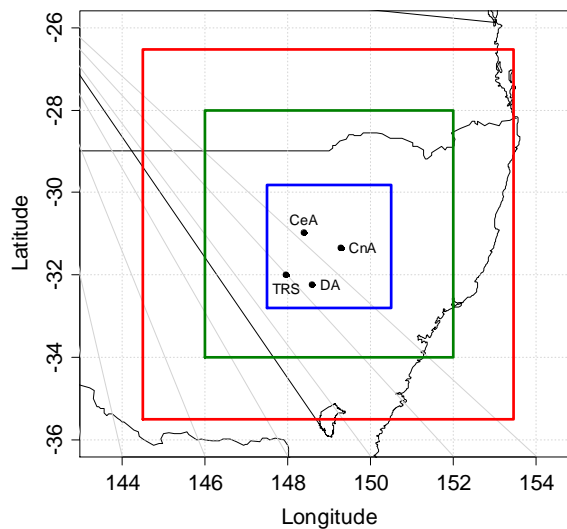
The atmospheric model within ACCESS is non-hydrostatic, with an Arakawa-C grid in the horizontal and a Charney-Phillips grid in the vertical (Puri et al. 2010). Consequently, regridding was required for the calculation of some fire-relevant meteorological quantities, such as wind speed and direction.





All five stages of the modelling used 50 vertical levels, with the lowest model level being approximately 10 metres above the surface for some variables (e.g., the u and v components of the horizontal wind) and approximately 20 metres above the surface for other variables (e.g., potential temperature  $\theta$ ). The top level was around 60 km above sea level. The vertical aspects of the gridding were the same across all five stages; a stretched grid with 10 levels in the lowest 2000 m.

For the coarser resolutions ( $0.036^\circ$  and above), the model used a parameterised convection scheme. The lowest 13 model levels, approximately the lowest 3000 metres of the atmosphere, were treated as being potentially boundary-layer levels. Boundary-layer mixing was parameterised using the one-dimensional scheme of Lock et al. (2000). For the finer resolutions (G12, G075 and G05), the parameterised convection scheme was turned off. Also turned on at these finer resolutions was a sub-grid turbulence scheme applied in three dimensions for model levels 2 to 49. The whole vertical extent of the model domain was in effect treated as being potentially available for the boundary layer to grow into, and in fact boundary-layer depths of up to 5000 metres were seen in the simulations.



**Figure 2: Model domains and resolutions (G36 in red, G12 in green and G075/G05 in blue). The locations of Coonabarabran Airport (CnA), Coonamblie Airport (CeA), Trangie Research Station (TRS) and Dubbo Airport (DA) are indicated. The fire was located in the Warrumbungle National Park, west of Coonabarabran and in the middle of the G05 domain.**

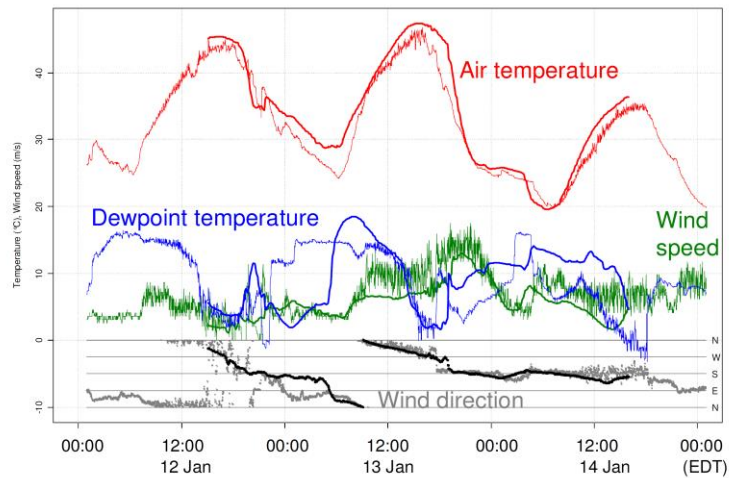
## MODEL VALIDATION

The meteorological quality of the simulations may be assessed in a qualitative sense by direct comparison of model grid-point data against independent observational data from automatic weather stations (AWSs). These observational data are independent in the sense that they have not been used to prepare the global initial state employed at the start of the model numerical integration. The observational data were obtained from the Bureau of Meteorology's Australia Data Archive for Meteorology (ADAM) database.

Figure 3 shows one such comparison for Coonamblie Airport northwest of the fire. As with our previous studies (Fawcett et al. 2012, 2013), we find that air temperatures and wind directions are



generally well-simulated. Dewpoint temperatures are less well-simulated, and peak wind speeds tend to be under-estimated.



**Figure 3: Near-surface (10-metre) wind and screen air/dewpoint temperature data for Coonamble Airport, northwest of the fire on 12 to 14 January 2013. Thick lines / black dots are five-minute model data from the G12 model run, thin lines / grey dots are one-minute-interval Automatic Weather Station (AWS) data. Model data are from the grid point nearest the AWS location.**

An additional route to model verification is through the use of radar data. Figure 4 shows a comparison between the modelled screen-level dewpoint temperature and 10-metre wind field at one point in time (0715 UTC on 13 January) and radar reflectivity observations one minute earlier. Two lines of convection are visible in Figure 4 and Figure 5. The more southerly one travels in a northeasterly direction across the southwest quadrant of the radar's field of view, from around 0530 UTC until 0830 UTC. This feature is well captured by the modelling: in Figure 4a it takes the form of elevated surface dewpoint temperatures (i.e., locally moister air) and divergent surface winds (indicative of downdrafts). Several air-mass boundaries are evident in the modelling: these take the form of dewpoint temperature discontinuities in Figure 4a.

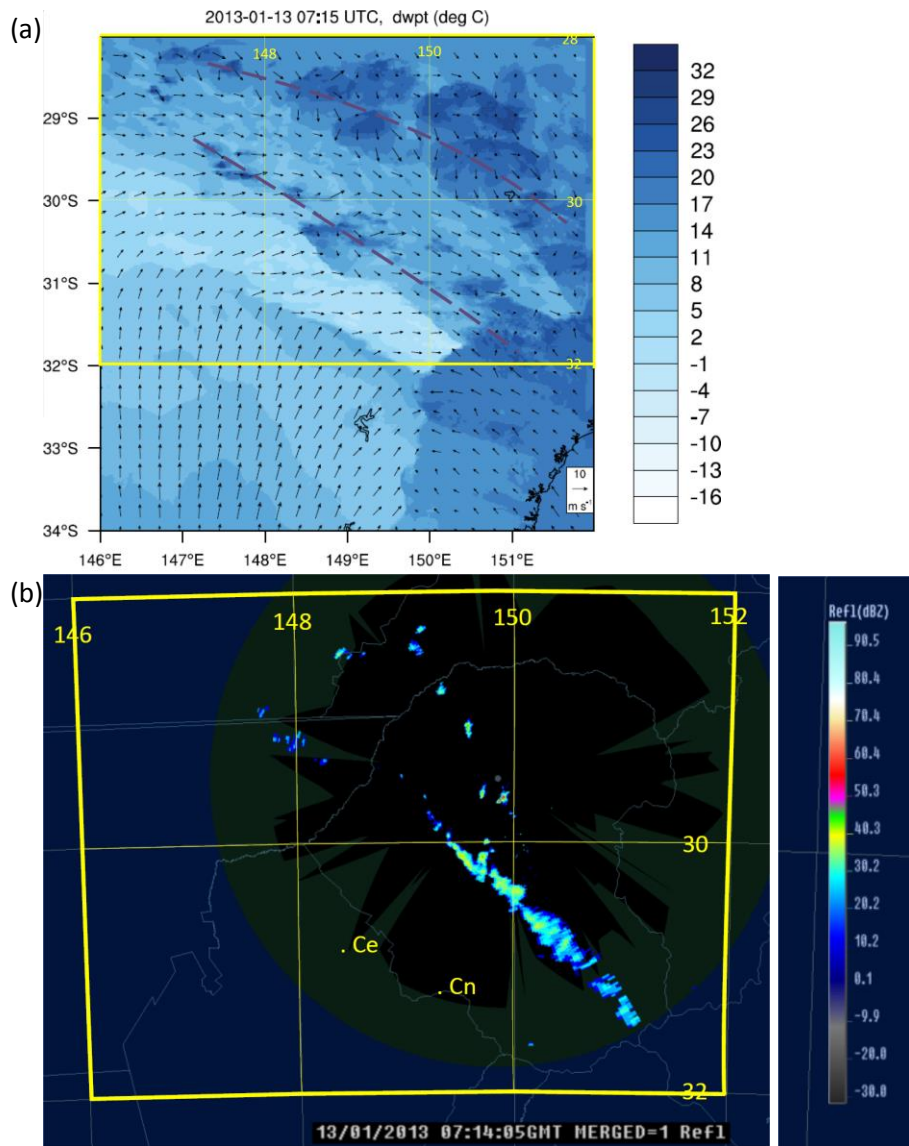


Figure 4: (a) Modelled screen-level dewpoint temperature (in °C) and 10-metre wind vectors for 0715 UTC on 13 January 2013, from the G12 simulation, and (b) merged radar reflectivity (in dBZ) from the Moree radar for 0714 UTC. The location of the Moree radar is indicated by a grey dot in (b). Areas shaded dark blue in (b) are outside the radar's range. The yellow lines denote latitude/longitude lines at 2° intervals for purposes of comparison, as the map projections of the two panels are different. In (b), the locations of Coonabarabran (Cn) and Coonamble (Ce) are indicated. The entire G12 model domain is shown in (a). The dashed lines in (a) denote the approximate positions of the lines of modelled convection.

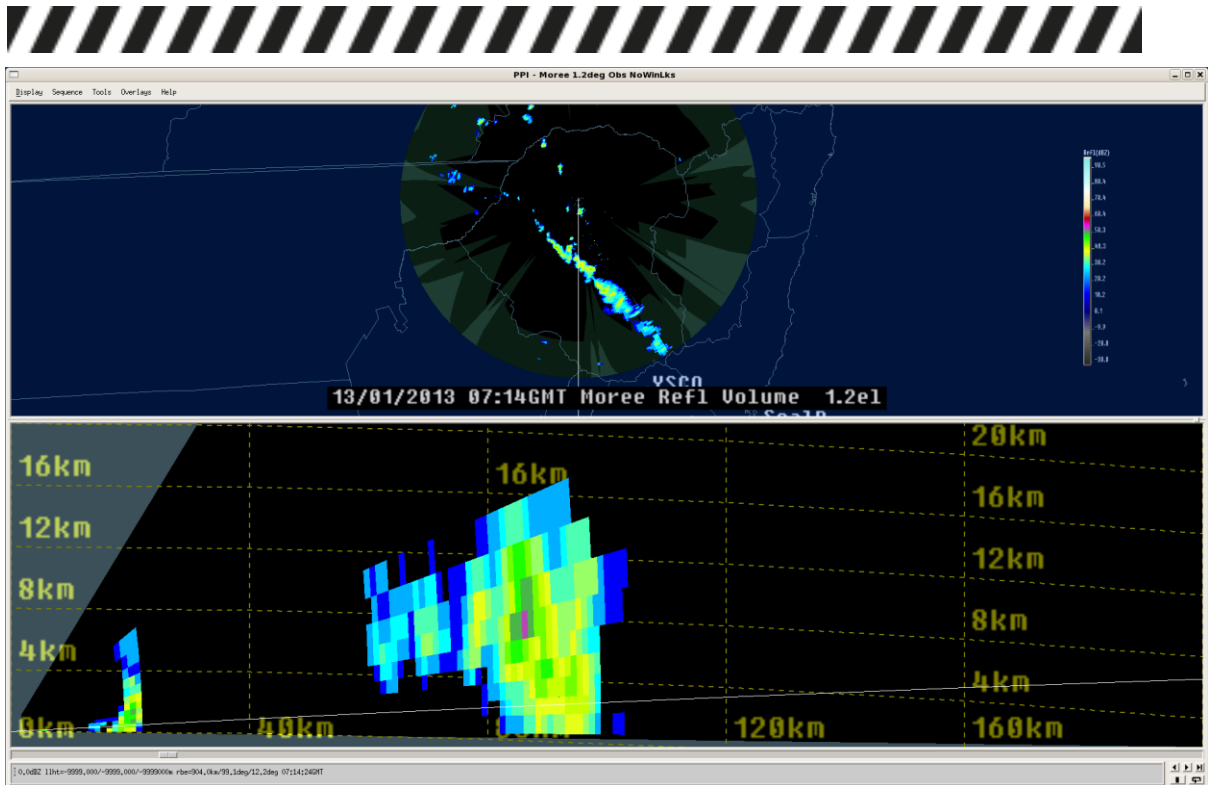
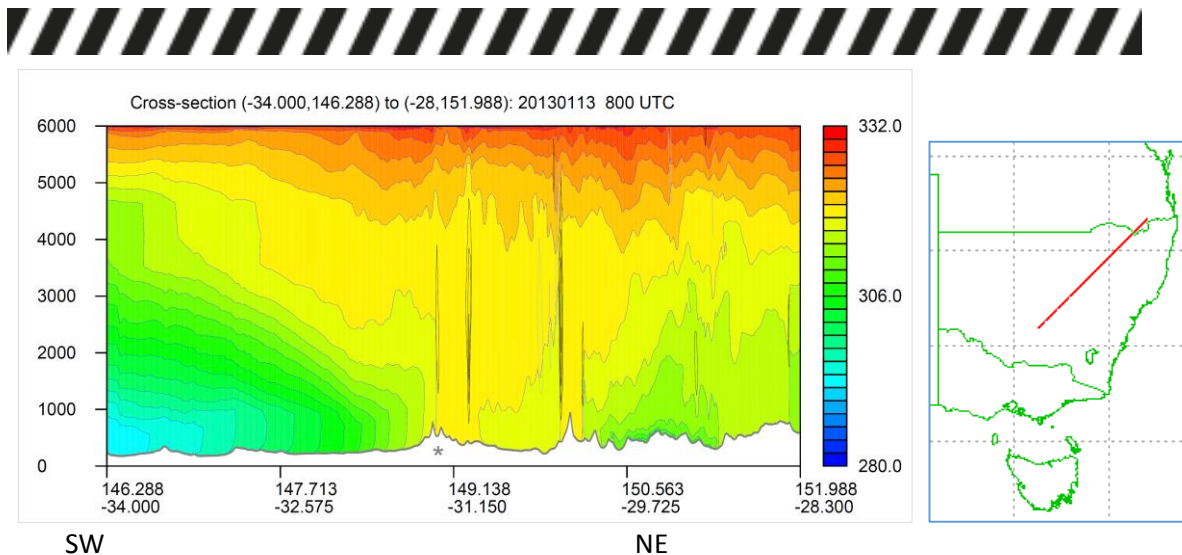


Figure 5: Plan radar reflectivity view (in dBZ) at 1.2° of elevation (upper panel) and vertical cross section (lower panel) looking south from Moree radar at 0714 UTC on 13 January. The horizontal coordinate in the lower panel is distance from the radar, with the curved yellow lines indicating height above the radar. The line of cross-section is indicated by a vertical white line in the upper panel, while the 1.2° elevation cone of the upper panel is indicated by the white line in the lower panel.

Unfortunately, the fire plume near Coonabarabran is sufficiently distant from the two nearest radars (Namoi, around 90 km distant and Moree, around 200 km distant) as to be not well observed by the Bureau's weather-watch radar network.

## DISCUSSION

The ability to suppress fires is highly dependent on a number of weather features. These include air temperature and humidity, wind strength and variability, atmospheric stability, and the strength and timing of wind changes. It is therefore important that these basic meteorological properties be well modelled: this is also an essential ingredient for the successful prediction of fire intensity and spread.



**Figure 6: Vertical cross-section (left) along the line shown in red in the map (right) at 0800 UTC (1900 EDT) on 13 January. This is approximately the time at which the primary wind change passes across the Warrumbungle National Park (indicated by the grey asterisk at around 149°E). The cross-section also passes near Mt Kaputar to the northeast. The colours denote potential temperature (in K), with the black (grey) contours denoting upwards (downwards) vertical velocity (in contour intervals of  $1.5 \text{ m s}^{-1}$ ). The vertical coordinate is height (in metres) above mean sea level.**

The simulations show a complicated array of interacting features. As noted above, the primary feature is the passage of a trough moving northeast across the fireground in the afternoon on 13 January. This trough was accompanied by cooler temperatures (Figure 6) and a wind change. Added to that are the effects of sea breezes from the NSW coast, generated on the day together with the residues of those generated on the previous day.

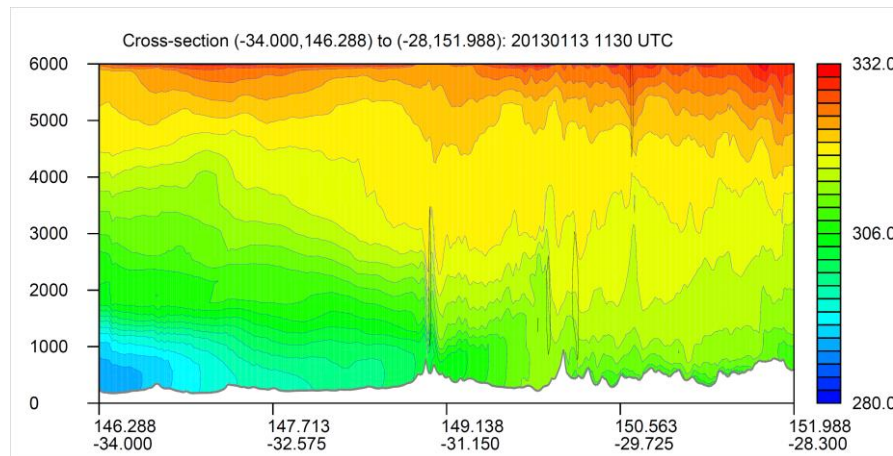
Figure 6 hints at the complexity of the meteorological situation. On the left hand side of the plot (i.e., southwest of the WNP), the cooler temperatures associated with the approaching cool change are clearly evident. Just ahead of the change (i.e., over the WNP itself) is a band of air which is well-mixed to around 4000 metres (yellow shades). This is typical of a hot summer day, but strikingly it is very different from the air masses to the southwest and northeast at this point in the afternoon (the well-mixed layer covered a much broader area earlier in the day). Either side of this band are two updrafts. The left (i.e., southwest) one is associated with the wind change, but the other appears to be associated with a simulated convective downdraft whose northeastern flank causes the third indicated updraft from the left. On the right hand side of the plot the air is also relatively cool, due to (evaporatively cooled) convective downdrafts.

The cool change as it impinges upon the WNP is around 1 km deep and generates updrafts to around  $5 \text{ m s}^{-1}$  in the G12 simulation. In comparison, analogous simulations of the Black Saturday (7 February 2009) change over Victoria (Fawcett et al. 2012) modelled a slightly shallower depth but significantly stronger updrafts to around  $10 \text{ m s}^{-1}$ , while analogous simulations of the Eyre Peninsula (11 January 2005) change (Fawcett et al. 2013) showed updrafts in excess of  $6 \text{ m s}^{-1}$ . Following the change, the modelling indicated the presence of mountain waves over the WNP from around 0900 UTC (2000 EDT) on the 13th until around 2100 UTC (0800 EDT on the 14th). The modelled waves were at their strongest from around 1030 UTC until around 1230 UTC (Figure 7). Such waves could



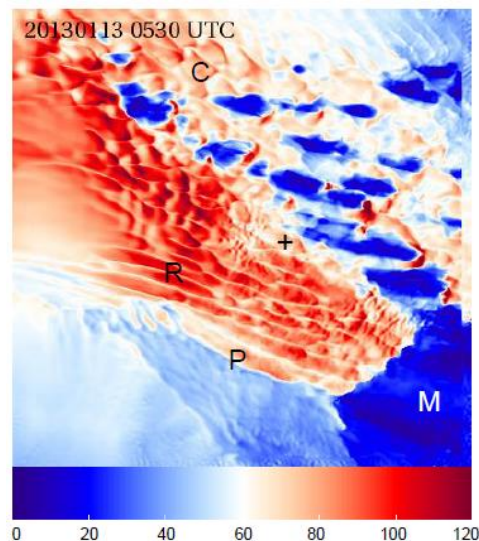


be the cause of strong winds and increased gustiness at the surface, with consequent significance for a going fire underneath them (see for example Kepert and Fawcett 2013). Night-time mountain waves of smaller amplitude were also simulated for the previous night.

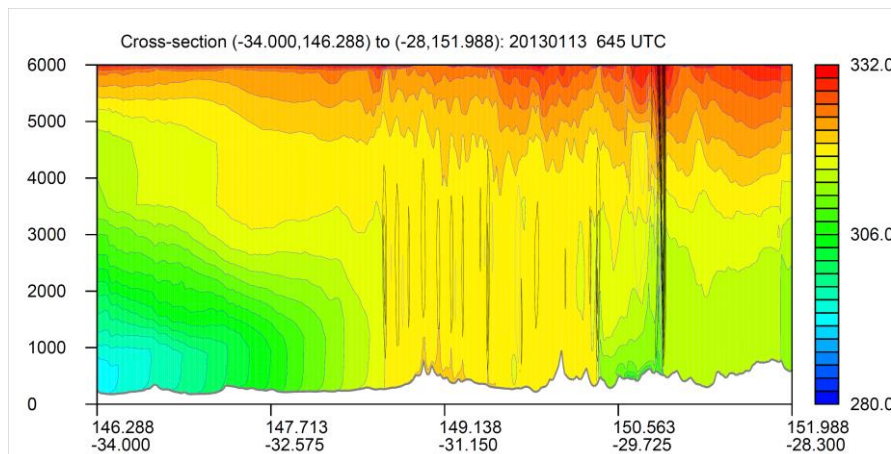


**Figure 7: As per Figure 6 but at 1130 UTC (2230 EDT). Mountain waves with updrafts (black contours) and downdrafts (grey contours) in excess of  $1.5 \text{ m s}^{-1}$  are modelled over the WNP around this time.**

Lastly the model simulates many convective cells, with their attendant wind changes. The simulations suggest a range of features seen in analogous Black Saturday simulations: pre-change boundary-layer rolls (R; see also Figure 9) and cellular convection (C), and small vortices embedded in the primary wind change (P). Some of these features can be seen in Figure 8, which shows notional instantaneous Forest Fire Danger Index values (Mark 5; computed using the technique of Noble et al. 1980) some hours before the change reaches Coonabarabran. The incursion of maritime air into the region is indicated by the letter 'M'.



**Figure 8: Notional instantaneous FFDI values for 0530 UTC (1630 EDT) on 13 January, in the G075 simulation. A drought factor of +10 has been assumed across the entire domain: conditions as observed at Coonabarabran and Coonamble were this dry (M Logan pers. comm.). The region plotted in the figure is that indicated by the blue box in Figure 2. The black cross indicates the location of Coonabarabran Airport. The fire is located in the middle of the plot, a little to the west of the cross.**



**Figure 9: As per Figure 6 but at 0645 UTC (1745 EDT). The regularly spaced updrafts in the middle of the plot suggest the presence of boundary-layer rolls in the pre-change air mass.**

## CONCLUDING REMARKS

The simulations for 13 January 2013 described in this paper contain many meteorological features which could have a significant impact on a going fire. Apart from the general conditions of a hot summer day, there is a significant synoptic cool change with its attendant wind change. Ahead of the change there are indications of boundary-layer rolls which are associated with increased short-term wind direction variability. There are afternoon convective downdrafts proceeding in different directions on shorter spatial scales. After the change, there are suggestions of mountain wave activity over the Warrumbungle National Park. On the larger scale, there is the typical summer sea-breeze proceeding inland from the New South Wales coast, oriented approximately perpendicular to the synoptic change. Such meteorological complexity could pose a significant communication challenge for weather forecasters attempting to convey the relevant details to fire agencies and their staff, and likewise for the fire agencies to make appropriate use of that information while fighting a going fire.

## ACKNOWLEDGEMENTS

This work was partially funded by the Bushfire Cooperative Research Centre, through its Fire Impact and Risk Evaluation – Decision Support Tool (FIRE-DST) project. The assistance of colleagues within The Centre for Australian Weather and Climate Research for their assistance in setting up the ACCESS simulations is also gratefully acknowledged.





## REFERENCES

- Fawcett R J B, Thurston W, Kepert J D and Tory K J 2012. Modelling the fire weather of Black Saturday. Proceedings of Bushfire CRC & AFAC 2012 Conference Research Forum, 28 August 2012, Perth, Australia (eds. R P Thornton and L J Wright). Bushfire CRC. pp135-149.
- Fawcett R J B, Thurston W, Kepert J D and Tory K J 2013. The Eyre Peninsula Fire of 11 January 2005: an ACCESS case study. Proceedings of Bushfire CRC & AFAC 2013 Conference Research Forum, 2 September 2013, Melbourne, Australia (ed. L J Wright). Bushfire CRC. pp82-89.
- Jones D A, Wang W and Fawcett R 2009. High-quality spatial climate data-sets for Australia. Australian Meteorological and Oceanographic Journal, 58, 233-248.
- Kepert J D and Fawcett R J B 2013. Meteorological aspects of the Margaret River fires of November 2011. Proceedings of the 20th International Congress on Modelling and Simulation, Adelaide, Australia, 1–6 December 2013. pp180-186.
- Lock A P, Brown A R, Bush M R, Martin G M and Smith R N B 2000. A new boundary layer mixing scheme. Part I. Scheme description and single-column model tests. Quarterly Journal of the Royal Meteorological Society, 128, 3189-3199.
- Noble I R, Bary G A V and Gill AM 1980: McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology, 5, 201-203.
- NSW RFS 2013: Ferocious: The Wambelong fire. Bush Fire Bulletin, 35(1), 8-11.
- Puri K and coauthors 2010. Preliminary results from Numerical Weather Prediction implementation of ACCESS. CAWCR Research Letters, 5, 15-22. Obtained from <http://cawcr.gov.au/publications/researchletters.php> .