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EFFECT OF PRESCRIBED BURNING ON WILDFIRE SEVERITY - A LANDSCAPE CASE STUDY FROM THE 2003 FIRES IN VICTORIA

Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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INTRODUCTION

This study examined the effect of previous fuel reduction burning (FRB) on the severity of the 1 million ha+ 2003 Alpine Fire in eastern Victoria, which was one of the most extensive and severe fires to have occurred in south-eastern Australia in the preceding century. Over one million hectares of largely forests, woodlands and alpine vegetation was burnt in January and February 2003 in the state of Victoria, and another contiguous 600,000 ha was burnt in New South Wales and the Australian Capital Territory, making these the most extensive fires in the area since 1939.

Some of the unusual features of this fire were that it burnt a large contiguous area stretching 180 km from east to west and 110 km from north to south in Victoria, and it burnt over a full two-month period. The size of the fire and the severity of the seasonal conditions (Bureau of Meteorology 2003) meant that about 49 per cent of the area burnt resulted in complete overstorey canopy removal, either through crown fire or scorching and resultant leaf loss. Very few areas remained unburnt within the perimeter of the fire. As the burnt area contained 100+ recent fuel reduction burns and wildfires (last 10 years, Fig. 1), this posed a rare opportunity to assess the effectiveness of prescribed burning on such a large scale and subjected to such high-intensity fires.

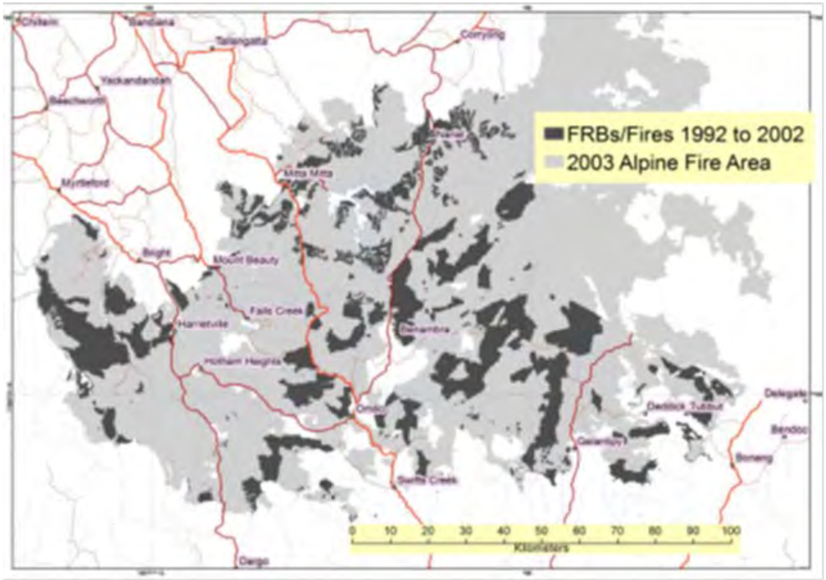

FIGURE 1. EXTENT AND LOCATION OF THE PRESCRIBED FIRES AND WILDFIRES THAT HAD OCCURRED IN THE 10 YEARS PRIOR TO 2003 AND WITHIN THE 2003 ALPINE FIRE AREA IN VICTORIA.

Various Australian researchers had looked at individual fire events where previous fuel reduction modified fire behaviour (Cheney 2010, Rawson et al. 1985, Billing 1981, Grant & Wouters 1993, McCaw 2010, Underwood *et al.* 1985). Cheney (1996) had earlier summarised generalised findings in relation to fuel reduction effectiveness in fire management around Australia, and various researchers had looked at the generalised effects of fuel reduction on both fuels and ecology (Bradstock et al. 1998, Gill and McCarthy 1998, Gill 2009, Adams and Attiwill 2011). Project Vesta (Gould et al. 2007) tested fire behaviour experimentally in dry eucalypt forests in Western Australia, and found some specific effects of fuel age on potentially reducing likely wildfire behaviour. In Victoria McCarthy and Tolhurst (2001) looked at the effect of previous fuel reduction burning on the suppression of 100+ fires statewide, and modelled the likely effects of fuel age, fuel hazard and fire weather on possible suppression assistance.

Internationally Fernandes and Bothelo (2003) reviewed fuel reduction burning effectiveness around the most fire prone parts of the world. This review concluded that the best effects of fuel reduction burning on decreasing wildfire severity were generally reported for the first two to four– years following planned burning, but that current results were not conclusive on longer-term effects. They also reported that there were few studies to comprehensively examine this issue, and that there was a definite need for well-designed scientific studies to better study fuel reduction effects at the landscape level.

The main objective of this study was to examine areas affected by previous fuel reduction within the million hectare burnt area, to see if they reduced fire behaviour and potentially reduced suppression difficulty, compared with similar areas with fuels mostly unchanged by recent burning. A further objective of this analysis was to identify the principal factors responsible for determining fire severity differences at a landscape level.

METHODS

Sixty-five paired observations (130 total) of fire severity were completed across the broad fire area using GIS analysis (ArcGIS 3.x, ESRI 2000). The impact of the fire in areas previously burnt (by either prescribed burning or wildfire) was undertaken by comparing the fire severity within a previously burnt area with a comparative area nearby (hence the paired observations). The comparative area was chosen to be similar in its size, vegetation, elevation and time of burning by the 2003 wildfire. Selection was based on paired areas where there was the best reliability of them being burnt at the same time, and under the same weather conditions (Fig. 2).

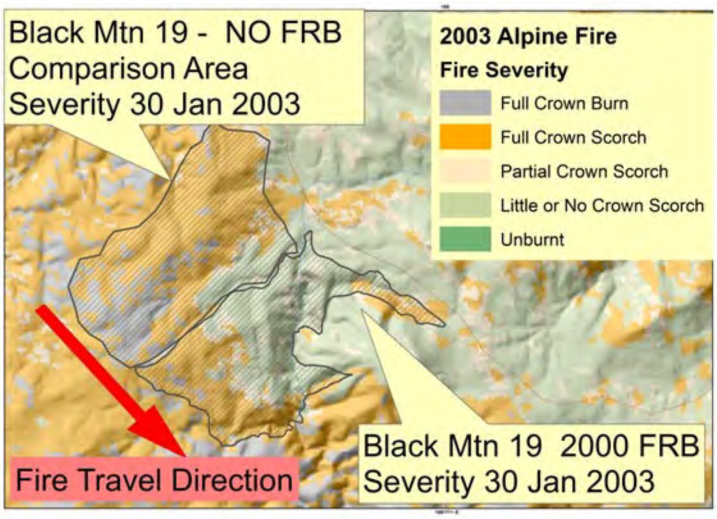

FIGURE 2. EXAMPLE OF PAIRED POLYGONS FOR FIRE SEVERITY ANALYSIS – POLYGON AFFECTED BY PREVIOUS FRB AND ADJACENT POLYGON UNAFFECTED BY PREVIOUS FRB

A Fire Severity Index (FSI) was calculated (for each area of each fire severity class) as a single indicator of fire severity. This FSI was calculated using the proportion of fire severity in each of the four severity classes (mentioned previously) within the sampled polygons. A weighting of 1.0 was applied to Full Crown Burn, 0.7 to Severe (Full) Crown Scorch, 0.3 to Moderate (Partial) Crown Scorch and 0.05 to Light Scorch/Unburnt areas to calculate the FSI.

$$FSI = 0.2256 + 0.00778 FDIwt + 0.047 \ln FIREage - 0.118 AspectNW$$

($n=142$, $p<0.001$, $r^2=0.4343$)

where: *FSI* = Fire Severity Index
FDIwt = weighted Forest Fire Danger Index
FIREage = time since last fire in area (yrs)
AspectNW = proportion of area with a northerly or westerly aspect

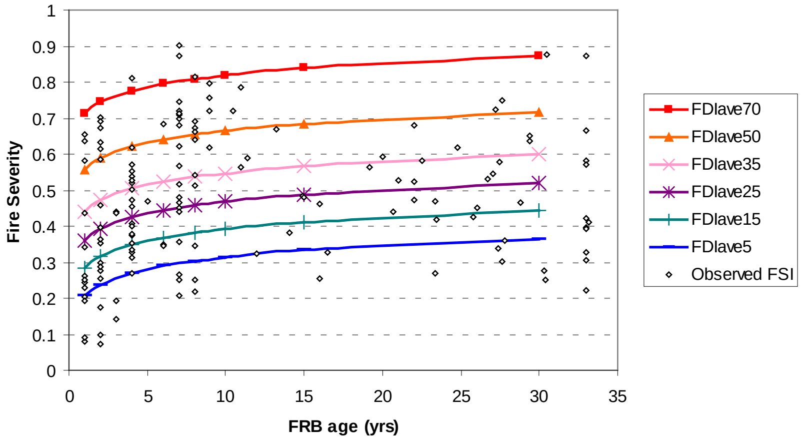

FIGURE 3. COMBINED EFFECT OF FIRE DANGER INDEX AND FIRE AGE ON FIRE SEVERITY.

The most important finding was that the reduction in fire severity and suppression assistance effects of previous fuel-reduction burning started to decline substantially when the FFDI exceeded 50. Above FFDI 50, landscape-scale fires became 'weather-dominated' and variations in fuel and topography became less important to continued fire spread.

The weather conditions under which fuels, the fire, topography, or the weather itself dominate fire behaviour can be shown relative to the McArthur's (1967, 1977) Forest Fire Danger Index (Fig. 4). This interplay of dominance could be expressed in terms of the amount of energy being contributed by each factor relative to the others. In the case of topography and unstable weather conditions, it represents the lack of resistance to fire growth which results in the need for less energy to be provided by the fire, fuel or weather to enable the fire to grow rapidly.

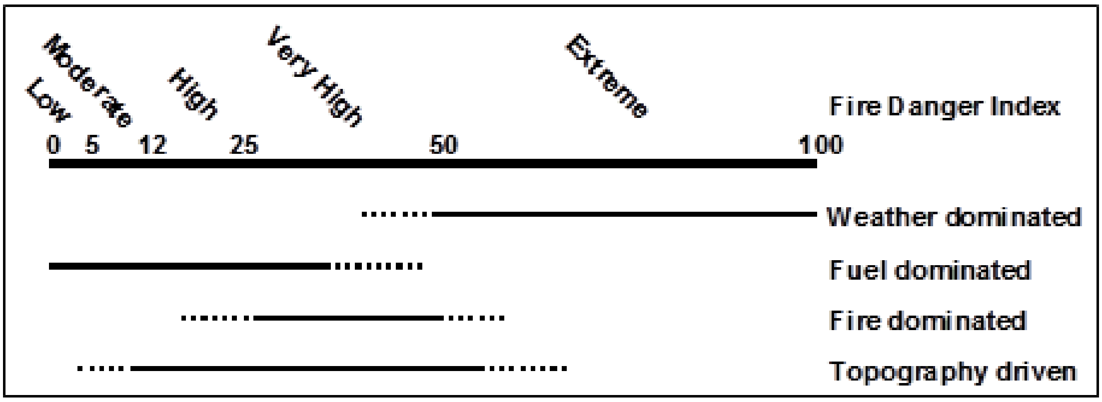

FIGURE 4. FIRE WEATHER CONDITIONS (MCARTHUR 1967) IN WHICH DIFFERENT FACTORS MAY DOMINATE FIRE BEHAVIOUR (TOLHURST 2004).

Some fire-severity reduction effects were still evident for FRBs up to 10 years old, but there was almost no evidence of FRBs older than 10 years having any effect on fire-severity. The greatest effects of previous FRB in reducing wildfire severity and in assisting fire suppression occurred when (1) the FFDI fell to 25 or less (late in the evening and overnight); (2) the age of the FRB was less than 3 years (i.e. when all three components of fuel—surface, bark and elevated material—were still substantially reduced). This gave substantial confirmation to the trends found in an earlier study of the effectiveness of fuel reduction burning from 2001 (Fig 5 and Fig 6).

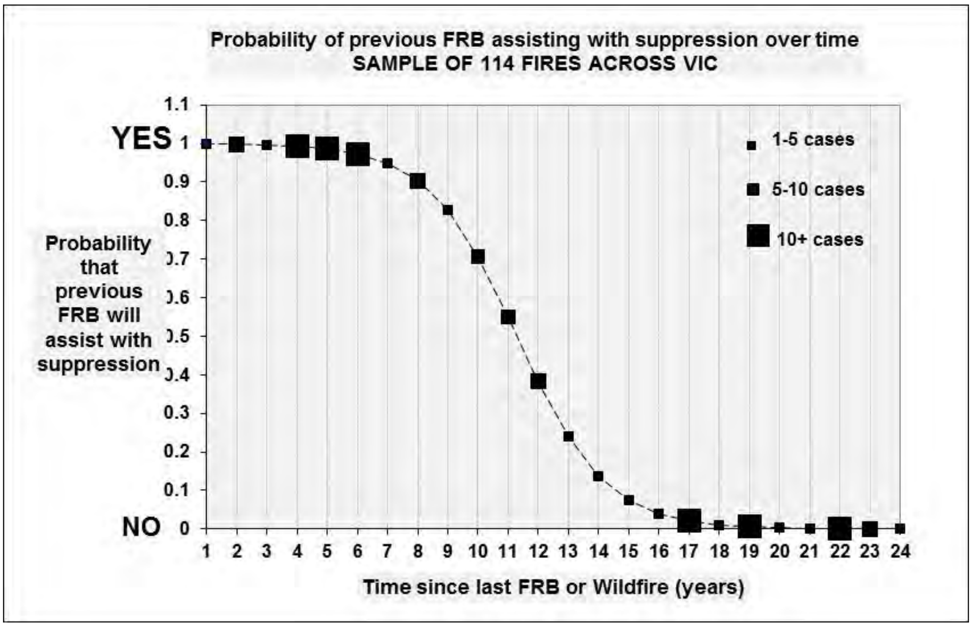

FIGURE 5. PROBABILITY OF A PREVIOUS FRB ASSISTING WITH SUPPRESSION OF A SUBSEQUENT WILDFIRE ON THE SAME SITE, AS A FUNCTION OF TIME SINCE THE LAST FRB OR WILDFIRE. LOGISTIC MODEL FROM MCCARTHY AND TOLHURST (2001) – SAMPLE OF 114 FIRES FROM ACROSS VICTORIA.

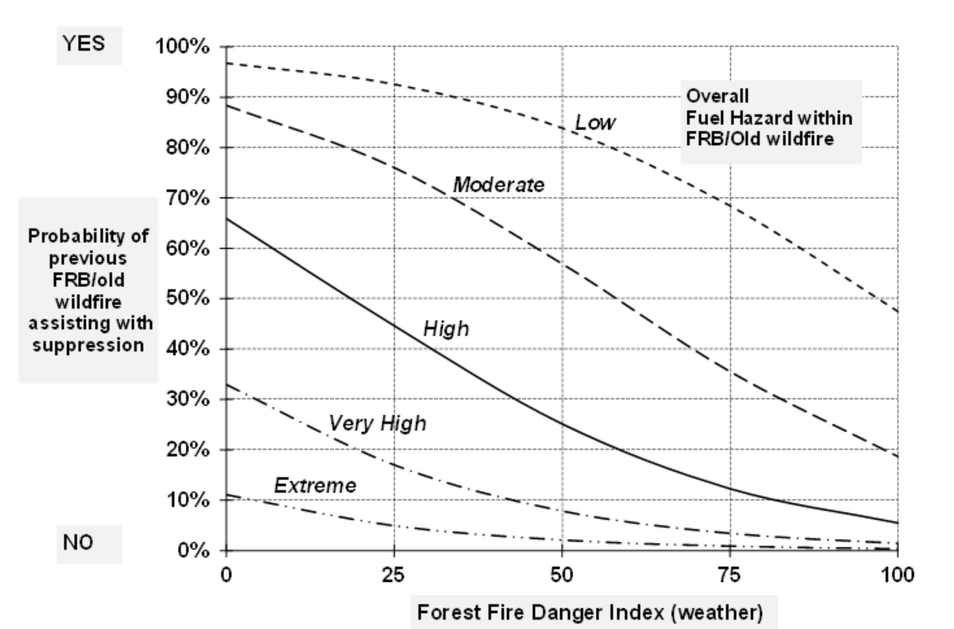

FIGURE 6. RELATIONSHIP BETWEEN FRB ASSISTANCE WITH SUBSEQUENT SUPPRESSION, AND FUEL AND WEATHER CONDITIONS (MCCARTHY AND TOLHURST 2001).

FRBs up to 10 years old also had measurable effects on increasing burnt area patchiness and decreasing canopy loss, both of which have ecological implications (Figs. 7 and 8).

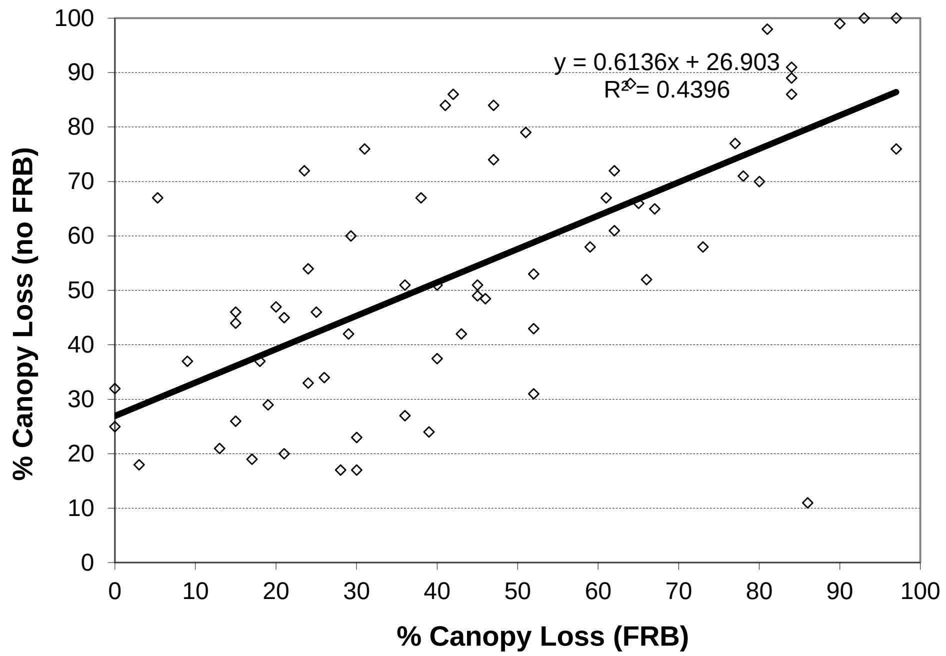

FIGURE 7. COMPARISON IN THE PERCENTAGE OF AREA WITH PATCHILY BURNT BETWEEN THE AREAS BURNT IN THE 10 YEARS BEFORE 2003 (FRB) AND THOSE AREAS LONGER UNBURNT (NO FRB).

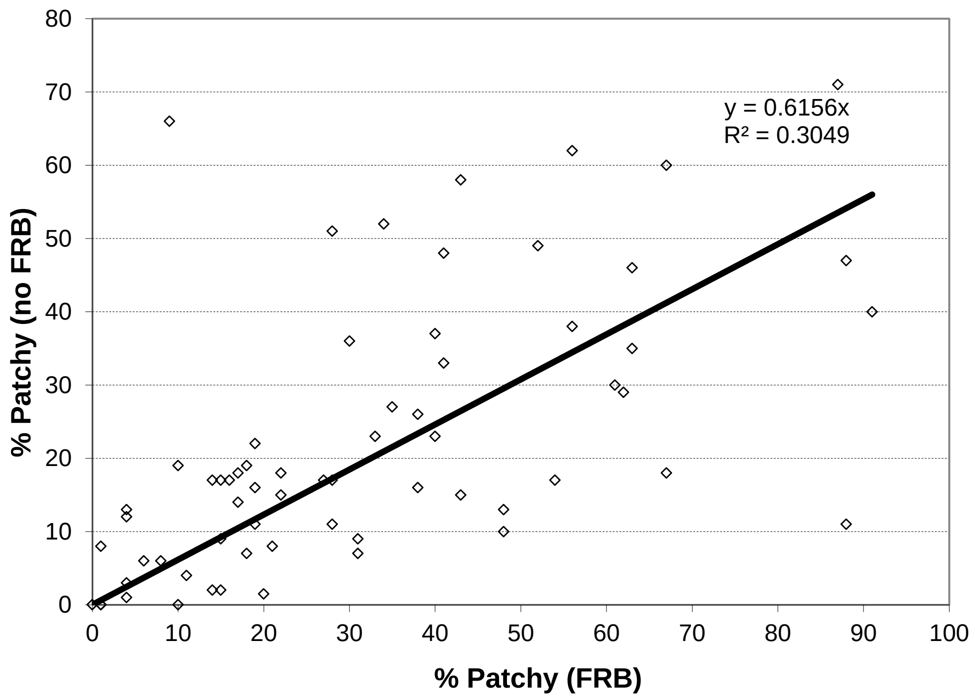

FIGURE 8. COMPARISON IN THE PERCENTAGE OF AREA WITH COMPLETE CANOPY LOSS BETWEEN THE AREAS BURNT IN THE 10 YEARS BEFORE 2003 (FRB) AND THOSE AREAS LONGER UNBURNT (NO FRB).

At the other end of the fire severity range, complete canopy loss was more common in the long-unburnt areas. The intercept in Figure 20 shows no complete canopy loss in the recently burnt areas (previous 10 years), compared with 27 per cent complete canopy loss in the long unburnt areas. The benefit of recent burning decreased as the fire intensity and hence severity increased, so that when there was 100 per cent of the burnt area with complete canopy loss in the long-unburnt areas, there was also 100 per cent complete canopy loss in the recently burnt areas as well. The main benefit in reducing fire severity was therefore greatest under less severe fire behaviour. As fire behaviour decreased, the benefit to the recently burnt area became increasingly great.

DISCUSSION

The broad scatter of fire severity data shown here indicates that fire severity at any point in the landscape is a result of many interacting factors. This scatter of data also indicates that it would be possible to selectively choose examples (case studies) to support a range of arguments, extending from prescribed burning being extremely effective in reducing fire severity, through to arguments that prescribed burning is completely ineffective at reducing fire severity, and not worth the cost and effort to undertake. This demonstrates a potential limitation in the selective case-study approach of assessing the effectiveness of prescribed burning in reducing fire severity (Billing 1981, Underwood et al. 1985, Grant and Wouters 1993, Cheney 2010). Selective case studies may present 'successful' cases, while not reporting on 'unsuccessful' cases. This study provided a rare opportunity to assess the effectiveness of prescribed burning in a single event, but with many independent cases, burnt under a wide range of weather and fire intensity conditions. Thus it allowed both 'successful' and 'unsuccessful' cases to be studied simultaneously.

An earlier study (McCarthy & Tolhurst 1998) of 50 fires showed that the two main factors affecting the effectiveness of first attack suppression was the Forest Fire Danger Index (the fire weather) and the Overall Fuel Hazard level (McCarthy et al. 1999). In this study, there were no pre-fire fuel assessments available in either the recently burnt sites or the longer unburnt sites. The best factors correlated to fuel hazard levels were time since last fire (FIREage), broad vegetation type (HEDMS), aspect and to some extent elevation.

A more recent study on the effectiveness of broadscale fuel reduction burning in assisting with wildfire control in Victoria (McCarthy & Tolhurst 2001) concluded that fuel reduction burning had been effective in assisting with fire control. Results of this study (114 fires) indicated that areas which had been burnt for fuel management, had a measurable effect on assisting in fire suppressing for up to about 15 years, but began to become less helpful after about age 10–11 (Fig. 2).

As with the first attack effectiveness study (McCarthy & Tolhurst 1998), the effectiveness of previous burning had been found to be dependent on the Forest Fire Danger Index and the Overall Fuel Hazard levels. These results reinforce the findings of this study, where there has been a measurable reduction in fire severity in areas fuel reduced less than 10 years previously. The dryness of the seasonal conditions (driest period in 100 years of records) may have been the cause for the difference in the period of effective reduction in fire severity being only 10 years in this study compared with 15 years in the 2001 study. This indicates that the effectiveness of previous burning was probably affected by the seasonal dryness, as well as the scale of the fire impacting on the fuel reduced area.

Despite the limitations of the data, there was still a clear indication that the major factors affecting fire severity were the Forest Fire Danger Index (fire weather, including long and short-term drought effects), the time since last fire (most probably a surrogate for fuel hazard levels), and topographic aspect (also probably fuel related). The importance of assessing the effectiveness of prescribed burning in reducing fire severity, and in assisting fire suppression, must be made in the context of the factors dominating fire behaviour at any particular time. Whilst recent burning locally reduced the amount of total canopy loss and increased the abundance of unburnt or patchily burnt areas, these effects are less likely when the fire is weather dominated.

This study provides fire managers planning rotational landscape FRB with important information on likely effects of the burning on fire severity. Particularly it indicates: (1) how frequently fuel reduction burning must be undertaken to remain effective at reducing fire severity; (2) that the most effective and longest lasting fuel reduction burns remove both surface and elevated fuels (most effectively achieved on northern and western aspects); and (3) that above FFDI 50, fires tend to become 'weather-dominated' and variations in fuel (including even recent FRBs) become less important in restricting fire spread.

CONCLUSIONS

Previous fuel reduction burning significantly reduced the severity of the 2003 fire. Fuel reduced areas less than 10 years old on average experienced lower fire severity.

Fire severity across the 2003 fire area was modelled using a Fire Severity Index, the variations in which were best explained by fire weather (FDI), the age of the previous fire, and the amount of NW aspect. This clearly indicated that, at FDIs greater than 50, even recent fuel reduction burns may not have much effect on reducing fire severity. At these higher FDIs, major fire runs in the 2003 fire area became weather-dominated, and variations in fuel became much less important to determining fire severity.

Recently fuel reduced areas (<10 years) contributed a significant proportion of the final fire boundary, confirming the importance of these areas to fire control.

Very recent fuel reduction burns (three years old or less) had the greatest effect on reducing fire severity. This accords with previous studies of prescribed burn age and effectiveness. It is likely that this effect is due to surface fuels, in addition to bark and elevated fuels, being also substantially reduced for this immediate post fire period.

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WIND SPEED REDUCTION INDUCED BY POST-FIRE VEGETATION REGROWTH

Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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ABSTRACT

In the current suite of operational fire spread models, wind speeds measured in the open environment (above the vegetation layer) are modified to represent wind speeds at `mid-flame' height using adjustment factors. In general, these adjustment factors assume constant vertical wind speed profiles throughout the vegetation layer. However, empirical studies have shown that wind speeds beneath canopies can vary significantly with height above ground as well as with forest type and prevailing wind speed. Empirical wind reduction profiles have been developed for a number of different forest types in flat terrain using data collected across Victoria, Australia.

The present research aims to extend these empirical studies to better understand the impacts of topography and post-fire vegetation regrowth on the reduction of wind speeds beneath the canopy. Wind data collected over fire affected regions of rugged terrain in South Eastern Australia are used to analyse wind speed reduction induced by post-fire regrowth and complex topography. A secondary study is used to analyse wind speed reduction caused by Radiata pine plantation in undulating terrain.

Results of this study suggest that empirical wind reduction profiles perform well at the broader landscape-scale, i.e. ridge tops and valley floors. However, more complex topographical features appear to have a compounding affect on wind speed reduction within rugged terrain. Through better understanding of wind speed reduction beneath the canopy across landscapes from mountainous ranges through to flat plains, wind speed reduction models for bushfire spread prediction can be adapted to incorporate the variation observed in vertical wind speed profiles within the vegetation layer.

1 INTRODUCTION

Vertical wind profiles within the boundary layer are most often described using a logarithmic profile (Touma, 1977). This profile becomes disturbed near the surface due to roughness of varying lengths, from topographical scales down to vegetation (Finnigan, 2000; Belcher et al., 2012). These disturbances close to the ground, or at `mid-flame height' are the wind patterns that drive surface bushfires beneath the canopy. In the current suite of fire spread prediction models, wind speeds measured in the open environment (with no vegetation or above the vegetation layer) are translated to predict wind speeds within forests or vegetation using adjustment factors. The `wind reduction factor' (WRF) (Cionco, 1972; Rothermel, 1972) and `wind adjustment factor' (WAF) (Andrews, 2012) are defined empirically for a number of structural vegetation features including crown ratios and vegetation age.

Both the WRF and WAF assume the wind reduction profile to be constant throughout the vegetation layer, whereas Moon et al. (2013) presented empirical wind speed profiles for different forest types, showing that wind speed profiles within the canopy were in fact non-constant. These wind profiles varied considerably with prevailing wind speeds as well as height above ground within the canopy. Cruz and Alexander (2013) noted that aside from topographical features, the principal drivers behind the behaviour of spreading fires are fuel moisture and wind speed; it can therefore be asserted that along-side the recognition by VanWagner (1989) that the prediction of surface fires may well be more difficult than that of crown fires due to the complexity of understorey fuels, the variation of wind fields within the vegetation layer adds further complications to the modelling of surface fires spreading beneath the canopy.

Since fire spread prediction models are not immune to the effects of error accumulation, and it has been noted that the main sources of errors in fire model predictions include input data error (Cruz and Alexander, 2013), it is within the interest of the fire research industry to better understand, and therefore model, the variability of wind fields within vegetation layers. Recent work (Moon et al., 2016) has shown that wind reduction profiles within the canopy depend upon open wind speeds and height within the layer. An empirical GAMS (general algebraic modelling system) model is under development to model wind reduction profiles under various conditions.

This new model for wind reduction profiles is based upon data collected in flat terrain areas, where the impacts of topography were intentionally minimised. Although there is a significant body of work on wind behaviour over topographical features such as hills, escarpments or wind breaks (Holmes et al., 1997; Glanville and Kwok, 1997; Cleugh, 2002; Allen, 2006), these studies focus on the wind behaviour and profiles above such features or in areas of minimal vegetation, rather than the impacts of such features on the wind fields experienced on the ground, especially within the vegetation layer.

This study aims to extend the work of Moon et al. (2013, 2016) to understand the impacts of vegetation regrowth on wind speeds experienced within the canopy over complex terrain. Wind data collected across sites in South-Eastern Australia are used to evaluate the applicability of the empirical wind profiles described in Moon et al. (2013, 2016) to rugged landscapes, particularly valley structures within mountain ranges and ridge top spurs across undulating hills.

2 DATA AND METHODS

2.1 CASE STUDIES

In this research, wind data were collected across two case studies. Davis Vantage Pro 2 Portable Automatic Weather Stations (PAWS) with cup anemometers were used to collect wind data at a height of 5 metres above ground level. These stations also collected data on temperature, relative humidity and solar radiation. In both case studies, the weather stations were located within vegetated areas.

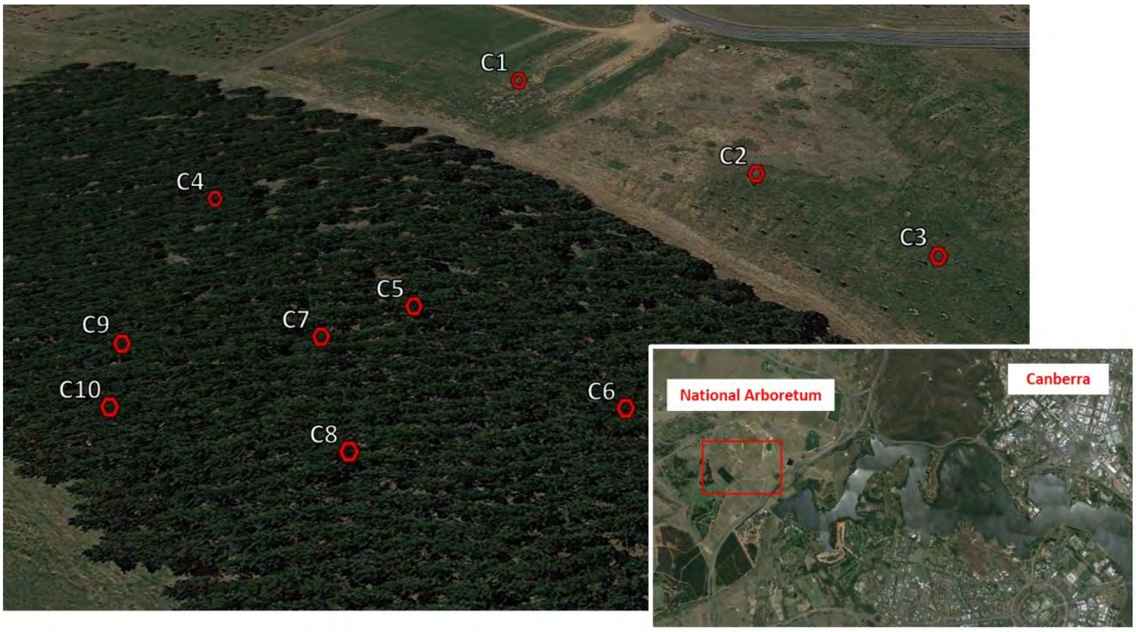
In 2003, much of the mountainous region west of Canberra was devastated by bushfires. The fires spread rapidly from the Brindabella Ranges through to the edges of the city, exhibiting extreme fire behaviour which has been extensively documented (e.g. McRae, 2004; Sharples et al., 2012). The Flea Creek Valley (FCV) area (approximately 70km west of Canberra) was heavily burnt by the McIntyres Hut fire which ignited along the Goodradigbee River. The North-South valley runs approximately perpendicular to the dominant prevailing West-North-Westerly (WNW) winds.

In 2007, after 4 years of post-fire regrowth, wind data were collected across a 3-4km East-West transect of the valley (Figure 1, A). Sharples et al. (2010) describes this data and the relationship between the wind behaviours observed and potential for extreme fire behaviours such as those experienced in 2003. In 2014, after 11 years of uninterrupted vegetation regrowth, wind data were collected along the same transect of Flea Creek Valley (Figure 1, B). Both data sets were collected over prolonged periods throughout each year; 9 months from January to October in 2007, and 9 months from April to December in 2014.

The vegetation observed in 2007 would be classed as 'open regrowth forest (30 year old)' as used in Moon et al (2016), or `regrowth open forest' used in Moon et al. (2013). Whereas, the vegetation observed in 2014 would be more akin to the 'open regrowth forest (110 year old)' referred to by Moon et al. (2016), or the `mature open forest' used in Moon et al. (2013). Both sets of data were collected in forests with average heights considerably lower than reported by Moon et al. (2016) (approximately 10 -15m, rather than 25 - 35m).

FIGURE 1 LOCATIONS OF DATA COLLECTION SITES AT FLEA CREEK VALLEY IN 2014 (A) AND 2007 (B).

In 2015, eleven weather stations were positioned on a spur along one of the highest ridge lines at the National Arboretum Canberra (NAC) for 9 months from April to December. The ridge line again runs approximately perpendicular to the dominant WNW prevailing winds experienced in the region. Three of the stations were located on a cleared area of the ridge line; one on the ridge itself and two on the leeward slope to the dominant prevailing winds (Figure 2, C1 to C3). The remaining eight stations were located within an adjacent Radiata pine stand (Figure 2, C4 to C10). Three of these eight stations were located along a parallel transect to those on the clear slope (C4 to C6). The vegetation at the National Arboretum is equivalent to the `Pine plantation' class used by Moon et al. (2013, 2016), with average vegetation height around 15m as opposed to



23m.

FIGURE 2 LOCATIONS OF DATA COLLECTION SITES AT THE NATIONAL ARBORETUM CANBERRA IN 2015.

2.2 EMPIRICAL WIND PROFILES

Moon et al. (2013, 2016) describe the collection and analysis of wind data collected across seven different vegetation types in Victoria, Australia. Data were collected at heights of 1, 2, 5, 10 and 15m using guyed-masts with horizontal cup anemometers. At each site, average 30-minute wind speed measurements were taken between four closely located weather stations, with a fifth station located at a nearby `open environment' site. Data were collected over approximate month long periods at each site.

To avoid the effects of topography, the stations were located in flat areas, and all stations were at least 20 times the vegetation height away from the vegetation boundary to avoid edge effects. To account for the accuracy of the cup anemometers, wind speeds below 1 km h^{-1} (≈ 0.278 m s^{-1}) were excluded from the analysis presented in Moon et al. (2016). In this study, wind speed below 0.4 m s^{-1} (≈ 1.4 km h^{-1}) were excluded, again to account for the accuracy of the instrumentation.

	≥ 0.4 m s^{-1}	≥ 2 m s^{-1}	≥ 4 m s^{-1}
A1	1.2090	2.6781	4.4435
A2	0.5873	0.6480	0.7660
A3	0.9092	1.1160	1.5614
A4	0.6243	0.7307	1.0115
A5	0.7178	0.9981	1.3709
B1	1.2583	2.6655	4.2722
B2	0.8484	1.3801	2.5013
B3	0.9670	1.3848	1.8590
B4	0.8699	1.3225	1.5974
B5	0.8365	1.2587	1.6217
C1	3.8754	5.2196	6.5378
C2	2.7591	3.4209	4.2462
C3	2.2523	2.6587	3.1843
C4	0.5913	0.5921	0.5968
C5	0.8171	0.8215	0.8342
C6	0.6547	0.6545	0.6529

TABLE 1 AVERAGE WIND SPEEDS FOR EACH SITE ACROSS FCV (A AND B) AN THE NAC ©, AT OPEN WIND SPEED THRESHOLDS.

The reduction of wind speed induced by each forest type was calculated as the wind speed measured within the vegetation, U_V, divided by the wind speed measured at the nearby `open' site, U_O, and terms Relative Wind Speed, RWS (Moon et al., 2013, 2016);

$RWS = U_V/U_O$

Relative wind speeds were calculated under increasing minimum prevailing wind speed thresholds (observed at the `open' ridge top sites) to understand the changes in RWS as prevailing wind speeds increased; $T \geq 0.4$ m $s^{-1} \approx 1.4$ km h^{-1}, $T \geq 2$ m $s^{-1} \approx 7.2$ km h^{-1} and $T \geq 4$ m $s^{-1} \approx 14.4$ km h^{-1}. Average wind speeds for each station, at each wind speed threshold are shown in Table 1. Relative wind speed results for each study site were compared to expected RWS values given in Moon et al. (2013, Fig. 3) for 10 to 20 km h^{-1} winds, as well as the wind speed profiles and results shown in Moon et al. (2016, Fig. 2 and 3).

At Flea Creek Valley, the 2014 winds were considered relative to 2007 winds where vegetation already existed. Therefore, the expected relative wind speed between the two years was calculated by taking the ratio of RWS for the regrowth open forest and RWS for the mature open forest. For the normalised height of 0.3 (i.e. at 5m in 15m high vegetation), the relative wind speeds shown in Moon et al. (2013, Fig. 3) were both 0.11 for regrowth and mature open forest, for 10-20 km h^{-1} open winds. If height was read directly at 5m, the RWS values were 0.11 and 0.09 for regrowth and mature open forest, respectively. Thus, using this direct 5m vegetation height, the RWS from regrowth to mature open forest was approximately 0.82, while considering the normalised height the RWS was 1.00. In addition, when considering the results shown in Moon et al. (2016, Fig. 2), the RWS for both regrowth and mature open forests at a normalised height of 0.3 was approximately 0.15, giving a RWS value between the two forest types of 1.00. Moon et al. (2016, Fig. 3) also shows that the RWS between regrowth and mature forest is approximately 1.00.

At the National Arboretum Canberra, the `open' wind speed was taken to be that recorded on the clear slope. The RWS was calculated between each weather station pair down the leeward facing slope, therefore maintaining similar topographical features between stations. Results from the NAC were directly comparable to results from the `Pine plantation' class in Moon et al. (2103, 2016). From Moon et al. (2013, Fig. 3), relative wind speeds in mature pine forest at a normalised height of 0.3 (or a direct height of 5m) and a wind speed between 10 a nd 20 km h^{-1}, were around 0.035. Moon et al. (2016, Fig. 3) indicates a higher RWS value of approximately 0.1 for a n ormalised height of 0.3. Furthermore, Moon et al. (2016, Fig. 3), shows that after wind speeds over approximately 4 m s^{-1} (≈ 14.4 km h^{-1}), the RWS stabilised at approximately 0.08. For lower wind speeds, however RWS values increase to approximately 0.2 for 2 m s^{-1} wind speeds, and up to 0.4 for wind speeds as low as 0.4 m s^{-1}.

3 RESULTS

Figure 3 shows the relative wind speed results from Flea Creek Valley. For the western ridge top pair (A1-B1), all RWS values at this site correspond well with the findings of Moon et al. (2013, 2016), after accounting for the relative change in vegetation, i.e. RWS values appear around 1.00 indicating that the increased vegetation between the two years has had very little impact on wind speeds experienced at this station.

Across the remainder of the valley, RWS values appear to decrease as the wind speed threshold increases. This concurs with the results shown in Moon et al. (2016, Fig. 3), but goes against the profiles shown in Moon et al. (2013). On the valley floor (A3-B3) and eastern ridge top (A5-B5), RWS values are at the lower end of the expected RWS range, indicating that the increased vegetation at these sites has induced higher levels of wind speed reduction than those observed by Moon et al. (2013, 2016).

Finally, on the walls of the valley, relative wind speeds appear considerably lower than those observed on flat terrain. On the predominantly windward slope (the eastern valley wall, A4-B4), RWS values are around 0.6, with increased wind speeds having limited impact on the RWS values. In contrast, on the predominantly leeward slope (or western valley wall, A2-B2), RWS values are approximately 0.7 for the lowest threshold, reducing to only 0.3 for the highest wind speed threshold. These results suggest that for increasing open wind speeds, greater reduction of wind speed beneath the canopy on the leeward slope is experienced. Indeed, when open wind speeds above 4m s^{-1}, wind speeds experienced beneath the mature canopy in 2014 were only a third of the speed of those experienced under the sparse canopy of 2007.

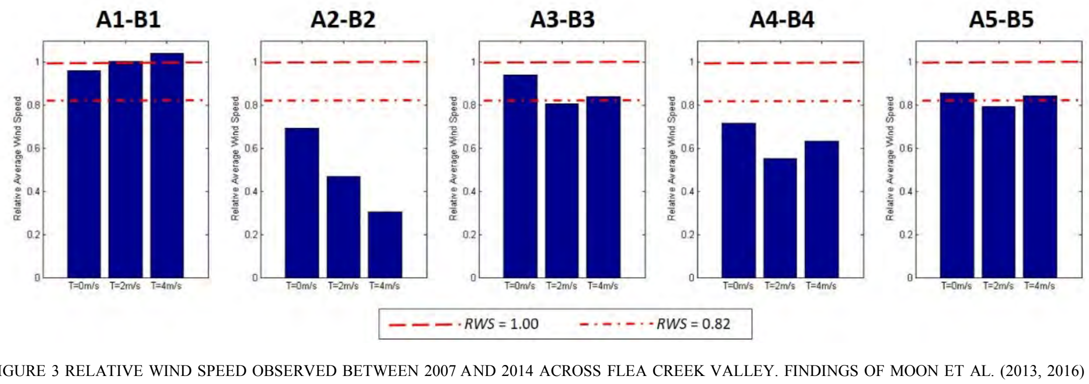
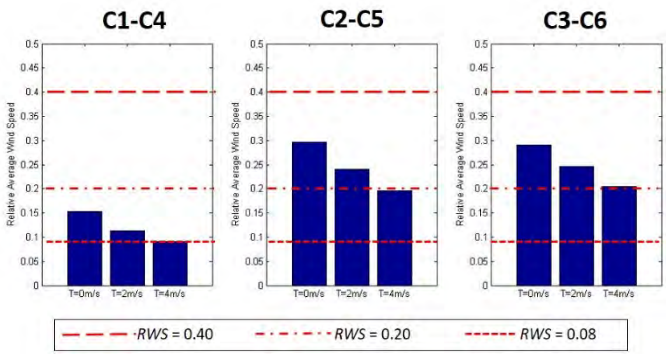


FIGURE 3 RELATIVE WIND SPEED OBSERVED BETWEEN 2007 AND 2014 ACROSS FLEA CREEK VALLEY. FINDINGS OF MOON ET AL. (2013, 2016) ARE INDICATED WITH THE RED DOTTED LINES.

Figure 4 shows the relative wind speeds between the parallel transects of the clear slope and the pine plantation slope at the National Arboretum Canberra. At the ridge-top stations (C1-C4), average wind speeds of 3.9 m s^{-1}, 5.2 m s^{-1} and 6.5 m s^{-1} are recorded for the three increasing open wind speed thresholds, respectively. At these wind speeds, it is expected from Moon et al. (2016) that the RWS values have reached stabilisation at 0.08. It is clear from Figure 4 that the observed RWS values approach this value as the wind speed threshold increases.

Down the predominantly lee-slope of the transect (C2-C5, C3-C6), RWS values are much higher, however average open wind speeds are lower; between 2.8

and 4.2 m s^{-1} for C2-C5 and between 2.3 and 3.2 m s^{-1} for C3-C6. At these lower open wind speeds, it is expected from Moon et al. (2016, Fig. 3) that RWS values



should be between 0.2 and 0.4. Clearly, results shown in Figure 4 agree with this expectation.

FIGURE 4 RELATIVE WIND SPEED OBSERVED BETWEEN CLEARED SLOPE AND RADIATA PINE STAND AT THE NATIONAL ARBORETUM CANBERRA. FINDINGS OF MOON ET AL. (20103, 2016) ARE INDICATED WITH THE RED DOTTED LINES.

4 DISCUSSION

Across Figure 3, results across sites representative of broader scale terrain or undulating landscapes (i.e. FCV ridge top and valley floor, or NAC transect) all show relatively good agreement with Moon et al. (2013, 2016) findings for the relevant forest types and wind speed thresholds (allowing for the relative change in forest type at FCV). On the leeward and windward slopes of Flea Creek Valley, wind speed reduction is much more significant between 2007 and 2014 than suggested by Moon et al. (2013, 2016). These results suggest that the terrain features have a compounding role to play in wind speed reduction caused by vegetation, and there is still further analysis required to better understand wind speed reduction beneath the canopy over complex terrain.

In further research, the compounding effects of topography may be characterised through the consideration of drag coefficients and streamlining (as noted by Moon et al., 2016). Consideration of vegetation structure and penetrability, as well as three-dimensional turbulence will also be relevant to this future discussion. As an immediate extension of this study, RWS could also be calculated between each NAC station within the vegetation (C4 to C10) and the station on the clear ridge top (C1). Differences between such results and those shown in Figure 4 would indicate any compounding effects of topography on RWS.

In this study, the average height of vegetation at both Flea Creek Valley and the National Arboretum Canberra was significantly less than heights reported by Moon et al. (2013, 2016). In addition, the vegetation structure was not quantified for both case studies, and it is important to consider where in the strata the 5 metre observations would sit. At the National Arboretum Canberra, within the pine stand, the 5 metre wind observations were within the dense pine canopy, but at Flea Creek Valley, within the open forest, it is possible that the observations were made within a secondary maximum in the wind speed profile. The comparison of normalised height results goes a considerable way to account for this with good agreement between results, but further quantification of vegetation structure would be necessary to progress this research and characterise the impacts of vegetation and topography on wind speed reduction.

It is noted by Moon et al. (2016) that the vegetation structure is itself dynamic, and varies over time. This variation is contemplated over long periods of time, with vegetation growth and interference due to human or natural causes. With shorter periods of data collection, i.e. less than one year, the seasonality of plant density, particularly through the open Eucalypt forest may have a significant impact on relative wind speeds. In this study, although data collection periods spanned considerably different time scales (9 months for the case studies compared to 1 month collected by Moon et al. (2013, 2016)), there was good agreement between results at the broader landscape scale. Further investigation into the impacts of seasonality on RWS is possible with this data set and it would be expected to further advance the discussion of drag effects and penetrability as areas for characterisation of the impacts of vegetation and topography on wind speed reduction. This could have significant implications for the application of wind speed reduction factors or models in fire spread prediction.

This study is limited by the caveats of wind data collection in the `real world'. Data were collected using low-cost Davis cup anemometers which have been reported to show a bias towards lower wind speeds (Moon et al., 2016). This form of data collection records horizontal wind speeds - limiting analysis to the horizontal while vertical wind flow is unaccounted for and may have significant impacts on fire spread below the canopy. More accurate data collection and more detailed analysis would be possible with three-dimensional sonic anemometers, as noted by Moon et al. (2016).

The possibility that edge effects at the NAC may play a significant role in the wind behaviour observed on both the clear slope and within the Radiata pine and thus needs to be also considered as a limiting factor in this study. Stations are at distances in the order of only a few times the height of the vegetation from the boundary of the pine stand, rather than 20 times the height of the vegetation as used by Moon et al. (2013, 2016). In light of this, it might be expected that the wind reduction observed at the stations would be less than that observed further away from the edge of the vegetation. However, in the results shown in Figure 4, this does not appear to be the case. Furthermore, analysis of wind direction across the NAC has shown that edge effects have minimal impacts on the wind fields experienced at the study sites.

Finally, it should be noted that reported wind speeds in this study were generally relatively low, but in application to fire spread prediction, high wind speeds are of most relevance in the context of extreme bushfire behaviour. Despite this, the focus here is on conditions driving surface fires beneath the canopy where conditions may be less extreme. Indeed, as noted by Moon et al. (2016), in cases of prescribed burns conditions are ideally mild, so understanding low wind speed interactions within the vegetation layer is important in the development of accurate bushfire spread models.

5 CONCLUSION

From this study, it is clear that observations over areas of broad scale topography or undulating terrain align well with the empirical wind profiles developed using data from flat terrain described by Moon et al. (2013, 2016). However, in amongst more complex landscape features, i.e. on valley walls and leeward slopes, the relative wind speeds observed were significantly lower than those shown in the empirical profiles constructed over flat terrain. This suggests that topographical features can have a s ignificant compounding effect on wind reduction across complex landscapes. There is potential to study these data more closely to understand the processes behind this variation, and adapt developing wind reduction models to application in fire spread models.

Although the collection and analysis of `real world' wind data has a number of caveats - perhaps leading to the lack of such data sets being available for model validation - results from this study show that the evaluation of models developed throughout the fire spread modelling process is a necessary step to reducing errors in the modelling process and improving fire spread predictions.

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NON-PEER REVIEWED EXTENDED ABSTRACTS

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A HIGH-RESOLUTION LAND DRYNESS ANALYSIS SYSTEM FOR AUSTRALIA

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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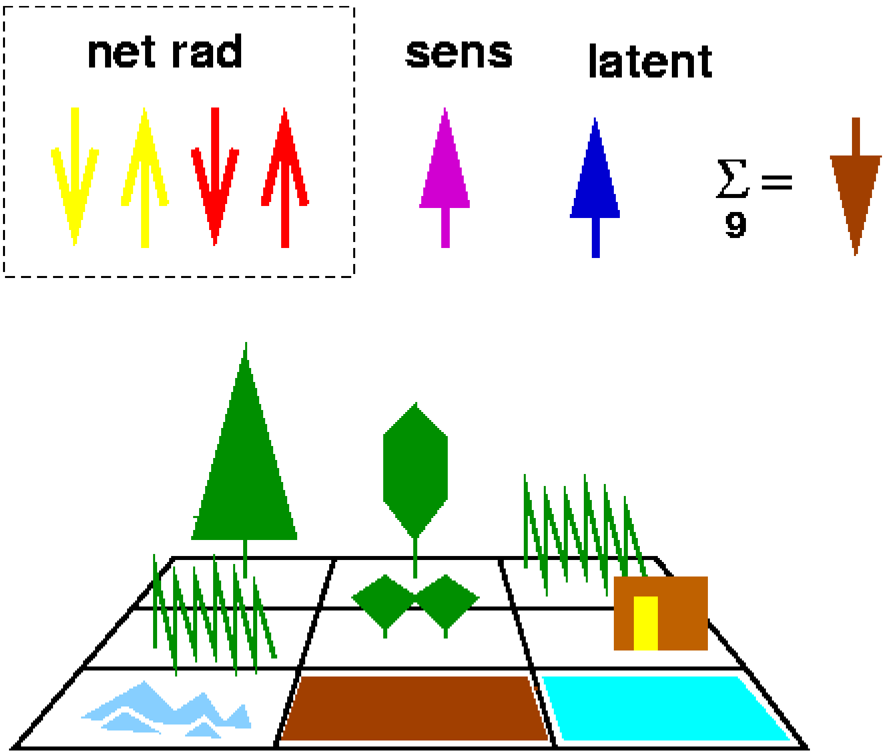
ABSTRACT

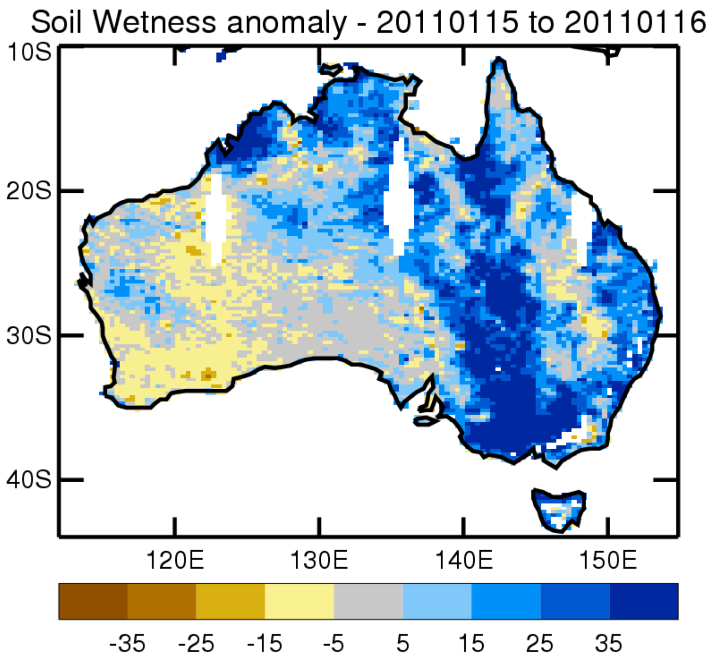
Good estimates of landscape dryness underpin fire danger rating, fire behaviour models, flood prediction, and landslip warning. Soil dryness also strongly influences heatwave development by driving the transfer of solar heating from the soil surface into air temperature rise. Currently landscape dryness, for fire danger prediction, is estimated using very crude models developed in the 1960s that do not take into account different soil types, slope, aspect and many other factors. This work presents a high-resolution soil dryness analysis system that includes data from many sources; such as surface observations of rainfall, temperature, dew-point temperature, wind speed, surface pressure, as well as satellite-derived measurements of rainfall, surface soil moisture, downward surface shortwave radiation, skin temperature, leaf area index and tree heights. The analysis system estimates soil dryness on four soil layers over the top three metres of soil, the surface layer has a thickness of 10cm. The system takes into account the effect of different vegetation types, root depth, stomatal resistance and spatially varying soil texture. The analysis system has a one hour time-step with daily updating. Data assimilation methods are used to extract the maximum amount of useful information from the observations and model. 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 apply quality control and bias correction. In addition, satellite measurements are infrequent with 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. Verification against ground-based soil moisture observations from the OzNet, CosmOz and OzFlux networks shows that the new system is significantly more accurate than the traditional soil dryness indices.

PHYSICALLY BASED LAND SURFACE MODEL



Modern land models calculate landscape dryness with greater sophistication and account for details such as soil texture, solar insolation, root depth, vegetation type and stomatal resistance. The Australian Community Climate and Earth System Simulator model has four soil layers. The topmost layer from the surface to 10cm is critical for the exchange of moisture between the soil and forest litter fuels. The lowest layer extends down to three metres.

SATELLITE DATA



There are few ground-based observations of soil moisture and temperature. However, a number of new satellite systems have been launched that can provide information about surface soil moisture, soil temperature and vegetation properties such as leaf area index. The advantage of these satellite systems is that they provide national coverage on a daily timescale. Advanced land data assimilation schemes can be used to blend the satellite measurements with model forecasts.

LAND SURFACE DATA ASSIMILATION

Data assimilation is the process through which the maximum amount of useful information can be extracted from observations and models. New flexible land data assimilation systems have been developed that can assimilate a wide variety of measurements such as 2m temperature and humidity, satellite-derived surface soil wetness, satellite-derived land surface temperature and vegetation properties such as LAI. The data assimilation can also propagate the surface information into the deeper soil layers.

EXAMPLE ANALYSIS OUTPUT

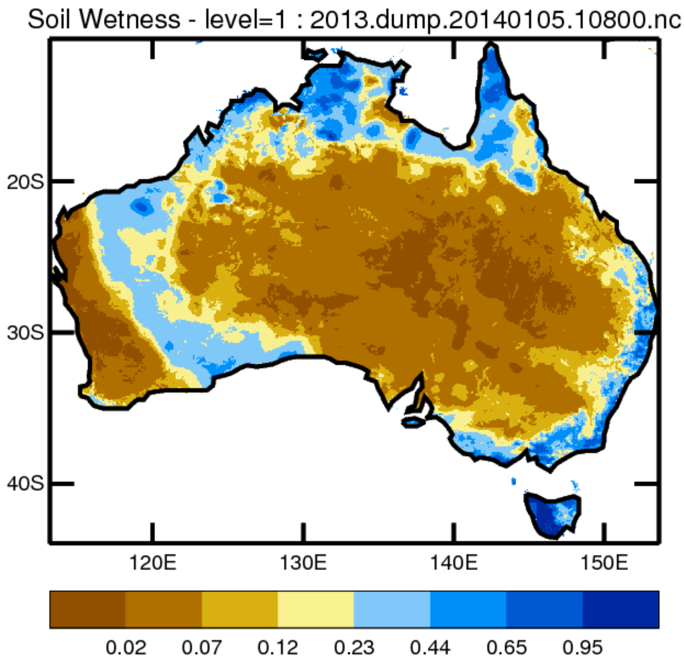
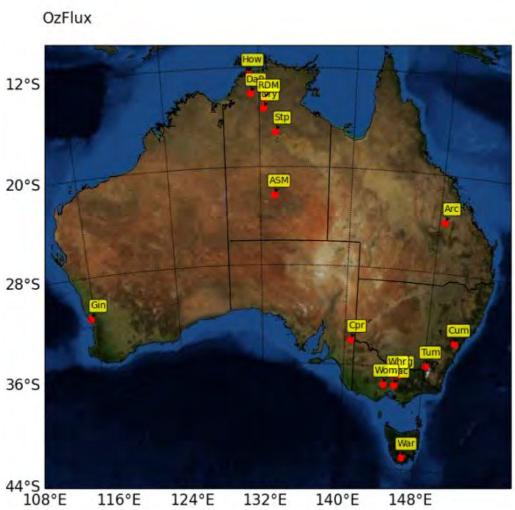
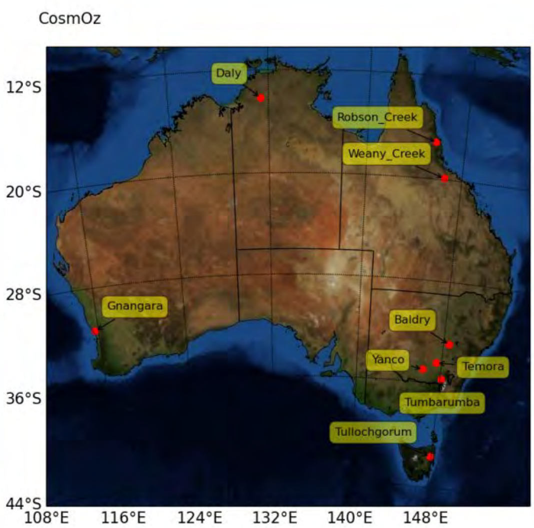


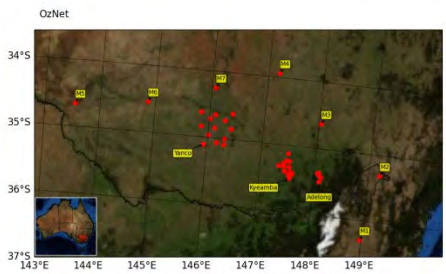
FIGURE 1. SOIL WETNESS IN THE TOP 10CM OF SOIL FOR 5/1/2014.

VERIFICATION

The high resolution soil dryness analyses are verified against in-situ soil moisture observations from the OzFlux, CosmOz and OzNet network.







CONCLUSIONS

This work presents a high resolution land dryness analysis system. Verification against in-situ observations show that this system can provide fire agencies with far more accurate information than the simple models currently used.

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NON-MARKET VALUATION IN THE ECONOMIC ANALYSIS OF NATURAL HAZARDS

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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ABSTRACT

To achieve value for money from investments in management of natural hazards (including mitigation, emergency response and clean up) economists advocate the use of tools like Benefit: Cost Analysis (BCA) to evaluate actions or policies (e.g. Milne et al. 2015). Many governments worldwide encourage the use of BCA for policy evaluation. For example, according to its Best Practice Regulation Handbook, 'The Australian Government is committed to the use of cost–benefit analysis to assess regulatory proposals to encourage better decision making' (Australian Government 2010, p. 61).

Some of the relevant benefits and costs related to natural hazard management are relatively difficult to quantify, particularly in financial-equivalent terms. There are a number of advantages from expressing non-financial impacts in financial-equivalent terms: to compare the benefits and costs of policy or management actions in order to evaluate whether they are worthwhile policies or actions; to rank alternative investments in terms of value for money; and to make rigorous business cases for investment.

Economists have developed a range of techniques to do so, known as 'non-market valuation', but they remain underutilized in the natural hazard sector. The first purpose of this presentation is to identify the methods available to quantify non-market values in financial-equivalent terms. Non-market valuation techniques use empirical evidence about human behaviour or statements in surveys to quantify preferences for the provision of a public good or service.

The technique applied to estimate the value of a non-market good depends on the type of value the non-market good provides to the community. 'Use' values cover non-consumptive uses such as recreation and amenity. 'Non-use' values cover those unconnected to a 'use value'. They include existence value (knowing a good, like a national park, exists), bequest value (maintaining a good for future generations) and option value (protecting a good for a future, undiscovered use option). Use and non-use value are conceptually distinct, but not mutually exclusive; they can both co-exist within the same individual or good (Carson and Hanemann 2005).

Different non-market valuation techniques are used to capture different value types. Significant research effort has been invested in developing and testing a range of techniques, which are broadly grouped into two main categories (Adamowicz 2004; Carson 2012). Techniques that draw conclusions based on actual behaviour (use values) are known as 'revealed preference' techniques, while those that rely on statements in surveys are called 'stated preference' techniques. A third technique, benefit transfer, is the use of research results from pre-existing primary studies at one or more sites or policy contexts (often called study sites) to predict welfare estimates or related information for other, typically unstudied, sites or policy contexts (often called policy sites) (Rolfe et al. 2015). Benefit transfer is advocated for use in policy making, particularly for non-market values, because it is usually cheaper, takes less time and is more straightforward than conducting primary studies.

We provide a simple framework showing how the non-market values for a natural hazard event could be derived and aggregated, which is relevant to all of the estimation methods described above.

The second purpose of this presentation is to identify the non-market values that might be affected by natural hazards. They include values related to human health, the environment, and social issues. The values of these things to society could be improved or, in some cases, diminished by the implementation of mitigation actions. We discuss the non-market valuation literature available for each value type. There are thousands of non-market valuation studies. However, for some value types there are no non-market valuation studies available.

The third purpose of this presentation is to provide guidance on the existing literature that estimates non-market values relevant to natural hazards. Despite a large body of literature, our review reveals gaps in the availability of WTP estimates for the value types we identify as being relevant to natural disasters. Amenity and safety values from floods, earthquake and bushfires have the most comprehensive information available. The majority of studies employ the hedonic price method (revealed preference) to infer the value of amenity and safety from variations in property prices. Morbidity and recreation also have a handful of studies that are relevant to the bushfire mitigation context.

For the other value types, there are few estimates specific to a natural disaster context. Meta-analysis functions are available for water quality, life, ecosystem degradation and threatened species. For stored carbon there are multiple estimates of the market value of stored carbon, and a handful that estimate the non-market aspect of the social cost from lost soil carbon. For animal welfare, cultural heritage, invasive species, social disruption and injury, stress or anxiety, pain and grief, there are few studies available.

The challenge for analysts and policy makers is to use the values information within a decision framework for prioritising mitigation actions. New studies could be conducted, if budgets and time permit, to provide accurate estimates for the specific policy question. New studies are required for those value types where no or few existing WTP data is available.

Benefit transfer is advocated as a suitable approach for value types for which estimates are well documented within the literature. However there are some potential issues with applying benefit transfer to a natural disaster context. The first is whether the influence of disaster context (cause, severity) significantly affects the WTP estimate. Jones-Lee and Spackmann (2013) provide some insight into the likely difference in value estimates for fatalities within the UK transport sector:

> *"…the prevailing view [previous studies] appears to be that the prevention of a statistical fatality in a large-scale multiple fatality accident does not warrant a higher value than is applied in the small-scale single fatality case";*

The second issue with the transfer accuracy of a WTP estimate is the target population to be considered. Natural disasters often impact large geographical areas. For example, the 2010/2011 Queensland floods affected more than 78 per cent of the state and over 2.5 million people, killed 33 people, inundated 29,000 homes and businesses and cost in excess of $5 billion (Queensland Flood Commission of Inquiry, 2012). In this case the socio-demographic profile of the target population is variable, meaning that a single fixed unit could not be transferred to all sites. For example, age and health status have been reported to affect the VSL estimate (Krupnic et al. 2002). This is likely to be important when evaluating mitigation strategies for natural disasters. In an analysis of fatalities in Victoria's Black Saturday fires, O'Neill and Handmer (2012) found

> *"…fatality dataset highlighted how many of the fatalities (44%) were particularly vulnerable due to age (either 70 or over, or under 12) and/or had a chronic and/or acute disability. Note that these vulnerabilities were sometimes compounded—2% of fatalities had both a chronic and an acute disability; and a further 9% had a chronic disability and were 70 or over."*

The third issue is the potential influence of the context for a non-market value. For example, there is evidence emerging that the cause of death matters in people's valuation of reducing risk of death (e.g. Viscusi 2009). If one were to transfer a VSL derived from traffic accidents surveys, this may not reflect the VSL from a bushfire or drowning incident.

In conclusion, there is scope to use existing WTP studies, through benefit transfer, for some of the values affected by natural disasters. For some types of impacts, existing evidence is likely to be sufficient to support benefit transfer, while for others, additional studies are needed to fill information gaps.

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THE SOCIAL LIFE OF SCIENCE IN BUSHFIRE POLICY AND PLANNING: TALES FROM VICTORIA AND THE NORTHERN TERRITORY

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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ABSTRACT

Quite rightly, practitioners in the natural hazards sector hold science in high regard. Scientific research has provided significant insights into our predictions of, and preparation for, events whose behaviours and occurrence are both high consequence and highly uncertain. As such, it is unsurprising that government agencies often emphasise their commitment to having 'science-led' or 'evidence-based' policies. But the routes between science, policy and planning are complex and variable. That is, while we may often hear (or say) that there is a straightforward relationship between scientific research, natural hazards policy and management practice this is based more in aspiration than reality. Experience suggests that having more scientific research does not always lead to less scientific uncertainty, just as having more scientific research or less scientific uncertainty does not always lead to more political action.

To briefly note three reasons for this lack of linearity, let us first begin with science itself. Scientific research is necessarily an open-ended process in which uncertainties can often be reduced but cannot be resolved; all going according to plan it follows a parabolic curve towards a certainty it cannot reach. The consequence of this is that there are often abundant reasons to delay decisions about how to proceed, just as there are abundant opportunities for scientists, politicians, policymakers or others to deliberate on the meaning of remaining uncertainties (Sarewitz, 2004). Secondly, as researchers from diverse fields have shown, the interface between scientific research and government policy is pervasively shaped by contemporary politics. Funders, researchers, policymakers, administrators and practitioners are not immune to the influence, whether directly or indirectly, of the priorities and affordances of the systems they find themselves in. Thirdly, and perhaps most importantly, there are many obstacles to integrating scientific research within government agencies. These include resource constraints and institutional cultures that influence how, and if, new research is utilised.

In short, scientific research has a 'social life'. We mean this in the sense that it emerges from and circulates within social settings with their own intricate dynamics, including research institutions, government agencies, field sites, parliaments, newsrooms, and so on. As political scientist Brian Head argues (2008; 2014), policy decisions typically stem from politics, judgment and debate, rather than just powerful research results. This suggests that while any successful implementation requires systematic research (or 'science'), program management experience (or 'practice'), and political judgment, there is also no universal recipe for success. Diverse capacities and institutions are necessary and their cumulative and individual effectiveness is more often something determined by their interactions than by a checklist of criteria (Hunt and Shackley, 1999). The 'success' of scientific findings, policies and hazard management agencies are interdependent, meaning one cannot be successful without the others.

In this paper, we do not seek to provide advice about how the interface between natural hazard science, policy and practice could or should be managed. Instead we approach this interface from, in a sense, the 'other side'. Rather than adopt more standard approaches to these issues, such as the analysis of policy documents, our research focuses instead upon practitioners' perceptions and experiences. In Australia, as elsewhere, there has been little social science research of such expert communities. However, we believe they provide crucial insight into the undercurrents of policy and practice. Attention solely to policy documents or

scientific innovations, we suggest, would lead us to elide or miss other significant factors driving sectors' successes and failures in addressing issues such as natural hazard risk. Through empirical case studies of risk mitigation we address how scientific research has been influential in shaping policy and practice. Drawing upon interviews and workshops with practitioners, we explore three different but related lines of inquiry. First, what are the influences shaping how scientific research has been integrated into these contexts? Second, how do practitioners encounter and manage uncertainties? Third, what does 'science' mean in these contexts?

To this end, the researchers have pursued two empirical case studies in the north and south of Australia. In each we begin by interviewing practitioners in the area to gain an understanding from them of how science and other forms of knowledge inform their work and what they feel are the key issues and uncertainties that they face. We then hold a workshop to discuss these factors using scenario exercises where practitioners are given different scenarios, or predictions, of what the area they work in might be like in 20 years' time (see Wodak and Neale, 2015). Understandably, people who work in the natural hazards sector are often focused upon the immediate context: What is going to happen this season? What is happening in the community this year? A scenario exercise is a sound method for both moving discussions outside established parameters and to gain critical perspective on those parameters (James et al., 2015). For this research project the focus has fallen on longer trends, how should we best prepare for these futures, and how science can and should inform these preparations. To date we have held workshops for two case studies, one in the Barwon-Otway area of south-west Victoria and one in the Greater Darwin area of the Northern Territory.

These case studies were chosen on the basis of expert advice about sites in which scientific knowledge was changing how risk is calculated and managed. For example, for the last several years the Barwon-Otway area has been the site of a pilot, led by the Department of Environment, Land, Water and Planning, to test an alternative strategy to how to mitigate bushfire risk. To simplify significantly, the risk-based strategy involves, first, the generation of loss estimates from suites of bushfires simulated within PHOENIX RapidFire (a two-dimensional bushfire simulator) and, second, the comparison of asset losses between those suites (Ackland et al., 2014). This might involve, for example, simulating fires under worst case (i.e. Black Saturday conditions) weather conditions, in which a) no planned or unplanned fires have occurred for several decades, b) all public land has been prescribed burned, as well as c) some accidental fires and some prescribed burning have occurred. Given the model's ability to predict house losses from the intensity of each fire, the three suites can therefore be compared to reveal the benefit of fire in the landscape and the residual risk that remains. A more complex arrangement, also trialled, might compare multiple asset losses across multiple suites, each comprising thousands of simulations using random ignition and weather scenarios.

The Northern Territory is quite a different context to 'down south,' as Territorians often point out, though it also presents interesting parallels in natural hazard management. As part of the tropical savannah, the Greater Darwin area has an annual bushfire season in which approximately 40 per cent of the total area is typically burnt. Every year, as the wet season subsides, practitioners work to 'burn off' with the aim of reducing fuel loads during the late dry season; this abundance of fire is widely accepted as part of Territory life and its environment. However, there are several trends at work in the Greater Darwin area that are now changing the bushfire risk and its mitigation. One primary driver in this situation is Gamba grass, a pasture species introduced in the 1970s and 1980s that grows tall, thick and flammable if not grazed intensively (Setterfield et al., 2013). Gamba is very invasive and has, over the past decade, turned parts of the Greater Darwin area to monoculture, creating high fuel loads that, in the right conditions, produce up to eight times more heat that native grassfires. Another driver of change is the increased level of subdivision and housing development surrounding Darwin, as areas such as Palmerston and Litchfield take up some of the city's population pressure. Bushfires, previously understood as a minor risk in the Northern Territory, are beginning to claim houses and other assets in the areas infested with gamba. Our qualitative research with practitioners has given us a new understanding of how crucial science and practitioners have been to understanding this risk and responding to it through policy and planning.

In the full version of this paper, we will report on key findings from these two case studies and establish several links between them. While practitioners often stress the importance of pairing scientific tools and research, they also place significant emphasis on the importance of professional experience, local knowledge, and interpersonal trust in applying them. One aspect of this is that, in order to be utilised in practice or incorporated into policy, new knowledge must often overcome a variety of institutional obstacles (however minor). Another is that while we may often narrate hazard management as led by scientific progress, practitioners are keenly aware of the extent to which much of the real world does not fit tidily within algorithms. The many uncertainties practitioners still face are often managed through discretion, intuition and experience, exposing them to forms of liability and responsibility they in turn assess in terms of 'risk'. Additionally, whether or not scientific knowledge ameliorates existing uncertainties of risk mitigation, there is clear evidence that it routinely creates new uncertainties that may or may not be amenable to technical solutions. For example, once agencies have a new level of information about where risk lies in the landscape, or the benefit and potential of mitigation, what is the ethical requirement for passing that information on to the wider public? What is the best strategy technically? What is the best strategy politically? While, as Eburn and Handmer argue (2012: 19), there 'is no legal impediment to releasing reasonably accurate hazard information,' there are clear disincentives to freely releasing information that is highly complex and has the potential to be reused in negative ways.

What is clear is that scientific research, whether in a laboratory or a landscape, is never simply technical. Nor is there a single stable entity we might call 'science'; it is instead, as van Kerkhoff and Lebel state (2006), a 'permeable, changeable, and contestable' thing. As such, the ways in which decision-makers and practitioners integrate and utilise science is a thoroughly social question, shaped by the capacities and affordances of the contexts in which they operate. While it is important to continue to place a high value on scientific research in the natural hazards sector, it is also important to remember that this research is embedded in social dynamics and social networks – a 'social life' which we are, at present, only beginning to understand.

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HOW DO ISLAND COMMUNITIES BALANCE DISASTER RESILIENCE AND WHAT CAN MAINLANDERS LEARN FROM THAT?

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
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ABSTRACT

This paper will look at the aspects of the character and balance of disaster risk reduction behaviour and resilience in island contexts focusing on the case study of Pulau Simeulue (Simeulue Island).

The paper is in four parts, each setting out a context for understanding the relevance of islands for disaster risk reduction. The first will introduce the case study of Simeulue and its relevance to our understanding of disaster risk reduction ('DRR'). The second section discusses the way in which islands have a special place in individual and community narratives and perceptions. It is argued that, far from being esoteric matters, the fact that we are capable of documenting different and deep-seated perceptions can lead to some wider lessons about mechanisms to build community resilience. The third section considers a biogeographic model of islands and the role they have played in the natural world, but also the how we have come to understand that world. Through a close examination of variability on and between islands we have come to a deeper understanding of biology generally. This context potentially lends itself to a wider understanding of DRR. Finally it will identify some of the specific properties of island communities that make them worthy of deeper consideration for a better understanding of DRR and growing community resilience in 'mainland' contexts.

ISLAND CASE STUDY: PULAU SIMEULUE

Pulau Simeulue is an island is 150 km off the south-west coast of Sumatra. With a total area just over 2000 km^2 its current population is 85,000. Simeulue is part of the Aceh Special Region and is predominantly a Muslim community, but given its remoteness and isolation it has been largely unaffected by the separatist conflict with the Indonesian government. Simeulue is located near the margin of the Eurasian tectonic plate and the subduction zone of the Indian/Australian plate. This results in the island and nearby areas being subject to regular earthquakes, and occasionally tsunami. The proximity to the source of the earthquakes meant that Simeulue was the first landfall for the Indian Ocean tsunami in 2004. Despite the proximity of the island to the source and the fact that a great deal of infrastructure was destroyed by the wave, only a handful of people died. In contrast, neighbouring mainland localities of similar size had tens of thousands of casualties.

The United Nations praised the community for Pulau Simeulue for maintaining their traditional knowledge and using that as the core of their disaster risk reduction strategy. The narrative regarding the success of the response to the 2004 tsunami revolves around the retention of knowledge of a similar event that occurred in 1907. This earlier disaster caused the loss of a great many lives with repercussions for generations in the small and isolated population. The story of how to recognise the conditions for a tsunami and what to do about it have been kept alive for the intervening one hundred or so years with everyone 'running to the hills'.

While this narrative is certainly true, it is not in a real sense an explanation of the success of the people of Simeulue. There are of course many other island communities who have strong local knowledge and rich traditions that include instances of disasters. There are other communities that are Muslim, agriculturalists, in remote areas, with little formal emergency management support from the central government. And there are many examples where these communities were devastated, or indeed obliterated by disaster.

Further, the fact of the maintenance of the local tradition is referred to, but there is no indication of how this information was maintained and transmitted effectively and accurately. Most societies struggle to maintain a clear message over a generation let alone 100 years. New information or perspectives invariably arise and old and new information contest for relevance in changing social and political contexts. The rise of technology during the period in question has had a profound influence in even the most remote parts of the world. Why did this not impact upon the maintenance of the story of tsunami on Simeulue?

In addition to merely transmitting the correct information over four generations, the Simeulue community managed to transmit the metadata about the importance to act upon the disaster narrative. To contextualise this one need only think about the response to a fire drill in one's workplace. The fact that all members of the workplace understand what is required does not necessarily translate into prompt or appropriate action. On Simeulue, 97 years after the initial disaster and despite the fact that earthquakes occur every year, everyone on the island stopped what they were doing and immediately made for the escape route.

There are a range of other specific areas of interest in the Simeulue story stemming from the fact that earthquakes occur every year and major earthquakes over 6.0MMS are also frequent. Despite the regular shaking, the community did not appear to suffer from 'warning fatigue' or complacency.

Seeking deeper answers to the questions raised by the case study of Pulau Simeulue has the potential to inform how agencies and communities work together to build resilience and strengthen DRR. While islands are actually physically separated from other communities and this informs perceptions and identity, all communities can be characterised as separate in some fashion. Thought might then be given to identifying how the mechanisms by which Pulau Simeulue kept itself alive might be adapted to other communities elsewhere.

POPULAR PERCEPTIONS AND THE ISLAND

While the ultimate objective of DRR must be a hard-headed attention to saving lives, there is a growing sense that building resilience requires emergency managers and planners to engage with the social, cultural and psychological forces that inform and influence human behaviour. These are the things that result in individuals and communities preparing for disaster and taking the appropriate response action when disaster strikes. Narratives are an important element of this understanding of what influences whether people prepare. With this in mind some consideration of the narrative of islands is presented to set some context for research into island DRR.

At a basic level islands are at once mysterious and remote but none-the-less desirable and attractive. In literature and popular culture they are isolated Edens that can be an idyllic vacation or a home of head-hunters. Their remoteness lends them an element of danger, from the risk of stranding to attack by locals and any trip to an island is an adventure. Islands are inexorably defined by their otherness, their inhabitants proud to differentiate from and remain wary of mainlanders. And this seems to be scalable, from small communities like Magnetic Island off Townsville, to the State of Tasmania to nation states such as the UK or Japan, there is a vigorously pursued island tribalism that mainlanders disrespect at their own peril.

Against this narrative risk islands are places filled with possibilities and have for centuries been a popular setting for fictions involving rare and wonderful creatures, people and events; from Robinson Crusoe to Gulliver in Lilliput. In the Crusoe story the island is an exile but also a romance as the possibility is presented to the shipwreck survivor that he may do more than just survive, he may thrive grow and learn. This sense of the island as a haven for literate experimentation is taken to a logical extreme when a mad scientist wishes to conduct experiments that he knows would not pass even the lowest moral or ethical standards. In the Island of Dr Moreau, in an effort to improve on nature, the eponymous anti-hero instead makes monsters which are, fortunately, a long swim from the mainland.

This may seem a long way from the concerns of time-poor disaster managers or state authorities with limited budgets trying to make cost-effective investments to reduce disaster risks. But in the discussion of the nature of our understandings of islands the reader will recognise deep-seated perceptions that influence their own decisions and colour the way specific decisions are made about things like risk, necessity and capacity. That is, how do our perceptions of things affect our feelings of what risks (in going to visit an island say) exist, what things are necessary to minimise risks and what capacity an individual or community has to implement risk management measures.

BIOGEOGRAPHY AND THE ISLAND AS EXPERIMENT

Island biogeography has long been a source of fascination and insight in the natural sciences. Limitations on resource availability in island contexts and the lottery of the range of colonising species lead to a diversity of ecologies that reflect the nearest mainland but which are inevitably unique. Each of these separate creations appears as an experiment in ecology with adaptive radiations as colonising species diversify to take advantage of a range of newly available ecological niches. At the same time processes characterised as convergent evolution result in diverse colonising species adopting similar forms to take advantage of similar niches or cope with similar stresses. The diversity of unique flora and fauna range include adaptive radiations of flightless birds in New Zealand, marsupials in Australia, dwarf hominins in Flores and different giant tortoises on each of islands of the Galapagos.

Indeed, the Galapagos archipelago with its endemic but similar species of finches, iguana and tortoises led directly to the formulation of the modern understanding of evolution. That is, the close study of the unique ecology on different islands led to the most powerful explanatory tool available to modern biology.

The observation of islands and their ecology has also contributed to an understanding of a concept that might be described as ‘balance’. Over relatively long periods of time, ecological relationships became established that settled, more or less, into equilibrium states. In the modern era, the age of exploration and travel has led to the invasion of most islands by mainland (and sometimes other island) species with profound negative consequences for that equilibrium. Island communities have suffered the greatest extent of species loss as invasive species out-compete locals adapted for the specific conditions that pertained. Humans have been a part of this process, on occasions with catastrophic consequences. For example he denuding of Rapa Nui by the cult of the Moai led to the decimation of the population and the starvation of those who remained. Unable to escape or seek resources from outside, the inhabitants were forced to make radical cultural and economic changes in order to merely survive.

The biogeographical approach to islands therefore provides another context for understanding DRR and resilience. The unique arrangements put in place by local communities and the ‘balance’ that those solutions exhibit; the interplay between culture, economy and natural hazards offer an opportunity to better understand the mechanisms for growing resilience. Conversely, the mechanisms of human agency that turn natural hazards into disasters can be teased out with greater clarity in island contexts that on the mainland. While it is not expected that the research will generate the 'most powerful explanatory tool' in DRR, it seems reasonable to expect more humble advances might be made.

ISLANDS AS CHARACTERS

Research into DRR in island contexts does seem to identify a range of traits that could contribute to DRR and may underpin the successful disaster response on Pulau Simeulue. Having said that, it must be recognised that there are many examples of island communities devastated by disasters. This includes island struck by the 2004 Indian Ocean tsunami. Famously tourist destinations such as Phuket do not seem to have benefited from being islands in any sense.

It is the case however that of the few examples of excellent DRR behaviour leading to the saving of lives, islands such as Simeulue feature strongly. Examples include Taiwan, Laingpetahi (Indonesia), the Andaman and the Solomon Islands, in addition to Pulau Simeulue. It has been suggested that, the factors that lead to the islands 'difficulties' also lead to adaptation and innovation. In character these communities in these studies tend to be:

- Small
- Remote
- Isolated
- Neglected / overlooked
- Doughty
- Self-possessed
- Resourceful
- Knowledgeable of local conditions

The Pulau Simeulue case study is seeking to tease out the degree to which these character traits are 'real' and what that looks like, or if they are perceptions and the extent to which it matters. Identification of the factors 'real' or 'perceived' which lead to DRR and community resilience from this island and others offers a real potential for disaster managers and agencies and communities to develop tools to assist the development of disaster resilience.

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USING PARTICIPATORY MAPPING TO HARNESS LOCAL KNOWLEDGE AND INCREASE COMMUNITY CONNECTEDNESS IN BUSHFIRE PREPARATION

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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ABSTRACT

The increased ease of individuals to create, share and map geographic information combined with the need for timely, relevant and diverse information has resulted in a new disaster management context. Volunteered geographic information (VGI), or geographic information created by private citizens enabled through technologies like social media and web-based mapping, has changed the ways people create and use information for crisis events. Literature in this field has focused on disaster response while largely ignoring prevention and preparedness. Preparing for disasters reduces the likelihood of negative impacts on life and property, but despite strategies to educate communities, preparation remains low and increased preparation engagement is required. This study assesses the application and value of VGI in bushfire risk reduction. It examines VGI as a social practice and not simply a data source by considering the user experience of contributing VGI and the potential for these social activities to increase community connectedness for building disaster resilience. Participatory mapping workshops were held in four bushfire-risk communities in Tasmania. Workshops included a paper-mapping activity and web-based digital mapping. Survey results from 31 participants confirm the process of mapping and contributing local information for bushfire preparation with other community members can contribute to increased social connectedness, understanding of local bushfire risk, and engagement in risk reduction. The social aspect of VGI was engaging for participants and contributed to improved community connectedness. The social quality appeared even more engaging than the specific information shared, and this should be considered in future disaster risk reduction initiatives. Participants reported collaborative maps as effective for collating and sharing community bushfire information with a preference for digital mapping over paper-based methods. Local knowledge and shared information were seen as valuable, but further work is needed to extrapolate findings from the study sample to the broader population.

EXTENDED ABSTRACT

Background

The increased ease that individuals have to create, share and map geographic information combined with the need for timely, relevant and diverse information for emergencies has resulted in a new disaster management context (1; 2; 3). Social media and web-based mapping platforms have changed the ways people create and use information for crisis events (4; 5). This includes basic use of sites like Facebook to share text, images and videos (6; 7) as well as more complex activities such as data mining or crowdmapping (8; 9) (3). Through rapid exchange of geographic information between authorities and citizens for disaster response, and promoting connectedness and community engagement in disaster preparation practices, VGI contributes to all phases of disaster management, including prevention, preparedness, response, and recovery (PPRR) (2).

The majority of academic work in this field has tended to focus on disaster response while largely ignoring prevention and preparedness (2). Preparing for disasters dramatically reduces the likelihood of negative impacts on life and property, but, despite the impacts of past events, education and strategies to provide communities with relevant information, active preparation remains low (10; 11). This study differs to others in that it focuses on assessing the application and value of VGI in bushfire risk reduction. A recent study did focus on the potential use of VGI in bushfire preparation by considering technology uptake, community interest, and limitations to use (12). But the study was limited in that it did not address how VGI might be effectively utilised in bushfire preparation. Other studies have also tended to focus on VGI-enabling technologies and VGI data. This study considers VGI as a social practice and not simply a data source in disaster management. It examines the user experience of contributing VGI and the potential to increase community connectedness by working together in building disaster resilience. It does this through participatory mapping.

Involving local communities is a prerequisite to sustainable disaster risk reduction (13). Gaillard and Maceda (13) note that community-based disaster risk reduction fosters participation by involving communities in the identification of risk (including hazards, vulnerabilities, and capacities) and ways to reduce it. Although official and traditional information is critical, such participation can provide more up-to-date and useful risk information (14). One approach to involving communities in risk reduction is through participatory mapping, or public participation geographic information systems (PPGIS).

PPGIS methods incorporate end users, research subjects, and researchers into a collaborative environment (15), with an intended result being increased empowerment for communities involved (16). For reducing disaster risk, participatory mapping enables communities to delineate areas they perceive as vulnerable and prone to hazards, and to plot desired and useful risk reduction measures (13). Jing, Liu and Gang (15) describe a community-based system which allows local residents to report risk information for disaster mitigation which is both accessible to the community and useful for decision-makers. In the specific case of fire, public participation science research may lead to more effective bushfire management by increasing knowledge and prominence of bushfire issues in communities and providing opportunities for forest professionals to work with community members (17). Ferster and Coops (17) evaluated the quality of data collected via participatory mapping by tasking a group of volunteers in a local community to contribute VGI on forest fuel loading using a smartphone application. Conclusions of the study suggest approaches using smartphones and participatory mapping show considerable promise and warrant further investigation and development (17).

Study aims

The overall aim of this paper is to explore the notion that the process of mapping and contributing local information for bushfire preparation with other community members can contribute to increasing an individual's awareness and understanding of local bushfire risk, social connectedness, and engagement in risk reduction. More specifically, we ask:

1) Does the social practice of contributing and reviewing VGI increase engagement in bushfire preparation?

2) Does the activity of mapping together increase community connectedness?

3) Is the local knowledge and understanding gained from the mapping valuable to communities?

4) Is the map itself an effective medium for collating and sharing community bushfire information?

Methods

Workshops on participatory mapping for community bushfire preparation were held in four communities at bushfire risk in Tasmania: Kettering, St Marys, St Helens, and Tolmans Hill.

In Tasmania, bushfires are the most economically disastrous of all natural hazards and the impacts on communities are long-lasting (18). The 2015–16 Tasmania bushfire season exhibited above-normal risk conditions as a result of recent warm years and low rainfall (19). Thus Tasmania is ideal for studies concerning community bushfire safety.

Workshop participants were recruited in various ways, which included engaging known local contacts and community fire groups, sending invitations to local businesses, community organisations and other local services, local council advertising, residential mail-outs, letterbox flyer drops, sharing on social media sites and other relevant websites, and targeted promotion on Facebook.

Workshops included a paper mapping activity and a digital mapping activity before participants completed an evaluation questionnaire to capture their views on the experience of mapping, mapping methods, the value of local knowledge in bushfire preparation, and VGI and community connectedness. Paper mapping saw participants in groups of two to five marking-up paper maps and satellite images with any information they felt relevant to bushfire preparation in their community. The second activity involved collating the information from each group into a combined web map (though its GIS functionality is limited, the Zeemaps platform was used for its simplicity and accessibility). Participants were given a URL to the map and asked to contribute on laptop computers, smartphones and tablets live in the workshop.

Results

In total 31 people participated in the study workshops and completed a questionnaire. An even distribution of male and female participants attended. The age distribution of participants was skewed towards those over 35.

Workshop observations

During the workshops, researchers observed the participants' interactions with each other and with the activities. Participants appeared interested and motivated to learn and contribute to bushfire preparation in their community. In particular, the paper mapping activity yielded a high level of participant interaction. Some described working with others, the discussions had between community members, and the increased community connections generated through the mapping activities as the most valuable aspects of the workshop.

Main workshop discussion points included what content to map (content focused on services and community assets, potential hazards, areas of increased risk, neighbourhood bushfire groups, 'safer' places and potential evacuation routes), differences between mapping methods, and how a VGI map may be useful and applied in their broader community outside of the workshop setting. Participants described a preference for digital mapping, in contrast to the observations described above. Paper mapping was recognised as useful for community discussions and valuable for its low-tech simplicity for older people and those without internet or computer access. But participants also described difficulty in keeping a paper map up-to-date, sharing it with their broader community, and the challenge of getting the information 'out' of the paper map so it can be used in other ways, e.g. for the fire service.

Participants discussed the portability and currency of a web map. They discussed how online mapping would be useful for vulnerable groups such as travellers, people new to the area, and those who speak languages other than English. The web map was seen as better for examining finer detail information at 'micro' scales (e.g. who has a chainsaw on their street), sharing the map more widely and easily, maintaining information relevance, the convenience of contributing, the ability to include more detailed comments and photos, and the potential for greater data use (e.g. GIS analyses). Despite concerns such as power outages and computer access, map ownership and administration, privacy, and the risk of malicious intent, overall discussions on the potential use of web mapping and VGI for community bushfire preparation were positive.

Questionnaire responses

Broadly, participants described the experience of mapping their own information for their local community as positive. 97 per cent of respondents said the activities were useful for their bushfire preparation, 97 per cent thought maps were an effective way to present and share their information, and 76 per cent learnt something new about bushfire preparation in their community through mapping VGI. Further, undertaking the activities with other community members was seen as highly positive, with all participants reporting working with others was a positive experience, and 93 per cent confirming working with others helped them understand the broader bushfire risk and preparation activities in their wider community.

Some points raised by participants to consider in sharing information to a public community map included the accuracy of information and how it can be verified, privacy and awareness of who can access and use the information, and security concerns. Despite these concerns, 86 per cent of participants stated they would contribute to community maps like those used in the workshop in the future.

Participants were asked to comment on the differences between the paper mapping method for sharing community VGI and the digital mapping. They described an array of benefits and limitations of both. Strong preferences for digital mapping over paper for individual use and broader community application were reported.

Participants also described favourably the mapped-information itself. 83 per cent of participants felt the information was personally relevant and 73 per cent felt it increased their understanding of community bushfire preparation. 93 per cent believed VGI increased their awareness of other community members and their preparedness, and all participants reported the information would be useful to other members of their community. 93 per cent felt VGI would be useful to emergency management authorities.

Brief discussion

Results of the participatory mapping workshops provide strong evidence for the application and value of VGI in community bushfire preparation. The process of mapping and contributing local information for bushfire preparation with other community members can contribute to increased social connectedness, understanding of local bushfire risk, and individual engagement in risk reduction, but with considerations for implementation, such as map ownership and security.

The social practice of contributing VGI was engaging for participants. There was an understanding from participants that different people had different knowledge to contribute and also that bushfire is something that can potentially affect all members of the community and managing it should be a shared experience. The social quality of VGI appeared even more engaging than the specific information mapped and shared, and this should be considered in future efforts to engage communities in disaster risk reduction.

Further, the act of mapping together was revealed to increase community connectedness. Community connectedness and social capital (social networks and community norms; see 20) are important elements of disaster resilience in addition to the value they add in terms of social engagement in preparation activities. However, longitudinal studies are required to determine if participatory mapping and VGI enable ongoing community connectedness. Our study involved once-occurring workshops and we cannot comment on long-term outcomes.

The local knowledge shared and the information mapped was also of value to participants. A significant majority reported the VGI was personally relevant information and that it helped with their understanding of community bushfire preparation. A particularly meaningful finding was the 93 per cent who reported VGI increased their awareness of other community members and their preparedness. If bushfire resilience and disaster risk reduction is a shared experience and a shared responsibility, it is important that those involved have a common understanding of the risk, responsibilities and actions of those they share with, and thus the contribution of VGI reported here is significant. Given the limited and skewed sample size it is not possible to extrapolate findings to the broader population. The information mapped in the workshops may have been highly useful to those present, but the same information may or may not be useful to the groups of people not represented in the study sample, for example people under 35, people experiencing greater levels of social disadvantage, or visitors to the area.

However, community mapping was perceived as potentially being effective for capturing knowledge from the broader population and the map itself viewed as an effective medium for collating and sharing community bushfire information, especially in digital form. Given the study sample age bias towards older people, the engagement with the technological solution over offline methods is an encouraging result. The preferences for digital mapping and web technologies expressed in this study by a demographic not commonly associated with those technologies highlights the value and potential seen by participants for VGI to increase bushfire preparation on a broader community scale beyond individual concerns such as computer illiteracy. In addition, some initially hesitant to use the technology saw benefit after trying it themselves, which further illustrates the engaging nature of VGI and digital mapping in bushfire management.

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EVALUATING TOPOGRAPHIC INFLUENCES ON THE NEAR-SURFACE WIND FIELD OF TROPICAL CYCLONE ITA (2014) USING WRF-ARW

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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ABSTRACT

Tropical Cyclone (TC) Ita (2014) was a major storm that affected coastal areas of Northeast Queensland. Topographic features along the coastline are known to modify the structure and intensity of such events. This study utilises the Advanced Research version of the Weather Research and Forecasting (WRF-ARW) model to investigate topographic influences during the landfall phase of TC Ita. While the removal of topography over the whole domain steers the modelled TC far away from the landfall point, removing topography from only a smaller area allowed an investigation of the topographic influence on near-surface wind conditions in that area. Flow over the region of removed topography exhibit smaller inland velocity gradients for winds flowing onshore and a sharper acceleration of winds as they moved offshore.

INTRODUCTION

Tropical Cylone (TC) Ita (2014) was a major storm that made landfall in Queensland, Australia near Cooktown. In early April it originated over the Salomon Sea (Figure 1) as a low pressure system. Ita gradually intensified and drifted westward over the next few days before strengthening to a Category 1 cyclone on 5 April (BOM, 2014). Three days later, Ita strengthened to Category 3 status and brought heavy rainfall to parts of southeast Papua New Guinea. Through rapid intensification on 10 April, Ita turned into a Category 5 storm and weakened immediately before making landfall as a Category 4 cyclone on midday 11 April. Here, a maximum wind gust of about 44 m/s was recorded at the Cape Flattery automatic weather station (AWS), near to the landfall position.

FIGURE 1. BUREAU OF METEOROLOGY TRACK OF TC ITA (BOM, 2014).

Ita continued to weaken over land and turned into a Category 2 cyclone as it followed a southerly track passing approximately 20 km to the west of Cooktown. Before midday on 12 April, Ita became a Category 1 storm and moved further southward along the coast of Queensland before moving offshore between Townsville and Mackay one day later. Overall, approximately 200 structures experienced minor damage and major damage to 16 buildings was reported. Gust wind speeds of 34 m/s were recorded at the Cooktown Airport (BOM, 2014) and 26–28 m/s recorded by SWIRLnet towers (3.2 m elevation) located at a range of sites between the eye of the storm and Cooktown (Mason and Henderson, 2015).

The landfall phase of TC events like Ita is often associated with strong winds, heavy rainfall, and storm surges. Coastal topography can play a major role in reorienting TC path as well as modulating near-surface wind and precipitation fields (e.g. Hsu et al., 2013; Wu et al., 2015). Topography along the northeast Queensland coastline is known to have such an impact, and acts to enhance the destructive potential of landfalling TCs (Ramsay and Leslie, 2008).

This study aims to provide a first insight into topographic influences on near-surface winds during a TC event. To address this, the Advanced Research Weather Research and Forecasting (WRF-ARW) model (Skamarock et al, 2008) is used to simulate the near-surface wind field at 10 m height of TC Ita as it moved through Cooktown.

METHODOLOGY

Model description

The WRF-ARW version 3.7.1 (Skamarock et al, 2008) model was implemented with a moving nest configuration with the vortex-following option turned on for this study. Two domains are set up with grid and time step ratios of 1:3 with 27 vertical height levels. Domain one (d01) includes 230 × 230 grid points with a 10 km horizontal resolution, whereas domain two (d02) has a grid spacing of 3.3 km on a 220 × 220 grid. Model runs used a time step of three hours and the period between 9 April, 12 UTC through 14 April, 12 UTC is simulated. All initial and boundary conditions are sourced from the 1° × 1° NCEP final operational model global tropospheric analyses database (NCEP, 2000). These include air temperature, humidity, hydrostatic and sea level pressure. High-resolution topography data with a horizontal grid spacing of 4 km and 1 km were used for domains d01 and d02, respectively. The highest elevations are found around Cairns with mountains up to 1000 m.

Experimental design

Following Kloetzke et al. (2016), the Kain-Fritsch cumulus scheme, the WRF Single-Moment 3-class microphysics, and the Yonsei University boundary layer parameterisation were used to simulate TC Ita. This combination of physics options yielded the smallest track error with regards to the observed track. To test the influence of topography on the modelled track behaviour, two simulations were run for comparison with the default simulation results discussed in Kloetzke et al. (2016). The first simulation involved all topography throughout the domain being removed (*notop*). For the second, only the topography in the area around Cooktown, ranging from 16S to 14S and 144E to 146E was removed (*notopCT*). Topographic features throughout the remainder of the domain were maintained.

RESULTS

The first simulation used the WRF default physics configuration (Skamarock et al, 2008) with topography turned off for the entire domain (*notop*). As shown in Figure 2, this track matches fairly well with the best track and default (*top*) simulation at the beginning of the track, but quickly begins to diverge after 24 hours. While the WRF default simulation (top, red line) roughly follows the best track, the notop simulation moves fast southward due to a strong steering flow originating near Papua New Guinea. It turns out that by removing all topography throughout the domain has large scale influences, which leads to a blocking ridge to the west and a strong northerly steering flow that forces the storm to move southward in a manner unrepresentative of the actual event.

In an attempt to reproduce the same event track as the default simulation (*top*), but still investigate topographic influences, a smaller area of topography was removed (*notopCT*), as described above. Running this simulation, Figures 2 and 3 show very close replication of event characteristics in terms of track position and central pressure. The track position error (with respect to the best track data) for *notopCT* at landfall is only 11 km, which is in fact an improvement on the default simulation value of 27 km.

Figures 4A and 4B highlight the influence of removing the relatively small area of topography (up to 300 m height) for the broad region around Cooktown in the *notopCT* simulation. The Cooktown area modelled with zero topography values shows slower near-surface winds to the south of the TC core and faster winds to the north, when compared with the *top* case. The *notop* wind field is generally stronger than the flow in the area with topography, as hills and mountains act as blocking ridges that appears to slow winds in this area. Overall, these differences are comparably small due to the little area near Cooktown that was modulated and the non-complexity of terrain; however, the influence of topography cannot be denied.

CONCLUSIONS AND FUTURE WORK

The landfall phase of TC Ita has been investigated to understand the topographic influence on the near-surface wind field. When comparing results for simulations with and without topography in the Cooktown region it is evident that sudden decreases in wind speed occur as flow moves over land, but this slowdown is less pronounced when topographic features are not present. Further research will explore how changing the size of the selected topography removal region will influence results or regions with more complex terrain.

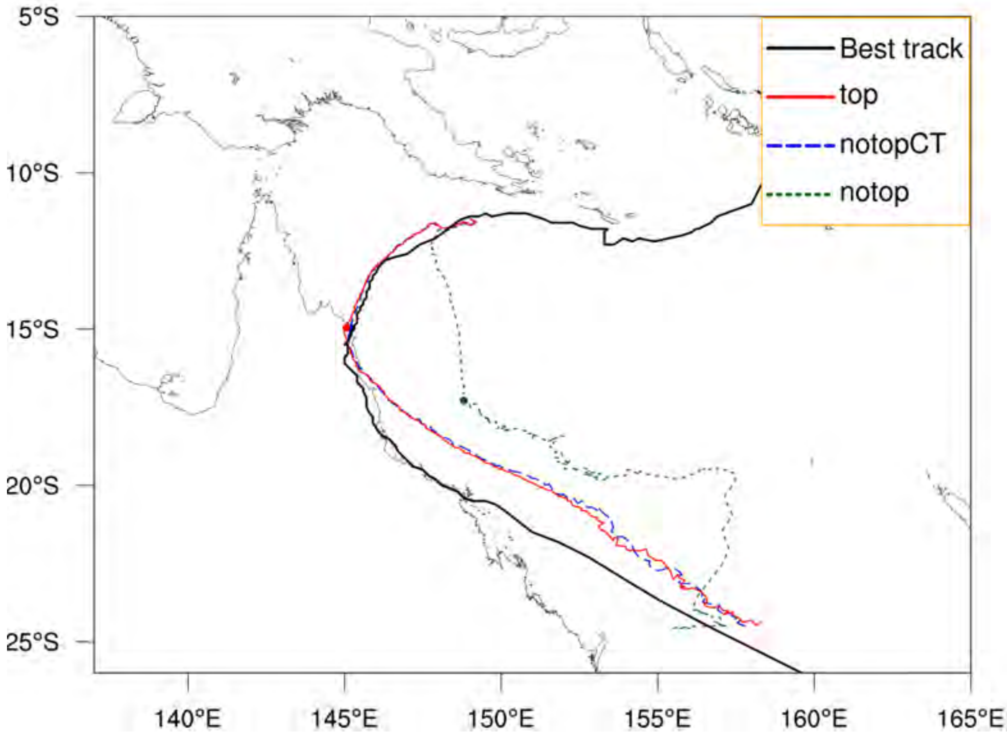

FIGURE 1. WRF MODELLED TRACKS AND BEST TRACK (BLACK) OF TC ITA. WRF DEFAULT PHYSICS MODELLED TRACK (RED), TOPOGRAPHY SET TO ZERO FOR THE ENTIRE DOMAIN (GREEN), AND TOPOGRAPHY TURNED OFF FOR THE COOKTOWN AREA ONLY (BLUE). LANDFALL POINTS ACCORDING TO THE BEST TRACK LANDFALL TIME ARE INDICATED WITH COLOURED DOTS.

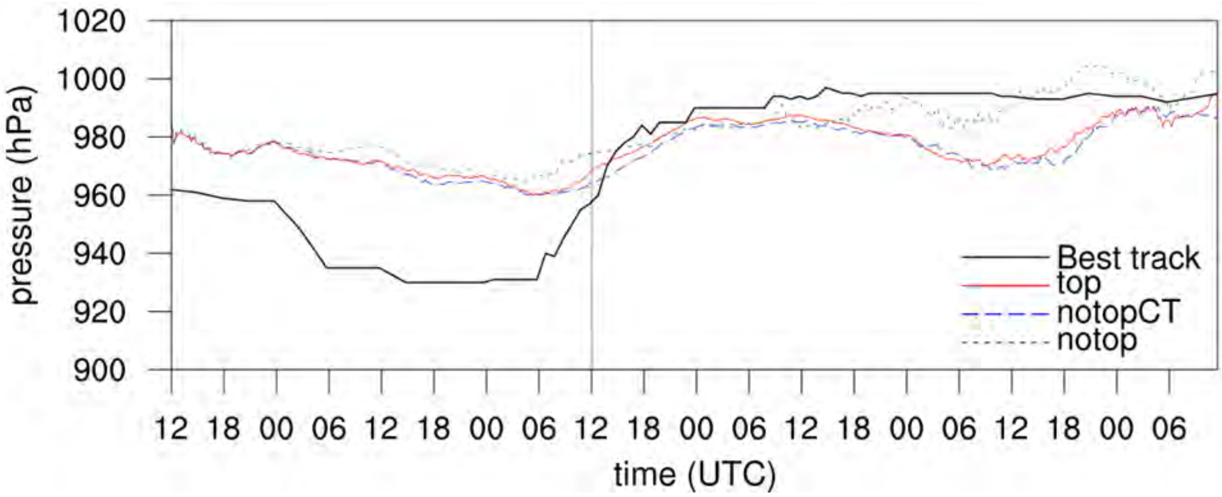

FIGURE 3. PRESSURE SHAPES FOR TRACKS IN FIGURE 2.

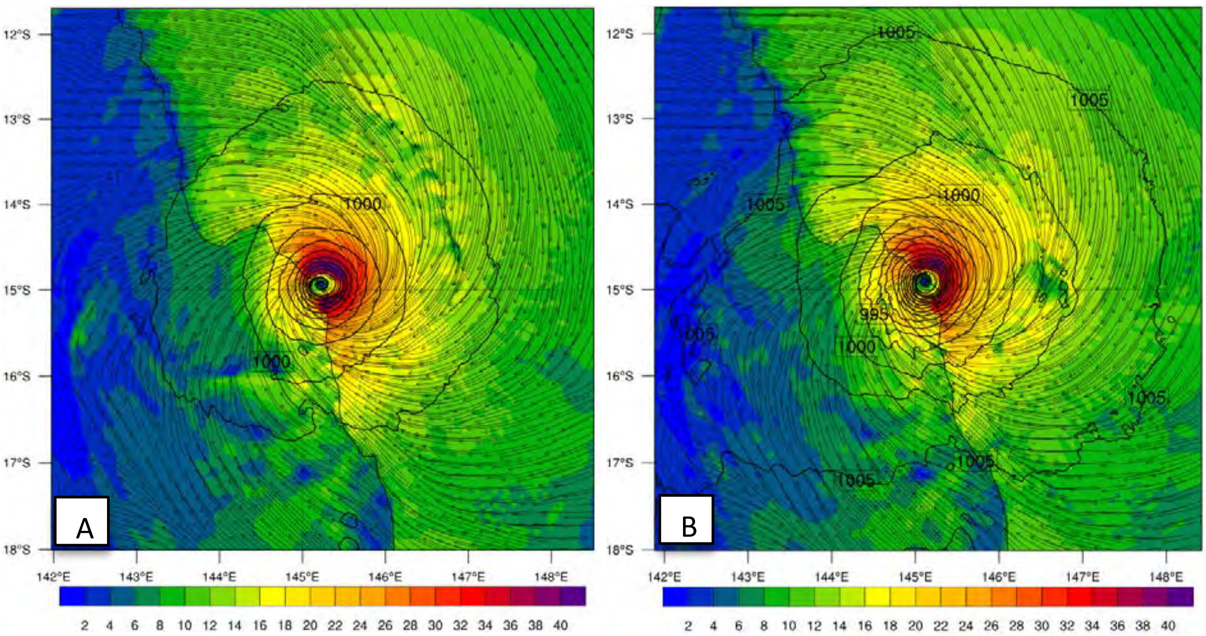

FIGURE 2. WIND SPEED AND PRESSURE FIELDS FOR THE 3.3 KM WRF-ARW RESOLUTION TC ITA AT LANDFALL. COLOURED CONTOURS INDICATE THE 10 M WIND SPEED MAGNITUDE, ISOBARS ARE DISPLAYED WITH SOLID BLACK LINES, AND WIND DIRECTION WITH ARROWS.

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OPPORTUNITIES AND CHALLENGES OF CITIZEN-LED RECOVERY IN POST-DISASTER SETTINGS

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INTRODUCTION

The rise of resilience thinking has seen a significant shift in responsibility for risk. Citizens are now expected to take greater responsibility for managing their own risks and are afforded more opportunities for participating in risk management processes. This shift is driven by recognition of the considerable knowledge and agency that exist among citizens, but also the diminished role of the state in service provision. This paper considers the complexities of a citizen-led, place-based recovery project initiated following the 2009 Black Saturday bushfires in south-eastern Australia. This innovative project aimed to provide practical assistance to people whose homes were destroyed by bushfire to enable them to begin the rebuilding process. A key strength of the project was that it was initiated and implemented by local people to meet specific local needs. As members of the affected community, project participants were able to draw on local knowledge, networks and resources to achieve their goals, and were highly responsive to changing local conditions. However, participants experienced significant difficulties in their interactions with official agencies and entanglements with bureaucratic processes and procedures. As local people, the strain of assisting affected people to rebuild and recover was also considerable. These findings reinforce the need to better assist and support community members who choose to participate in emergency and disaster management but are unfamiliar with bureaucratic processes and procedures, or the challenges of the post-disaster phase. It is also necessary to consider how to simplify processes and procedures to maximise community participation. Failure to do so may encourage people to circumvent formal processes, for better or worse.

BACKGROUND

Citizen participation is a key principle of disaster risk reduction and resilience building. Participatory approaches were central to the Hyogo Framework for Action 2005–2015, which declared that 'communities and local authorities should be empowered to manage and reduce disaster risk by having access to the necessary information, resources and authority to implement actions for disaster risk reduction' (UNISDR 2005, p. 5). Its successor, the Sendai Framework for Disaster Risk Reduction 2015-2030, calls for 'empowerment and inclusive, accessible and non-discriminatory participation', noting that 'special attention should be paid to the improvement of organised voluntary work of citizens' (UNISDR 2015, p.13). In Australia, the National Strategy for Disaster Resilience identifies 'Empowering individuals and communities to exercise choice and take responsibility' as a key priority (COAG 2011, p.10). Priority outcomes include that recovery strategies 'are developed in partnership with communities and account for long-term local needs' and 'recognise the assistance the community is likely to provide in the immediate recovery phase, and allow for the identification, facilitation and coordination of the community resources' (COAG 2011, pp. 13-14).

Of course, citizen participation in emergency and disaster management is not a new phenomenon. Research has shown that people and communities tend to become more cooperative and cohesive in times of crisis, often working together to overcome individual and collective challenges (e.g. Fritz and Mathewson, 1957; Stallings and Quarantelli, 1985; Perry and Lindell, 2004; Helsloot and Ruitenberg, 2004). Increasingly, the often important roles played by informal volunteers before, during and after emergencies and disasters are being recognised (e.g. Scanlon *et* *al*. 2014; Whittaker *et al*. 2015). Informal volunteers work outside of formal emergency and disaster management arrangements to help others who are at risk or are affected by emergencies and disasters. They may volunteer as individuals or as part of a group, on a short or longer-term basis, regularly or irregularly, and in situ or ex situ. Their participation may be spontaneous and unplanned, or deliberate and carefully planned. There are a range of opportunities and challenges associated with the participation of informal volunteers during emergencies and disasters (see Whittaker *et al*. 2015).

COMMUNITY ON GROUND ASSISTANCE

Community On Ground Assistance (COGA) was a citizen-initiated project that provided assistance to people who experienced property damage as a result of the 2009 Black Saturday bushfires in Victoria, Australia. The project was funded by the Victorian Bushfire Appeal Fund (VBAF) and utilised a workforce of qualified, paid employees and corporate volunteers. COGA assisted eligible individuals, couples and families to undertake a range of activities including: dangerous tree removal; removal of re-growth; property clean-up to enable rebuilding to start; cutting and splitting of fire affected trees for wood heating; minor fire-related earthworks; carpentry and building-related tasks; rebuilding and recovery planning and advice; referral to other relevant services; technical advice; and assistance and advocacy with occupancy permits.

The goal of the case study was to better understand the key characteristics, processes, activities and outcomes of the COGA project. It sought to learn from the experiences and perspectives of those involved in the project. It provides insights into the potential opportunities and challenges for undertaking community-led initiatives in the disaster recovery phase. The findings will be valuable for emergency management organisations and other government and non-government organisations that are working towards more localised, community-based approaches to community safety and engagement.

Semi-structured, in-depth interviews were conducted with: COGA founders and team members; corporate volunteers; COGA clients; state and local government officials; and representatives of auspice organisations. Interviews were audio-recorded and transcribed. The qualitative data analysis software NVivo v.10 was used to manage interview data and assist the analysis. A coding framework was developed, setting out the categories into which segments of interview text could be grouped to enable closer analysis and comparison. Interview data was supplemented by additional, secondary data from: COGA documents; annual and other reports of relevant government agencies; annual and other reports of auspice organisations; and media reports.

Key findings from the analysis include:

- **Relationships with other agencies:** COGA had strong ties to a number of organisations, including the Salvation Army and numerous community and faith-based organisations, which provided initial funding and support. Project members received considerable support from a number of officials with government agencies. However, over time, project members became frustrated by their relationships with some government agencies and officials. Participants believed that the focus shifted from helping clients to fulfilling bureaucratic requirements.

- **Benefits and impacts:** By undertaking tasks such as tree removal, property clean up, and the provision of technical advice and building services, the project helped people begin to rebuild. However, the projects impacts were not just physical. The 'person-centered approach' that was adopted meant that the project also had significant psychological or emotional benefits for clients.

- **Key strengths:** COGA was a highly innovative, community-initiated project designed to meet specific local needs. A key strength of the project was its holistic, client-centered approach.

- **Challenges:** COGA participants were challenged by their relationships with some agencies and officials, who they believed questioned their motivations and integrity. They also felt overburdened by reporting and other bureaucratic requirements. Some community members were disgruntled because they had been deemed ineligible to receive support.

IMPLICATIONS

The COGA project highlights some of the opportunities and challenges associated with citizen-led initiatives in post-disaster settings. A key strength of the project was that it was initiated and implemented by local people, who drew on local knowledge, networks and resources to achieve their goals. However, as local people, the strain of assisting affected people to rebuild and recover was considerable. Decisions regarding eligibility were particularly difficult. Relationships with some officials and the burden of reporting and other requirements also challenged the project. These findings reinforce the need to better assist and support community members who choose to participate in emergency and disaster management but are unfamiliar with bureaucratic processes and procedures, or the challenges of the post-disaster phase. It is also necessary to consider how to simplify processes and procedures to maximise community participation. Failure to do so may encourage people to circumvent formal processes, for better or worse.

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FORECASTING THE IMPACT OF TROPICAL CYCLONES USING GLOBAL NUMERICAL WEATHER PREDICTION ENSEMBLE FORECASTS: A TROPICAL CYCLONE MARCIA (2015) WIND AND RAINFALL CASE STUDY

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ABSTRACT

Wind hazard and rainfall models were coupled to estimate hourly open exposure maximum three-second gust wind speeds and rainfall totals for Tropical Cyclone (TC) Marcia (2015) using Bureau of Meteorology (BoM) best track data. Yeppoon The Esplanade automatic weather station (AWS) was used to perform a verification of the simulated hourly open exposure maximum three-second gust wind speed and rainfall totals with observed estimates. Preliminary verification results reveal that the wind hazard model overestimates the AWS hourly maximum three-second gust wind speed and the rainfall model underestimates the hourly total rainfall. Ensemble prediction system (EPS) forecasts from the European Centre for Medium-Range Forecasts (ECMWF) were examined to determine their utility in simulating TC Marcia's wind and rainfall fields and impacts. The ECMWF EPS fails to capture Marcia's rapid intensification at 72, 48, and 24 hours leading up to the landfall. A time-varying calibration factor is required at each forecast initialization in order to adjust each ensemble forecast member's minimum central pressure to a more realistic estimate of the minimum central pressure to properly simulate impacts to humans and the built environment.

INTRODUCTION

It is well recognized that tropical cyclones (TCs) pose a significant threat to life and property (Pielke and Landsea 1998). There is a continuing need to examine the uncertainty in the location and intensity of landfalling TCs to aid emergency services managers in the decision-making process. In this study, both wind hazard and rainfall models are coupled to simulate hourly maximum three-second gust wind speeds and rainfall totals during the landfall of TC Marcia (2015). Preliminary validation of the simulated gust wind speed and rainfall fields is conducted using Yeppoon The Esplanade automatic weather station (AWS) observations. Once the wind and rainfall models are verified against landfall observations, they are coupled with the European Centre for Medium-Range Forecasts(ECMWF) ensemble prediction system (EPS) forecasts so the variability in forecast hourly open exposure maximum three-second gust wind speed, rainfall and impacts to residential structures and humans can be assessed with respect to forecast time.

DATA AND METHODS

Using best track data from the Bureau of Meteorology (BoM) and empirical relationships developed by Harper and Holland (1999) and Powell et al. (2005) to estimate the Holland B parameter and radius of maximum wind (RMW, when necessary), respectively, a wind hazard model was used to generate Marcia's hourly open exposure near-surface (i.e. 10m) maximum three-second gust wind fields. To obtain these wind fields, first the gradient wind profile was estimated using the model described in Holland (1980). Then, a linear analytic tropical cyclone boundary layer (TCBL) model developed by Kepert (2001) was employed to adjust wind speeds at storm radii ≤ 400 km (Lin and Chavas 2012) to 10 m. Finally, the simulated near-surface wind field was adjusted for surface terrain conditions and averaging time using a gust factor approach. An example of an hourly open exposure near-surface maximum three-second gust wind field for TC Marcia two hours prior to landfall can be seen in Figure 1.

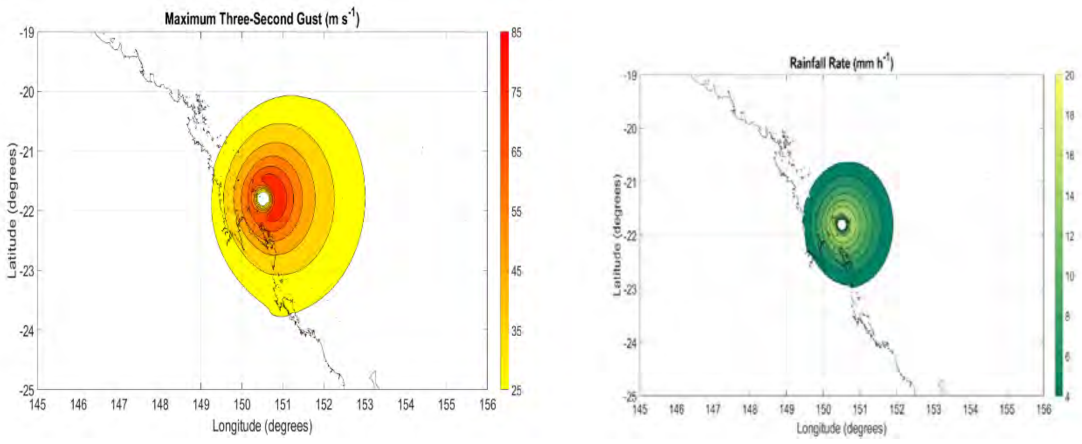

FIGURE. 1. TC MARCIA SIMULATED HOURLY MAXIMUM THREE-SECOND GUST WIND FIELD (LEFT) AND RAINFALL RATE (RIGHT) FIELDS GENERATED AT APPROXIMATELY TWO HOURS BEFORE LANDFALL (19 FEBRUARY 2015 AT 20:00 UTC).

To generate the rainfall rate fields, empirical relationships developed by Tuleya et al. (2007) using a modified (R-CLIPER) model were employed. The model only requires information regarding the maximum near-surface wind speed (i.e. hourly open exposure maximum three-second gust wind speed) and how it varies with respect to storm radius as an input. One caveat to the rainfall model is that the fitting coefficients were calibrated based on US terrain and storms. Future work will involve calibrating these model coefficients for terrain conditions in Australia. An example of rainfall rate field of TC Marcia two hours prior to landfall can also be seen in Figure 1. Using both the wind and rainfall fields, direct comparisons were made with available BoM automatic weather station (AWS) in situ wind and rainfall measurements (Figure 2). The reference AWS selected for comparison with the simulated maximum three-second gust wind speeds and hourly rainfall totals was Yeppoon The Esplanade AWS. Based on the preliminary comparisons shown in Figure 2, the wind hazard model overestimates the hourly open exposure 10 m maximum three-second gust wind speed during the landfall phase and slightly underestimates the inner core rainfall. Furthermore, the rainfall model completely missed the sharp peak in rainfall prior to landfall. This is believed to be a result of the symmetric rainfall model's inability to model rainband rainfall and is an acknowledged limitation of the model.

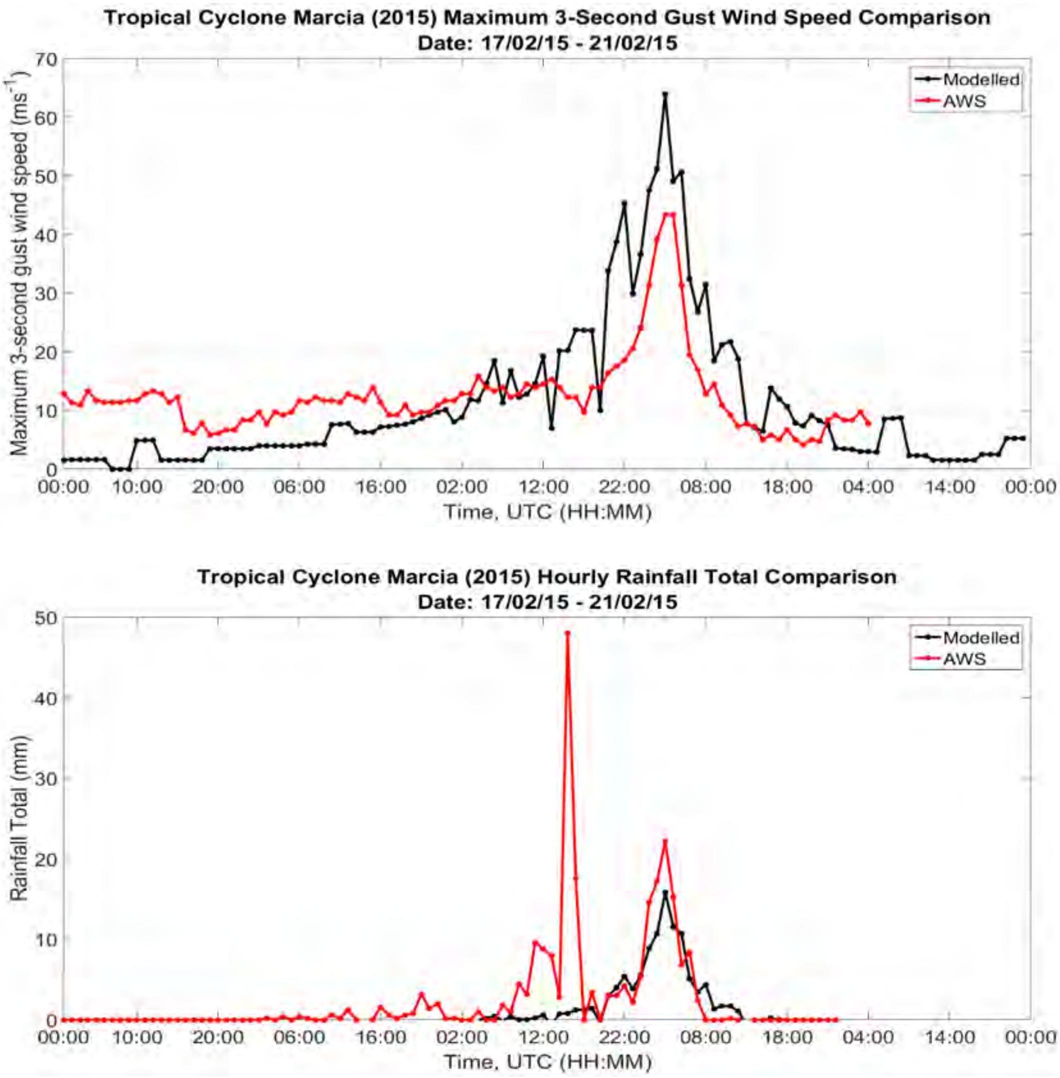

FIG. 2. COMPARISON OF SIMULATED (BLACK) VERSUS OBSERVED (RED) HOURLY MAXIMUM THREE-SECOND GUST WIND SPEEDS (TOP) AND RAINFALL TOTALS (BOTTOM) AT THE YEPPOON THE ESPLANADE AWS.

CASE STUDY: TROPICAL CYCLONE MARCIA (2015)

In an effort to re-create Marcia's landfall hourly open exposure 10 m maximum three-second gust wind field and simulate a range of possible impacts, the wind hazard model described in Section 2 was run with ECMWF EPS latitude, longitude, and minimum central pressure forecast output from each ensemble member at 72-, 48-, and 24-hr leading up to landfall (Figure 3).

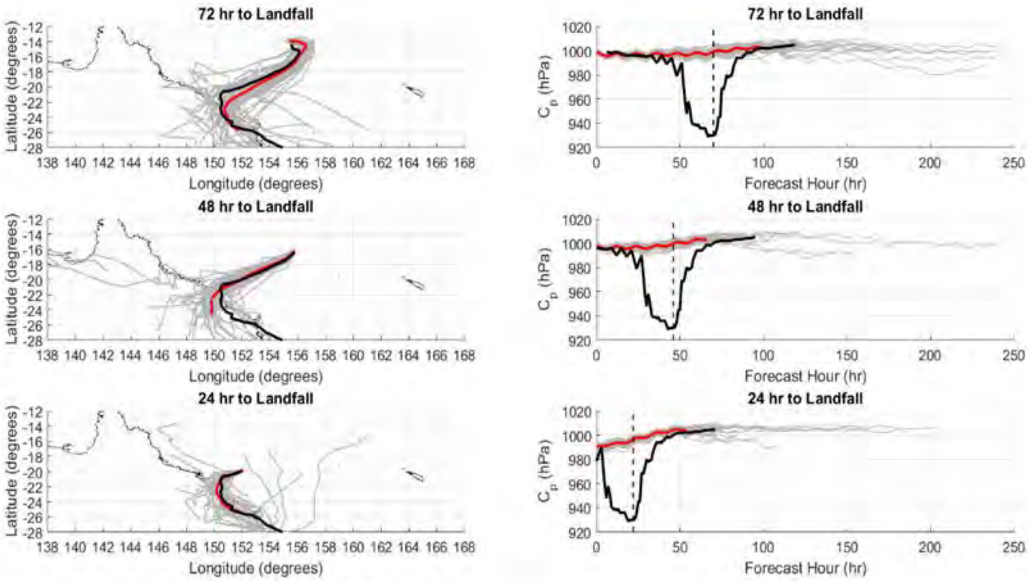

FIG. 3. ECMWF EPS FORECAST MEMBER (GRAY LINES) AND ENSEMBLE MEAN (RED LINE) TRACK AND MINIMUM CENTRAL PRESSURE FORECASTS 72-, 48-, AND 24-HR LEADING UP TO THE LANDFALL OF TC MARCIA. THE BLACK LINE REPRESENTS THE BOM BEST TRACK POSITION AND MINIMUM CENTRAL PRESSURE.

The same empirical relationships that were used to estimate the Holland B parameter and RMW for the verification analysis in Section 2 were used again here to generate ECMWF EPS estimates of the Holland B parameter and RMW. At 72-hr leading up to landfall, the ECMWF ensemble mean landfall location lies east of the BoM best track landfall position and the rapid intensification is completely missed by the EPS. In fact, at each forecast hour, the rapid drop in pressure is never resolved in the ECMWF EPS. As for the position at 48-hr and 24-hr leading up to landfall, the ECMWF ensemble mean track forecast shifts west of the BoM best track but lies within 50–100 km of the actual landfall location. As the forecast landfall time decreases, the spread in ensemble guidance narrows, indicating a higher degree of confidence in the EPS forecast of the mean position of Marcia with decreasing forecast time. Given that the ECMWF EPS does not fully capture the rapid intensification phase of Marcia, it was difficult to realistically simulate TC Marcia's wind and rainfall fields, as well as, wind-related damage to residential structures or the total number of people displaced from their homes, as initially planned.

CONCLUSIONS AND FUTURE WORK

A wind and rainfall hazard model was coupled with BoM best track data to reproduce the hourly maximum three-second gust wind speed and rainfall fields during the landfall of TC Marcia. Simulated hourly gust wind speeds and rainfall totals were verified against observations collected at the Yeppoon The Esplande AWS prior to and during landfall. Preliminary comparisons between the simulated and observed hourly gust wind speed and rainfall measurements suggest that the wind hazard model underestimates TC Marcia's peak landfall intensity and slightly underestimates the inner core rainfall. Outer rainband rainfall totals were grossly underestimated by the model, as expected, given the rainfall model cannot properly model rainband features.

ECMWF EPS forecasts were retrieved and both storm position and intensity (i.e. minimum central pressure) information was extracted to simulate the hourly maximum three-second gust wind speed and rainfall fields for all ensemble members. Based on a general assessment of the ECMWF EPS forecasts, ensemble mean, and BoM best track for position and intensity at 72-, 48-, and 24-hr leading up to the landfall, the model track envelope spread narrows with decreasing forecast time as expected and the ensemble mean position gets closer to the actual landfall location. However, the ECMWF EPS fails at every forecast hour to accurately capture and forecast the rapid intensification of TC Marcia prior to landfall, resulting in an inability to properly simulate impacts to the built environment and humans.
Future work will consist of further calibration of both the wind hazard and rainfall models using more storms (e.g. TCs Larry 2006, Yasi 2011, Ita 2014, and Nathan 2015). Once these models are fine-tuned, more EPS forecast output from the TIGGE archive and BoM will be retrieved to further assess how well other EPSs perform relative to the ECMWF EPS for TC Marcia and the above-mentioned historical landfall events.

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THE BUSHFIRE CONVECTIVE PLUME EXPERIMENT: MOBILE RADAR OBSERVATIONS OF PYRO-CONVECTION FROM THE MT BOLTON FIRE, 2016

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ABSTRACT

Immediately above fires are the extremely localised columns of buoyant air known as convective plumes. The intensity and evolution of convective plumes is critical in the understanding of lofting and spotting of firebrands, where plume structure begins to play an important role in how the firebrands are spatially distributed. Weather radar has been demonstrated as a highly effective tool in analysing plume structure and evolution, but there is very little research using mobile radar in the field despite its proven effectiveness in deconstructing the meteorology of severe convection in thunderstorms. In January 2016, observations were taken at two bushfires using a portable dual-polarisation X-band Doppler radar in Victoria. One of these fires at Mt Bolton showed significant plume-driven fire behaviour, with a convective plume extending up to 7 km above the surface captured on the mobile radar. Here we present the initial findings of this observational dataset of convective plume dynamics, with unprecedented detail in resolution including the development of a deep convective cloud above the fire. We also show that a unique differential reflectivity signature within the dual-polarisation data could bear potential links to the identification of ember and firebrand transport within the plume. This is explored for the Mt Bolton fire where several spot fires were documented over 5 km from the fireground.

EXTENDED ABSTRACT

The study of convective bushfire plumes is critical to improve accuracy of bushfire-spread models and has direct impacts on operational bushfire management. Weather radar has been demonstrated as a highly effective tool in observing pyro-convective plume structure and evolution, and is used by fire behaviour analysts. However, very little research has combined the analysis of radar data above fires with simultaneous measurement of the key thermodynamic aspects in the atmosphere that govern the development of convective plumes above fires. The Bushfire Convective Plume Experiment aims to identify key indicators of intense pyro-convections by means of direct observation using mobile weather radar and aerological soundings (weather balloons), along with other supporting instrumentation in the field at going bushfires. With the support of the Country Fire Authority, the first major observations were obtained following a deployment to the Mt Bolton bushfire in Victoria in early 2016.

While pyro-convective fires may only develop for a portion of bushfires in Australia, these fire-atmosphere coupled events are some of the most difficult fires to manage from an operational perspective. Research to date of pyro-convection in Australia has focused predominantly on numerical modelling, reflecting in part the challenges of direct observation. As promising results are arrived at, verification with direct measurements is becoming an increasingly pressing need (Cunningham and Reeder, 2009; Simpson et al., 2013; Thurston et al, 2013). For example, both nationally and internationally, debate continues in the field of fire-atmosphere interaction on the role of heat as compared to moisture in pyro-convective plumes (Potter, 2005; Achtemeier, 2006; Luderer et al., 2006; 2009; Parmar et al., 2006; Kiefer et al., 2012; Tory and Thurston, 2015).

The general structure of pyro-convective plumes is well established, and is built around the framework of the idealised model of a main updraft and downdraft, supported by various flow features and structures including vortices (Potter 2012ab). However, the spatial and temporal scales on which these features exist present a problem for investigation especially in the fire environment, requiring multiple lines of investigation that range in scale from metres with vortices to that of kilometres in overall plume growth. The recent review of pyro-cumulus and pyro-cumulonimbus (pyroCb) interaction with bushfire highlights operational problems associated with pyro-convection specifically for an Australian context. The review emphasized knowledge gaps pertaining to the role of the pyroCb in closing the feedback loop between fire and atmosphere in how pyro-convection influences surface fire behaviour as implied by Rothermel (1991) and Banta et al. (1992). Equally as important, they raised the question as to the relative importance of atmospheric environmental factors (such as stability) as compared to fire-induced factors (such as released heat and moisture) in triggering pyro-convection.

To begin to address the fundamental dearth of quantitative data on pyro-convection in an Australian context, the Bushfire Convective Plume Experiment undertook initial work during the 2014-2015 bushfire season in order to pilot, test equipment and establish procedures for direct measurement of pyro-convection. The framework of the experiment is a trailer equipped with portable dual-polarised X-Band Doppler radar (UQ-XPOL), ab atmospheric sounding system, Portable Automatic Weather Stations and timelapse cameras. This equipment is used for rapid deployments to the vicinity of going firegrounds to employ as much of it as is safely possible to observe the complex meteorology of pyro-convection. The development of this novel methodology involved extensive risk treatment and mitigation strategies to allow the research to take place in an ongoing bushfire environment with minimisation of impact on fire management operations. From January to March 2016, the fieldwork domain for collecting the first direct observations of pyro-convective plumes above bushfires was extended over all of south-east Australia with a focus on western Victoria where fuels were driest.

The deployment to the Mt Bolton bushfire on 23 February represented the first significant observations of pyro-convection using the UQ-XPOL radar. The fire burnt through a mixture of remnant bushland as well as pine and native plantations on a day of severe fire danger. It exhibited significant spotting behaviour, both short- and long-range before and after a significant wind change. A pyro-convective column observed by UQ-XPOL extended up to an approximate height of 6,000 metres, including deep cloud development associated with the fire. In addition to a large amount of dual-polarisation data collected pertinent to the microphysics of the column, the observations on the scale of the structure of the plume included several key results that relate directly to the fire behaviour and significant spotting on the day. These observations include tilting of the plume and interaction with upper level winds, as well as large fire-induced horizontal vortices. Previously, both tilting and vortices have been highlighted in the literature as important to the dynamics of long-range spotting but the lack of quantitative data on the atmospheric side of the process has limited the conclusions that can be made on their role (Berlad and Lee, 1968; Kerr et al., 1971). The observations are coupled with aerial photography of fire behaviour and spotting on the day, as well field mapping following the incident to provide a comprehensive picture of the plume dynamics on the day.

The success of the 2015–2016 field campaign for the Bushfire Convective Plume Experiment provides several standalone findings pertinent to convective plume dynamics and critically provides the proof of concept for the ability of a rapid deployment of mobile radar as a highly effective tool for deconstructing the behavior of convective plumes. With this proof of concept obtained, plans are in place for an extensive field campaign through the 2016–2017 bushfire season in south-east Australia.

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"I THINK I'M GOING TO BE FRIGHTENED OUT OF MY WITS" PSYCHOLOGICAL PREPAREDNESS AND VULNERABILITY: INSIGHTS FROM THE SAMPSON FLAT FIRE

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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INTRODUCTION

Bushfires and other natural disasters are becoming increasingly frequent and more severe. Australian bushfire projections suggest that by 2020 the number of days classified as 'very extreme' bushfire risk will double and by 2050 there may be as high as a four- to five-fold increase in frequency compared to data from 1990 (Lucas, Hennessy, Mills & Bathols, 2007).

Research into preparedness, therefore, is increasingly important. Preparedness commonly refers to actions taken to protect oneself, one's family and property. For bushfires, this typically involves material preparedness, such as creating a cleared area and the house and having battery-operated communication devices. This kind of physical preparation also involves developing a bushfire plan (e.g. to stay or leave early; how to look after pets in a fire) and acquiring greater knowledge and understanding about bushfires and bushfire risk. However, a growing body of research identifies psychological preparedness as an important factor in natural disaster preparedness.

Psychological preparedness is defined as a 'state of awareness, anticipation, and readiness - an internal, primed, capacity to anticipate and manage one's psychological response in an emergency situation' (Malkina-Pych, 2013). That is, psychological preparedness is not necessarily about removing feelings of anxiety or stress, as these may be adaptive, but in learning to anticipate, recognise and manage these effectively. Initial research drawing on the much larger body of research on the psychological correlates of physical preparedness also suggests that emotional preparedness may include cognitive states such as feeling confident about being able to cope with a disaster and a sense of personal control and self-reliance (Morrissey & Reser, 2003; Rhodes 2003)[1].

Although there is a substantial body of research on post-disaster psychology (e.g. Yun, Lurie & Hyde, 2010; Paton & Long 2010), there is as yet little on pre-disaster psychology. However, emerging research indicates that a lack of psychological preparedness is a significant vulnerability factor prior to, and during a disaster. An inability to anticipate and manage strong emotions can lead to cognitive disruption resulting disorientation, poor attention and memory recall; and poor decision-making and judgment (Malkina-Pykh, 2013). A lack of psychological preparedness has also been linked with lower physical preparedness (Morrissey & Reser 2003). Conversely, being psychologically prepared can increase confidence, as well as planning and preparation, assisting people to act more coolly and calmly (Reser & Morrissey, 2009). It is thought that being able to anticipate and manage psychological responses such as anxiety enhances people's coping ability and promotes better preparedness. In an evaluation of a psychological preparedness intervention utilising Stress Inoculation Theory, Morrissey & Reser (2003) found that it significantly increased feelings of efficacy and control, as well as people's ability to anticipate and identify emotions, as well as a moderately higher level of physical preparedness. It is also thought that pre-disaster psychological preparedness may act as a preventative against post-disaster trauma (Morrissey & Reser, 2003).

[1] Throughout the literature, the terms psychological, emotional and mental preparedness are used interchangeably. We have primarily used the term 'psychological' in this paper, as it encompasses both emotions as well as the cognitive states which may assist in managing these emotions. Our initial research used the terms 'emotionally prepared', as this was a more popularly understood term, as well as references to managing emotions and feeling in control, and we use these terms when reporting the results.

Despite its potential to improve bushfire readiness and support people in carrying out their plans, we know much less about psychological, as opposed to physical, preparedness. In particular, we know little about psychological preparedness for bushfires, which are unique in terms of preparedness in relation to the decision to stay or go. Further, there is as yet little research on psychological preparedness with people who have recently experienced a natural disaster as previous research has been theoretical rather than actual (although Morrissey & Reser 2003 is an exception to this).

Using the findings of a joint research project with the South Australian Country Fire Service (CFS), the Bushfire and Natural Hazards CRC, and the community affected by the Sampson Flat Fire in 2015, we explore psychological preparedness in a bushfire context – what it is, what it is related to, its consequences, and potential interventions.

Research questions

This research paper asks:

1. What factors are related to increased emotional preparedness?
2. What are the emotions people experienced, and what are their triggers?
3. What are the consequences of strong emotions before, during and after a fire?
4. What do these findings tell us about potential interventions to increase emotional preparedness?

METHOD

Data collection

Quantitative data was collected through an online survey and a telephone survey, while qualitative data was collected either via face-to-face or telephone interviews.

Participants for the online survey were recruited by the CFS through their website and Facebook page and printed posters and fliers. The online survey was open from 30 June 2015 until 30 July 2015. Overall, 207 people responded. Of these, 10 people began the survey but did not provide answers to any questions. These participants were removed from the analysis. Four participants were under the age of 18, and, for ethical reasons, these participants were also removed from the analysis. This left 193 responses[2].

Participants for the interviews were recruited by the CFS through the post-incident Building Impact Assessment Survey, which had identified people who were willing to participate in further research, and through printed flyers, their website and Facebook page. Further, participants were also recruited through the online survey which included contact details for the Chief Investigator. The interviews, which were a semi-structured conversation about people's experience in the Sampson Flat fire, were conducted between 13 July 2015 and 31 August 2015. These were either face-to-face in people's homes or conducted over the telephone, and ranged from one to two hours. A total of 15 people were interviewed.

[2] Not all respondents answered all the questions. Where not all respondents were included in the analysis, this is indicated in a footnote.

Data analysis

The quantitative data from the online survey was analysed using chi-squares (χ^2). The false discovery rate was controlled using the Benjamani and Hotchberg (1995) procedure. The qualitative interview data was analysed thematically, and as case studies and narratives which provided rich detail and depth to the findings of the quantitative analysis. It was used to illustrate the types of emotions people experienced, as well as their triggers and consequences.

RESULTS AND DISCUSSION

Whilst 75 per cent of those affected by the fire perceived themselves to be physically prepared, only 56 per cent felt emotionally prepared.

Emotional preparedness was gendered. Males were more likely to feel emotionally prepared than females (χ^2 (1) = 12.29, $p < .001$).

Emotional preparedness is heightened through understanding bushfire risk and safety. Those who said they felt emotionally prepared also reported having a high understanding of bushfire risk (χ^2 (3) = 16.61, $p = .001$) and a high understanding of bushfire safety (χ^2 (3) = 11.15, $p = .011$).

Increased emotional preparedness was linked with people undertaking some aspects of physical preparation. Discussing a bushfire plan was associated with emotional preparedness, with those who had discussed a plan also reported feeling emotionally prepared compared to those who had not, χ^2 (1) = 6.58, $p = .010$. However, participants who felt emotionally prepared were not more or less likely to have prepared a written plan, or to have practiced that plan (both $p > .05$).

Emotional preparedness was also related to leaving or staying. Although we may expect that those who stay or leave would be similarly emotionally prepared, findings showed that those who had planned to stay and defend their homes were more likely to report feeling emotionally prepared than those had planned to leave (χ^2 (4) = 20.36, $p < .001$).

However, this difference may have been mediated by physical preparedness. The majority of those who planned to stay and defend were also physically prepared with higher-level preparations, as 70.6 per cent of these participants had installed a fire-fighting pump and hose and two thirds had purchased fire-fighting equipment. For those who did not plan to stay and defend their homes, making the most basic preparations of cleaning gutters was associated with increased emotional preparedness (χ^2 (1) = 9.96, $p = .002$). That is, being physically prepared, even somewhat prepared, increased emotional preparedness.

We found that strong anxiety led to last minute changes to plans, placing people into dangerous situations, either by leaving late, or attempting to re-enter the fire ground too early. As one participant shared: 'We had a plan to stay…[but] my wife said "I think I'm going to be frightened out of my wits"…and I said okay lets shut up and we'll go…anyway we woke up about 6 and I said "we've got to go back". I didn't even think about it. How do you so go against all the rules of going into a dangerous area?'

However, importantly, those who felt emotionally prepared prior to the fire felt that they were able to manage anxiety and stress during the fire (χ^2 (1) = 18.51, $p < .001$) and felt they had some control in an uncontrollable situation (χ^2 (1) = 8.24, $p = .004$). As identified by Morrissey & Reser (2003) and Rhodes (2003) feeling in control and being able to manage emotions assist in responding more effectively to a disaster situation.

CONCLUSION

This research suggests an important shift is needed in bushfire preparedness from focusing almost solely on the physical to including the importance of the psychological.

But what might this look like and how might it be adapted for different people who show important differences in emotional preparedness (e.g. for men and women; for those who stay and those who go)?

In this presentation, we consider the implications of the research findings, such as the gendered nature of psychological preparedness and the lower preparedness of people who leave rather than stay and defend. We look at these issues through an agency lens—what are the challenges for agencies in undertaking psychological preparedness interventions, and what more do we need to know to assist people better in this?

This paper provides a greater understanding of emotional preparedness in a bushfire context, what it is, how it works, and what it effects, with a focus on how we might best work with at-risk people and communities to improve their psychological readiness for bushfires.

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HARNESSING THE CAPACITIES OF SPONTANEOUS VOLUNTEERS: APPLICATION AND ADAPTATION OF THE QUEENSLAND MODEL

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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EXTENDED ABSTRACT

Spontaneous volunteers are defined in Australia as: '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' (Australian Red Cross 2010; Cottrell 2010). Spontaneous volunteering by unaffiliated members of the public following a disaster event is certainly not a new occurrence (Whittaker et al. 2015). Known in the sociological disaster literature as convergence, it is recognised as an inevitable and normal response to — particularly large-scale — disasters (Drabek and McEntire 2003; Sharon 2004). A related term that is not commonly used in Australian emergency management is 'emergent volunteerism'. This 'involves new forms of volunteering that occur in response to unmet needs, whether perceived or real' (Whittaker et al., 2015, p.363).

Spontaneous volunteering has gradually gained in profile and legitimacy in Australia disaster management over the five to ten years (Australian Red Cross 2010). This process has sped up due to the combination of a number of high-profile volunteering efforts such as the Brisbane Mud Army, and the shift toward a resilience-based approach to disaster management (COAG 2011). Most recently, a National Spontaneous Volunteer Strategy was endorsed by the Australia–New Zealand Emergency Committee in late 2015 that provides guidance to emergency management organisations.

From a management and policy perspective, until recently spontaneous volunteering has largely been portrayed as an unpredictable and uncontrollable nuisance and risk rather than as a legitimate part of response and recovery (Helsloot and Ruitenberg 2004; Scanlon et al. 2014). Certainly, having unexperienced and uninformed members of the public converge on a disaster site presents many real and difficult to manage health, safety and wellbeing risks for volunteers, residents and trained responders alike (Whittaker et al., 2015). It can also disrupt the formal response effort and divert resources away from the people and communities that are directly impacted (Fernandez et al. 2006).

Critically, however, sociological research on informal citizen responses to disaster shows that the above risks are far greater when there are no plans in place to manage and harness the capacities of spontaneous and emergent volunteers (Fernandez et al. 2006). It also shows that spontaneous and emergent volunteering can contribute significantly to a range of important activities in the immediate aftermath of a disaster, including search and rescue, first aid, and the assessment of community needs (Whittaker et al. 2015). Furthermore, failing to effectively utilise spontaneous volunteers can lead to loss of life or injury, property damage, and poor public perception of the disaster response (Fernandez et al., 2006).

Against this backdrop, this paper reports on a two-part, qualitative case study of the application and adaptation of a Queensland model for coordinating spontaneous volunteers. Emergency Volunteering CREW (Community Response to Extreme Weather), or EV CREW, is an initiative of Volunteering Queensland: a small not-for-profit organisation and the peak volunteering body for the state of Queensland. Based on the model of a recruitment agency, EV CREW is a volunteer management model specifically designed to address the challenges of spontaneous volunteer coordination in the post-disaster context (Mclennan et al. 2016). Drawing on semi-structured interviews with internal and external stakeholders, it first examines key outcomes and challenges experienced in the development and application of EV CREW in Queensland. It then explores how volunteering peak bodies in the ACT, Victoria, and Tasmania are adapting the learning and experience from Queensland to develop similar models in those jurisdictions.

APPLICATION AND ADAPTATION OF EV CREW MODEL

Key outcomes of the application of the EV CREW model reported by its Queensland stakeholders included that (see also Mclennan et al. 2016):

• Spontaneous volunteers are able to undertake more valuable and rewarding roles;

• More disaster recovery organisations (including not-for-profit organisations and community groups working in relief and recovery) develop capacity and experience in using and managing these types of volunteers effectively and safely;

• Community resilience is strengthened because volunteers are matched as locally as possible to foster local social connectivity and cohesion;

• All parties involved, including communities affected by disaster, have reduced risk and greater transparency compared to when spontaneous volunteering is uncoordinated;

• There are improvements in the effectiveness of the disaster management effort, particularly in local-level recovery, as well as a reduction in the 'crowd control' burden put on disaster management organisations.

Both internal (Volunteering Queensland and partner organisations) and external (recipient disaster management organisations) stakeholders felt that EV CREW supported disaster recovery organisations to make better use of the skills and resources that existed locally. Notably, all stakeholders felt that Volunteering Queensland value-added to the disaster response and recovery effort through its expertise in volunteer management, and all felt that the basic model of having a third-party, centrally coordinated system to manage spontaneous volunteers was sound and a valuable resource for local response and recovery organisations.

Compared to the research literature on spontaneous volunteering, the reported outcomes of the EV-CREW model placed greater emphasis on its contribution to supporting community resilience as compared to the disaster response effort, and on the important psychosocial benefits that impacted residents get from receiving volunteered support from within their community (compare with Gordon 2006 for example).

There were also some caveats, risks and challenges identified that are important to consider for future developments of this type of model. For example, some stakeholders suggested that central coordination by a third-party may only be appropriate and necessary in larger population centres, or where other local sources of coordination were not already in place. One participant gave the example of Emerald as a community where centralised coordination would not have been suited. In this mining community the mining company was already well-placed to coordinate mine workers to help with flood recovery in 2010, while informal social ties were sufficient in this small community (approx. 13,000) to underpin a locally led and self-organised recovery effort without the need for centralised coordination by a third-party.

Challenges for putting such a model in place included: difficulties in managing expectations of, and adequately delineating the roles and responsibilities between, the coordinating organisation and the recipient organisations; and a lack of funding to maintain and improve the model's operation. For example, Volunteering Queensland does not supply volunteer insurance, induction or occupational health and safety support for volunteers. However, there was some expectation amongst its organisational users of at least partial support for these services.

There were also risks identified stemming from the varied capacities of recipient organisations that may be unfamiliar with spontaneous volunteer management. They included the risk of poorly managed or ill-conceived volunteering opportunities turning people away from volunteering, and small community-based organisations becoming over-burdened or overwhelmed during an emergency event. In Queensland, these risks were reduced through one-on-one support offered by the EV CREW coordinator. However, external stakeholders felt that the model would be improved with a greater on-the-ground presence from Volunteering Queensland, both to assist with on-site volunteer coordination, and to increase the profile of the service amongst potential volunteers and organisational users. Notably, Volunteering Queensland has unsuccessfully sought funding in the past to train people to provide more comprehensive and hands-on support with volunteer management.

Interviews with stakeholders involved in adapting EV CREW for other jurisdictions are ongoing. Emerging themes include the importance of Volunteering Queensland's support and expertise alongside the model itself, particularly in the area of communications and messaging with the public. A noteworthy adaptation being made in Victoria is merging the Victorian version of the EV CREW model, called 'HelpOut' with a funded program to train spontaneous volunteer managers that will assist recipient organisations on-the-ground in a way that Volunteering Queensland did not have capacity for. A key difference in the way adapted models were being developed in other jurisdictions was in the greater degree of structure and rigidity placed around the model's operation compared to Queensland. This was partly due to different political and governmental contexts and partly due to the fact that the Queensland model was developed through on-the-ground experience with repeated disasters, unlike other jurisdictions. Rolling out the model during 'peace time' can provide a space for better pre-planning and relationship-building. However, there is also a danger that a lack of use on-the-ground could lead to a loss of momentum and insufficient capacity to mobilise the model due to lack of experience and inability to maintain skills over time.

Factors that emerged from the case study as being particularly important for enabling effective centralised coordination of spontaneous volunteers were: improving general communication with the public about disaster management processes and procedures during and after events; pursuing a high degree of collaboration between volunteering peaks, local governments, and local divisions of emergency service agencies, as well as other community organisations; and the need to have targeted plans and supportive relationships for spontaneous volunteer management in place amongst all organisations involved prior to disaster events occurring.

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BUILDING COMMUNITY CYCLONE RESILIENCE THROUGH ACADEMIC AND COMMUNITY PARTNERSHIP

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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OVERVIEW

This paper will present research from collaboration between the Cyclone Testing Station at James Cook University and insurer Suncorp over the last two years. A key outcome of this work in 2016 has been Suncorp's recognition of homeowner mitigation efforts through an insurance premium reduction program known as the 'Cyclone Resilience Benefit'. The research methods and findings that informed this program as well as other key outcomes including recommendations for codes and standards will be discussed. A broader context will also be presented including the political backdrop of the Productivity Commission inquiry into natural disaster funding and the recent Northern Australia Insurance Affordability Taskforce.

CYCLONE RISK: INSURER VIEW

Suncorp has a significant exposure to cyclone risk due to a high market share of business in North Queensland. The occurrence of disasters such as Cyclone Larry and Cyclone Yasi have led to higher claims cost, increased reinsurance costs, and subsequent increases to customer premiums. Increasing costs coupled with the vulnerability of existing housing stock to cyclone risk, leaves Suncorp challenged in generating profitable growth. It is not possible to change the hazard itself, thus reducing exposure (i.e. housing vulnerability) is the only viable action.

Porter and Kramer [19] coined the term 'shared value' which revolves around the idea that a company's success and social progress are intertwined. Addressing issues of insurance premium affordability by improving the vulnerability of the housing stock in North Queensland was essentially a societal problem that would also create economic value for Suncorp and therefore a clear shared value opportunity.

Also important to shared value is the collaboration of different groups whose strategic goals are aligned. Suncorp had a wealth of cyclone claims data, but not the expertise to know how to best make use of it to solve the vulnerability problem. In 2014, Suncorp approached the Cyclone Testing Station (CTS) at James Cook University (JCU) to help improve their understanding of cyclone vulnerability with a common purpose of solving the issue together.

CYCLONE RISK: ACADEMIC VIEW

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 wellbeing of the community.

Structural retrofitting details exist for some forms of legacy housing but the uptake 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 ideal opportunity to improve resilience of the house and community. Hence, the issues of retrofitting legacy housing, including feasibility and hindrances on take-up, must be analyzed. The primary objective of this collaborative research is to develop and promote strategies for mitigating damage to housing from severe windstorms across Australia.

Tropical Cyclone Tracy resulted in extreme damage to housing in December 1974, especially in the Northern suburbs of Darwin [18]. Changes to design and building standards of houses were implemented during the reconstruction. The Queensland Home Building Code (HBC) was introduced as legislation in 1982 with realisation of the need to provide adequate strength in housing. By 1984 it is reasonable to presume that houses in the cyclonic region of Queensland were being fully designed and built to its requirements.

Damage investigations of housing, conducted by the Cyclone Testing Station (CTS) in the Northern Territory, Queensland, and Western Australia, 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 wind loads and remaining intact [1, 5, 7, 8, 12]. However, these reports also detail failures of contemporary construction at wind speeds below design requirements. The poor performance of these structures (Figures 1 and 2) resulted from design and construction failings or from degradation of construction elements (i.e. corroded screws, nails and straps, and decayed or insect-attacked timber). Hence, the development of retrofit solutions for structural vulnerabilities are critical to the performance longevity of all ages of housing.

FIGURE 1. REMOVAL OF ROOF CLADDING AND BATTENS FROM WINDWARD FACE

FIGURE 2. PART OF THE ROOF CLADDING WITH BATTENS STILL ATTACHED FLIPPED ON TO LEEWARD SIDE

INSURED LOSS

Figure 2 shows that cyclone and severe storm events together contributed to nearly half of all nominal natural hazard insurance losses over the period from 1970–2013. Whilst cyclone events are not frequent, the resulting losses are high. As one of the most costly, Cyclone Yasi estimated economic losses were over $2 billion, with insured losses at $1.469 billion (Table 1).

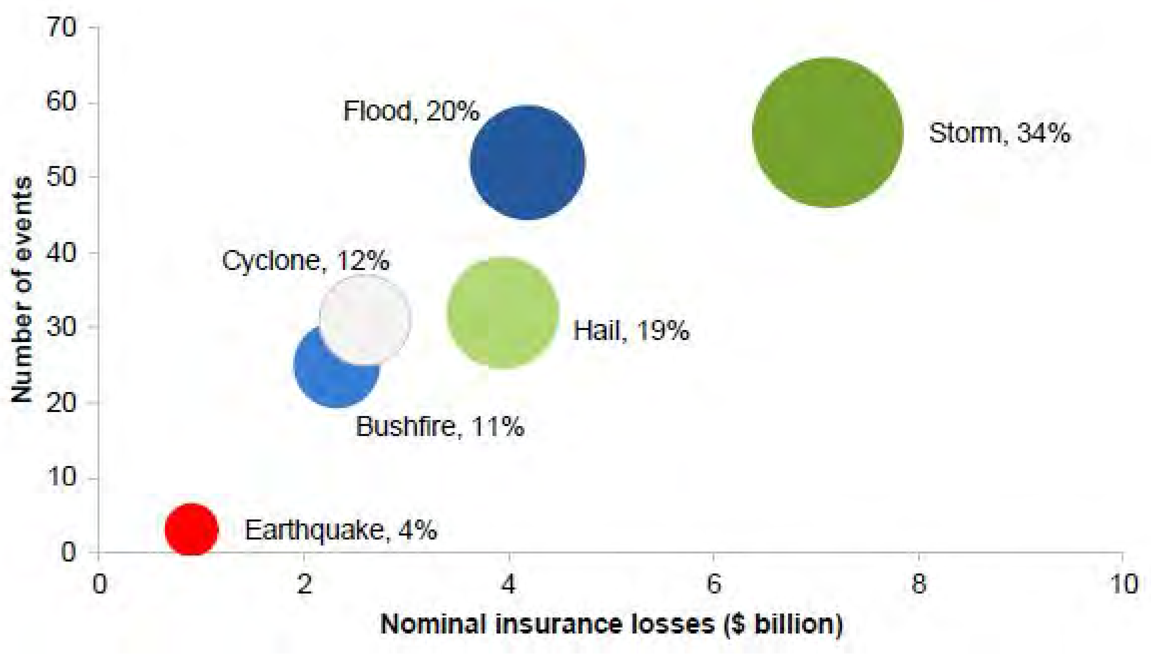

FIGURE 3. INSURANCE LOSSES BY NATURAL HAZARD [10]

Date	Event	2011 normalised economic loss $m[19]	2011 normalised insurance loss $m[20]	Insured %
March 2006	Tropical Cyclone Larry	1,692	609	36%
March 2007	Cyclones George and Jacob	N/A	12	
February 2011	Tropical Cyclone Yasi	2,080	1,469	71%
January 2013	Ex Tropical Cyclone Oswald (NSW & QLD)	1,650	1,098 (as at 31/03/2013)	67%
April 2014	Cyclone Ita (QLD)	N/A	8.4 (as at 15/04/2014)	

TABLE 1. LOSSES FROM WORST LAND FALLING CYCLONES IN AUSTRALIA SINCE 2006 [3]

RESEARCH FINDINGS

The CTS and Suncorp have worked together on two phases of research over the last 18 months. The first phase was concerned with getting a deeper understanding of the drivers of cyclone damage. The CTS used their expertise to investigate Suncorp's 25,000 Cyclone Larry and Yasi claims.

Below are some of the key findings from the Phase 1 study:

• 86 per cent of claims were for minor damage (less than 10 per cent of sum insured), making up a quarter of the total claims cost. These were largely preventable claims involving overgrown trees, shade sails, and outdoor furniture indicating that preparedness can be improved in north Queensland.

• Overall, less than 3 per cent of claims were severe or worse (over 50 per cent of sum insured), yet they accounted for 27 per cent of the total claims cost, presenting a clear case for strengthening older homes in the region.

• Homes built before 1982 (predating modern building codes) were more vulnerable to structural failure

• Windows and doors were often the weakest points in new buildings — when they fail, they allow wind and water into the building leading to further damage.

The second phase involved estimating the Benefit-Cost Ratio (BCR) with different cyclone mitigation options in collaboration with economic consultant Urbis. Key findings of the Phase 2 study included:

• Some upgrades pay for themselves after one cyclone — using Cyclone Yasi as a case study, low cost strapping upgrades at a cost of around $3,000 achieved a BCR of 1.5 for pre-1960 homes and a BCR of 1.4 for 1960-1980 homes

• Minor claims, for less than 10 per cent of the sum insured, can often be easily prevented. Targeting minor claims through a community awareness program achieves an average return of $10 for every dollar invested.

• Upgrading windows and doors in newer homes can result in significant claims cost reductions — after-market bracing costs just $300, and could save between $1,500 and $10,0000 in the event of a cyclone. DIY window protection can be installed for around $1,360, and can reduce claims costs by up to $15,000.

Mitigation option	Cost per household	Total benefit per household	BCR	Payback period
Community awareness campaign	$55–$136	$440–$820	3.2–14.8	<1–6 years
Opening protection – self installed (low cost scenario)	$1,660	$1,990–$6,400	1.2–3.9	4–21 years
Roofing option – strapping only (low cost scenario)	$3,000	$12,900–$38,800	4.3–12.9	2–4 years
Roofing option – over-batten system (medium cost scenario)	$12,000	$13,500–$39,400	1.1–3.3	5–37 years

TABLE 2. BENEFIT COST RATIOS FOR CYCLONE MITIGATION

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THE EFFECTS OF TURBULENT PLUME DYNAMICS ON LONG-RANGE SPOTTING

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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INTRODUCTION

Spotting is a hazardous phenomenon which leads to unpredictable fire behaviour and accelerated fire spread. Spot fires occur when embers are launched by bushfire plumes into the background wind, which then carries the embers a significant distance from the fire front. If the embers land in a suitable fuel bed and are still burning a spot fire may be ignited. The magnitude of the problem is illustrated by Cruz et al. (2012), who provide evidence of long-range spotting in excess of 30 km during the Black Saturday bushfires of February 2009. Therefore a better understanding of the processes that contribute to long-range spotting is essential for the prediction of fire spread. In this study we aim to assess the contribution of turbulent plume dynamics to the process of long-range spotting.

METHODOLOGY

We use a two-stage modelling approach to calculate the landing positions of potential firebrands launched by bushfire plumes. Firstly, we use the UK Met Office large-eddy model (LEM), described by Gray et al. (2001), to perform numerical simulations of idealised bushfire plumes. A number of plumes are simulated for background winds varying from 5 to 15 m s–1. Secondly, the three-dimensional, time-varying velocity fields produced by the LEM are used to drive a Lagrangian particle-transport model. More than 1.5 million potential firebrands are released near the base of the plume and then advected by the LEM velocity field minus a constant fall velocity of 6 m s–1, representative of jarrah and karri bark flakes (Ellis, 2010). In order to assess the contribution of the in-plume turbulence to the firebrand transport, the time-varying particle-transport calculations are then repeated using a steady-state plume velocity, calculated from the one-hour mean plume fields.

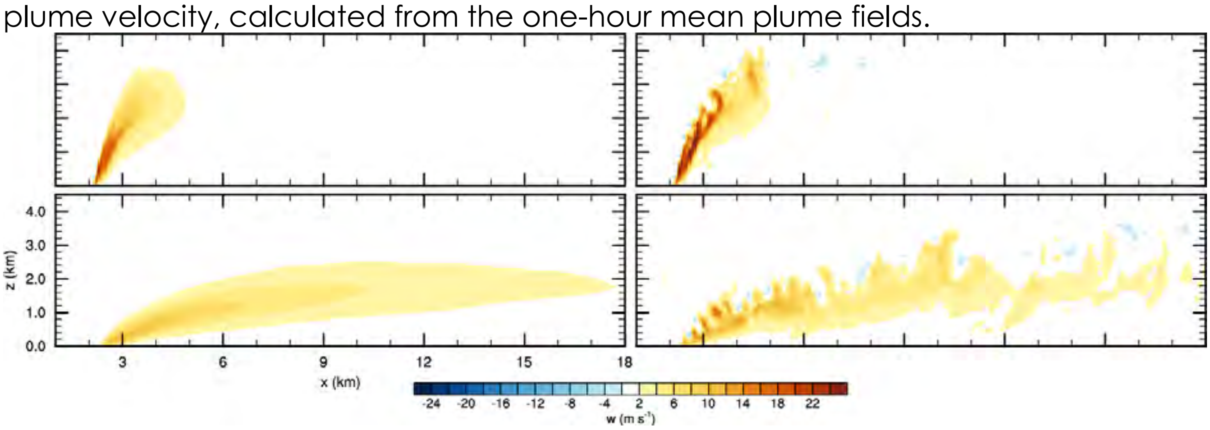

FIGURE 1. VERTICAL CROSS-SECTIONS OF THE MEAN (LEFT) AND INSTANTANEOUS (RIGHT) VERTICAL VELOCITY, M S–1, THROUGH THE PLUME CENTRE LINE, FOR BACKGROUND WIND SPEEDS OF 5 (TOP) AND 15 (BOTTOM) M S–1.

RESULTS

Vertical cross sections of the instantaneous and 1-h mean updrafts for plumes in the 5 m s–1 (weakest) and 15 m s–1 (strongest) background winds are shown in Figure 1. The instantaneous plumes in strong wind have weaker updrafts, and are more bent over than the plumes in weak wind. The instantaneous strong-wind plume is turbulent over its whole height, whereas its weak-wind counterpart is only fully turbulent above a height of about 2 km. Plan views of the weak-wind plume, (not shown here but seen in Thurston et al. (2014)), reveal that the plume has two updraft cores that form a counter-rotating vortex pair. The 1-h mean plumes do not exhibit any of the turbulence that is visible in the instantaneous plume updrafts, and as a result peak updraft is weaker, but more uniform.

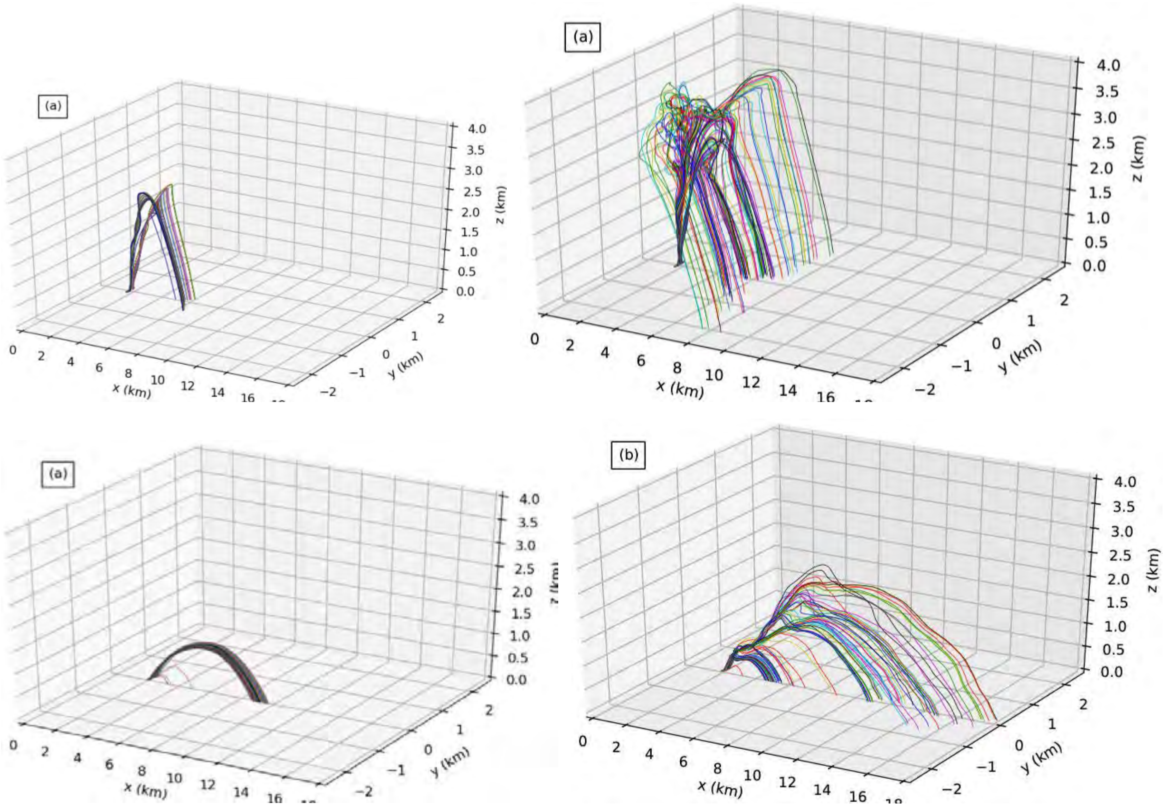

FIGURE 2. TRAJECTORIES OF 100 FIREBRANDS LOFTED BY THE MEAN (LEFT) AND T IME-VARYING (RIGHT) PLUMES UNDER BACKGROUND WIND SPEEDS OF 5 (TOP) AND 15 (BOTTOM) M S–1.

The trajectories of a sub-sample of 100 of the firebrands lofted by each of the plumes in Figure 1 are shown in Figure 2. Firebrands lofted by the time-varying weak-wind plume initially travel up the two branches of the counter-rotating vortex pair, and are then spread out further laterally as they reach the turbulent region of the plume above a height of 2 km. Firebrands lofted by the time-varying strong-wind plume do not exhibit any of this lateral spread, instead landing near the plume centre line. These firebrands appear to be lofted in clumps by the turbulent puffing of the plume, and hence tend to fall out in clusters. The trajectories of firebrands lofted by the 1-hr mean plumes highlight the importance of the in-plume turbulence. In the weak-wind case the firebrands still travel up the two branches of the counter-rotating vortex pair, but there is less lateral dispersion above 2 km. In the strong-wind case the effect of the in-plume turbulence is more pronounced, with most firebrands lofted by the 1-h mean plume now having similar trajectories.

Figure 3 shows the two-dimensional landing distributions for all of the 1.5+ million firebrands launched by each of the plumes in Figure 1. The counter-rotating vortex pair and upper-level turbulence of the time-varying weak-wind plume lead to the firebrands landing in a V-shaped pattern with considerable lateral spread. The landing positions of firebrands lofted by the 1-h mean plume in weak winds still form a V-shaped pattern, but there is less lateral spread due to the lack of in-plume turbulence. Firebrands lofted by the time-varying strong-wind plume travel on average about twice as far as their weak-wind plume counterparts, have more longitudinal spread and less lateral spread in their landing distribution. The landing positions of firebrands lofted by the 1-h mean plume in strong winds show much less spread and crucially the maximum spotting distance is reduced by half from about 16.7 km to 8.4 km.

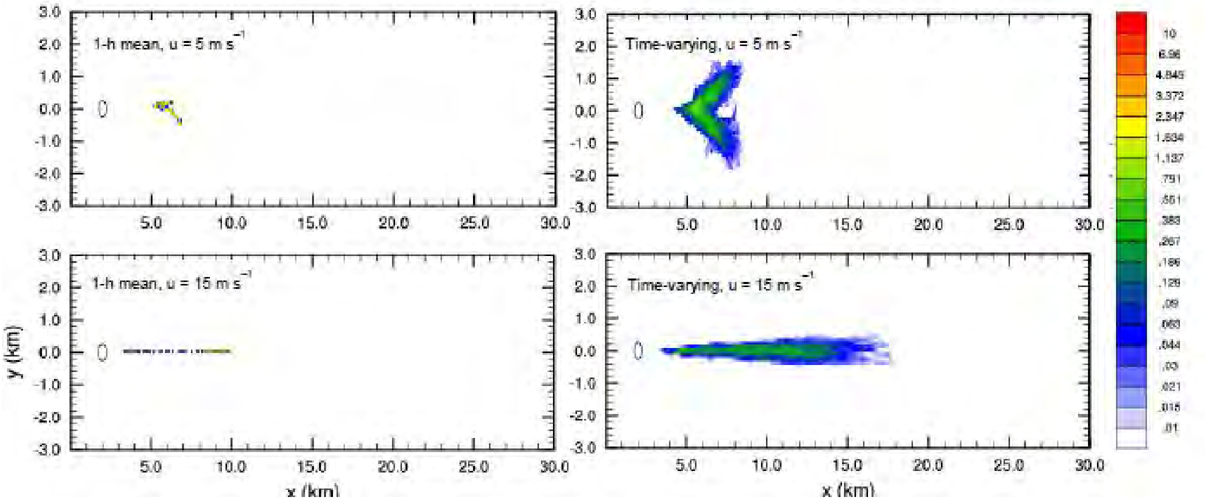

FIGURE 3. SPATIAL DISTRIBUTIONS OF FIREBRAND LANDING POSITION (PERCENT OF PARTICLES LAUNCHED PER KM2) FOR THE MEAN (LEFT) AND TIME-VARYING (RIGHT) PLUMES UNDER BACKGROUND WIND SPEEDS OF 5 (TOP) AND 15 (BOTTOM) M S–1.

A critical consideration in the potential for firebrands to start spot fires is whether they are still burning when they land. Therefore the flight times of the firebrands lofted by the time-varying weak-wind and strong-wind plumes are presented in Figure 4. Firebrands that are lofted by the weak-wind plume have a relatively long flight time, even if they do not travel a long distance. For example firebrands that are lofted by the weak-wind plume and subsequently travel only 0–2 km are in the air for 7.5–12.5 minutes, whereas firebrands that are lofted by the strong-wind plume and travel only 0–2 km are in the air for 1.5–3.5 minutes. This is caused by the plume dynamics seen in Figure 1; the weak-wind plume is more upright and has a stronger updraft, causing the firebrands to go almost straight up, reach a greater height and therefore be in the air for longer. This behaviour is confirmed by the trajectory plots of Figure 2. The firebrands that have travelled the furthest (16–18 km, in the strong-wind case) have a median flight time of 21.5 minutes and a 1st–99th percentile range of 19.3–23.4 minutes. This is similar to the maximum burnout time of ribbon gum bark observed in the wind tunnel studies of Hall et al. (2015) and would suggest that firebrands taking these trajectories would still be capable of starting spot fires.

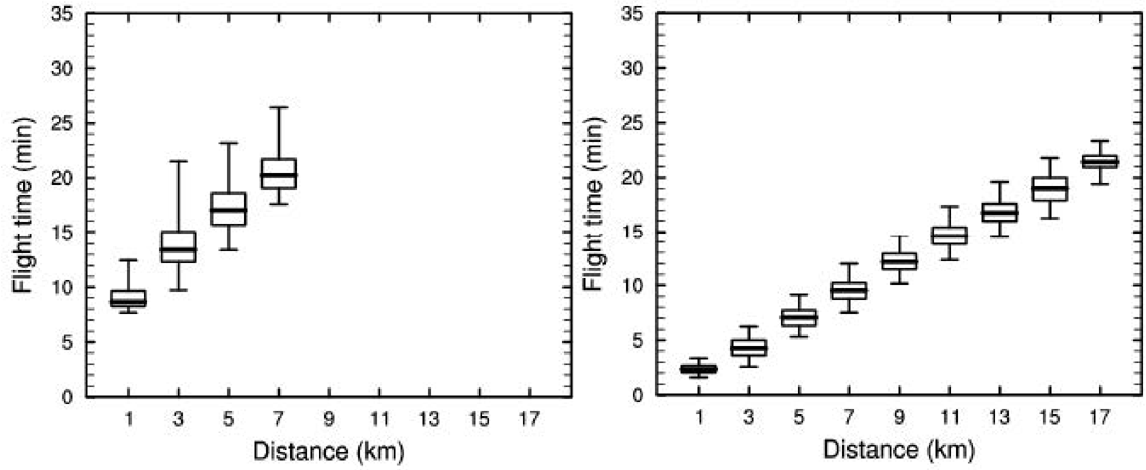

FIGURE 4. BOX AND WHISKER PLOTS OF FLIGHT TIMES FOR FIREBRANDS LOFTED BY THE TIME-VARYING PLUMES UNDER BACKGROUND WIND SPEEDS OF 5 (LEFT) AND 15 (RIGHT) M S–1. FLIGHT TIMES ARE BINNED ACCORDING TO THE DISTANCE TRAVELLED BY THE FIREBRAND, AT 2-KM INTERVALS. THE THICK LINE SHOWS THE MEDIAN FLIGHT TIME AND THE BOX SPANS THE INTERQUARTILE RANGE. WHISKERS REPRESENT THE 1ST AND 99TH PERCENTILE FLIGHT TIMES.

CONCLUSION

We have combined large-eddy simulations of bushfire plumes with Lagrangian particle transport modelling to investigate how turbulent plume dynamics can affect long-range spotting. Plumes exhibited different dynamical and turbulent behaviour depending on the strength of the background wind and this consequently leads to differences in firebrand transport. Plumes in weak winds contain a counter-rotating vortex pair, which leads to large lateral spread in firebrand landing position. Plumes in strong winds are more turbulent and bent over, leading to more longitudinal spread in firebrand landing position and a greater maximum spotting distance. In-plume turbulence was shown to substantially increase the lateral and longitudinal spread in firebrand landing position, and in the case of plumes in strong background winds increase the maximum spotting distance by a factor of two. Systematic studies such as this will inform the development of improved physically based spotting models.

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EVIDENCE-BASED PRACTICE, PRACTICE-BASED EVIDENCE: MOVING TOWARDS SCALED IMPLEMENTATION IN CHILD-CENTRED DISASTER RISK REDUCTION

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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EXTENDED ABSTRACT

Disaster risk reduction (DRR) research conducted through the Bushfire and Natural Hazards Cooperative Research Centre (CRC) is intended to have a focus on utilisation, translation and tightening the policy-practice-research nexus. An important link within this nexus relates to a fundamental proposition: Does the subject under empirical scrutiny have sufficient empirical support to be translated in both practice and policy sectors? In the case of our program of research in child-centered disaster risk reduction (CC-DRR), research has made some bona fide strides in the past 15 years producing data that supports two key questions linked to this fundamental proposition. The first question is 'Are CC-DRR initiatives effective in reducing risk and increasing resilience for children, families, communities?' The second question is 'Can CC-DRR initiatives be sustainably implemented at scale?'

Against this backdrop, this symposium intends to present findings of our program of research from 2014 to the present. These findings are drawn from a major scoping and review exercise, pilot research, co-development and co-evaluation of a practice framework for disaster resilience education and, in 2016, the evaluation of several flagship CC-DRR programs. The symposium will also present our CC-DRR research narrative, the accompanying conceptual framework and utilisation roadmap, and new perspectives on the sustainable and scaled implementation of evidence-based programs

Background to symposium

In a CRC model of research, the ultimate focus is on research translation and utilisation. In this context, the driving question is 'How can findings of research be translated into knowledge, skills and other applied products that solve particular societal problems?' One simple schematic to depict a focus on translation is one that links research with both policy and practice.

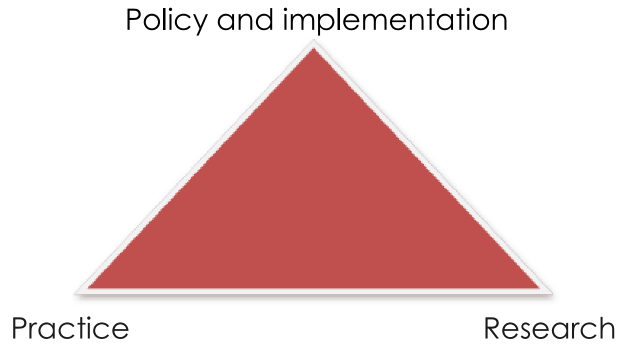

FIGURE 1. THE POLICY-PRACTICE-RESEARCH NEXUS

A guiding model for the current CRC-funded child-centered disaster risk reduction (CC-DRR) program of research has been developed. As seen in Figure 2, it incorporates this research-practice-policy nexus and speaks to two fundamental issues that review and scoping activities, both nationally and internationally (Ronan, 2015; see also Amri et al., 2016a; Ronan et al., 2015), have identified as the core themes of CC-DRR and disaster resilience education (DRE) research. The two main themes, or problems-to-be-solved, are ensuring the effectiveness of CC-DRR/DRE initiatives and facilitating CC-DRR/DRE policy and practice implementation.

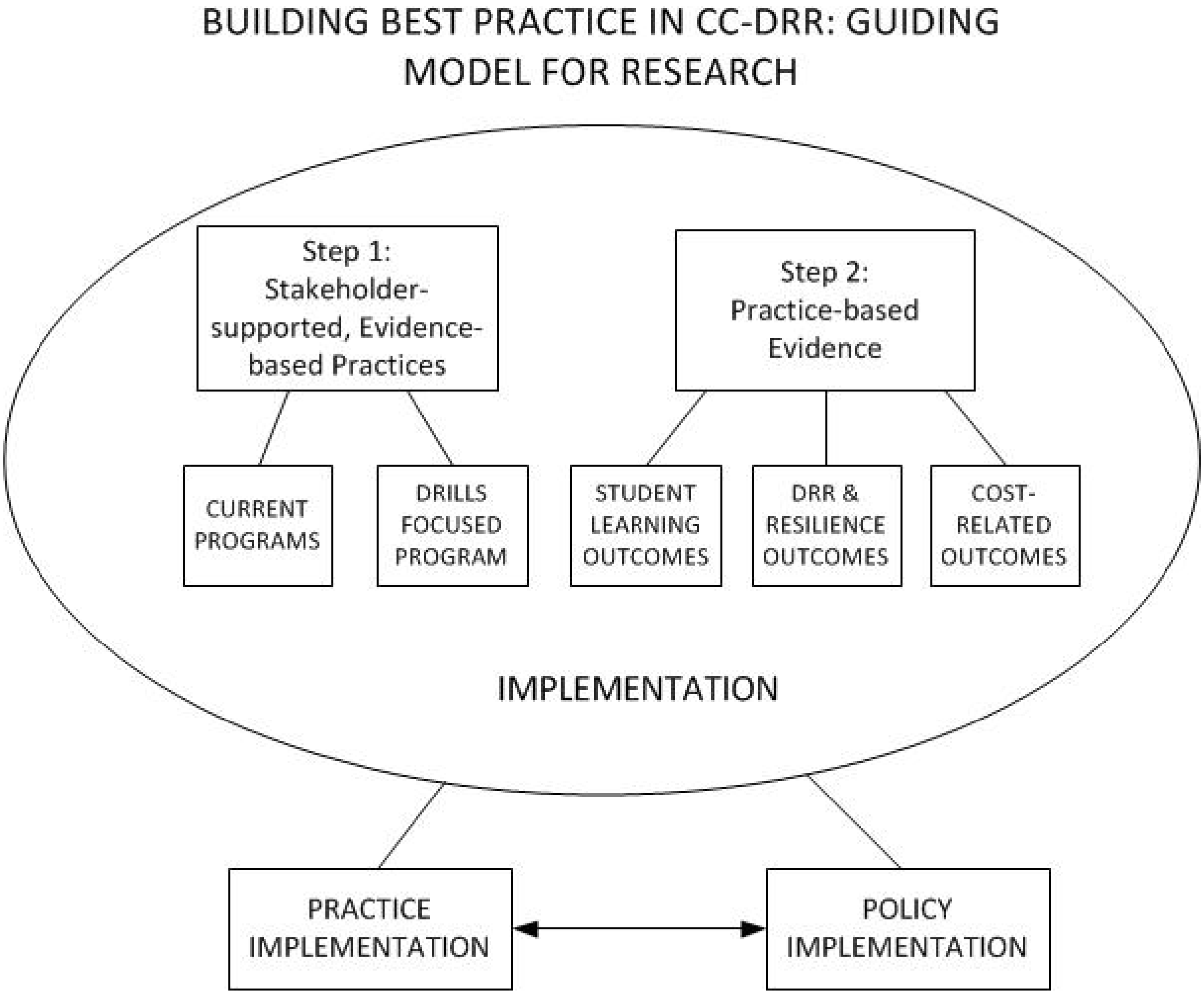

FIGURE 2. GUIDING MODEL FOR CC-DRR RESEARCH

CC-DRR research has expanded exponentially over the past 15 years. Prior to 2000, just one study had published, but over 40 studies have been published since. Most studies have focused on the effectiveness of programs in producing DRR and resilience outcomes for children and youth. A handful of studies have focused on extending child- and youth-based benefits into the household (Ronan et al., 2015). Overall, it is now clear that these programs are capable of producing significant, beneficial DRR and resilience outcomes. However, at the same time, significant challenges remain. For example, programs based on key safety messages and routine drilling can produce significant outcomes, including significant gains in DRR-related knowledge and skills, risk perceptions, self-efficacy, and household preparedness and mitigation activities (Johnson, Ronan, Johnston, & Peace, 2014a; see also Ronan et al., 2015, 2016). However, at the same time, a focus on key safety messages has also been shown to produce some unintended consequences (Ronan et al., 2016). In some cases, these unintended consequences can actually increase risk. The seminar will discuss some of these unintended consequences, one of which involves children engaging in behaviours that raise their risk for a range of negative consequences, including injury and death (e.g. running into buildings during an earthquake)(Ronan et al., 2016; Amri et al., 2016b; see also Johnson, Johnston, Ronan, & Peace, 2014).

In light of these findings, moving beyond a focus on key messages is warranted. Key messages themselves focus on ***what to do*** to reduce risk. However, they typically are not accompanied with the knowledge and skill development necessary for enacting those key messages in a real-life context. Thus, including a focus on important adaptive capacities, or resiliency skills, would be thought to assist children and youth to enact key messages in a manner that leads to intended consequences (e.g. increased safety) versus unintended consequences (e.g. increased risk). For example, problem-solving skills can help children step through not only the what to do to prevent, mitigate, prepare, respond, and recover, but also how to carry out behaviours in ways that consider the local context, changing contingencies, and how to work with others to reduce risks.

Initial stakeholder research has identified that a majority of children, parents/caregivers and teachers endorse the idea of children actively participating in DRE programs, and in household and school planning and decision-making (Amri et al., 2016b; Kelly & Ronan, 2016a, b). In addition, the majority of parents in a recent study (over 71 per cent) preferred a learning and teaching format that provides children with 'decision-making tools to solve problems' compared to a program format with a more singular focus on disaster preparedness (47 per cent) (Kelly & Ronan, 2016a). Thus, based on both research findings and stakeholder preferences, incorporating resiliency skills like problem-solving and decision-making into DRE programs has merit. Based on a large scale review of factors that promote resiliency in disasters, other adaptive capacities would include arousal management skills (e.g. how to stay calm to make good decisions under stress), helpful thinking strategies, how to cooperate and work with others to make decisions and get support, and strategies for enhancing a sense of mastery and confidence (Hobfoll et al., 2007).

In addition, educational research demonstrates that participatory, interactive and experiential learning approaches can translate into increased benefits, including on DRR and resilience outcomes (Haynes & Tanner, 2015; Ronan & Towers, 2014; Towers, 2015). A recent study in a high-hazard area in Canberra (Webb & Ronan, 2014) incorporated participatory, interactive and skill-building elements based on theory and research. The program was found to produce significant pre-post changes on a number of indicators (e.g. reduced fears of hazards; increased knowledge; increased DRR planning and practice skills; increased home preparedness). These changes included the biggest gains on knowledge and home-based preparedness that have been reported to date in the published literature. In addition, this study was one of the first to use a performance-based measure that focused on verified 'planning and practice' factors (e.g. have you and your family planned and practiced what to do in an emergency?). Similarly, Haynes and Tanner (2015) found that a participatory, interactive, problem-solving approach in the Philippines also produced important outcomes, including tangible DRR outcomes and policy-related improvements (Haynes & Tanner, 2015).

The symposium will discuss additional ways forward, linked to recent practice developments, including a CC-DRR practice framework (Towers et al., 2016), a new evidence- and stakeholder-informed tool to assist in developing programs of the sort described above. It will also explore policy developments, and related research, focused on 'comprehensive school safety' (UNISDR/GADRRES, 2014), including how a more systemic, holistic approach to CC-DRR and resilience building might confer added benefits, economic benefits, and how it might also enhance the potential for the scaled implementation of CC-DRR initiatives and education programs. The scaled implementation of CC-DRR initiatives and education programs represents a major challenge in Australia, New Zealand, and internationally (Amri et al., 2016b; Johnson et al., 2014b). Finally, a discussion of research translation will include a description of a recently developed CC-DRR research utilisation roadmap, including plans that anticipate the development of a toolkit to assist project end Users in developing, evaluating and implementing CC-DRR initiatives and education programs effectively.

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IMPROVING FLOOD FORECAST SKILL USING REMOTE SENSING DATA

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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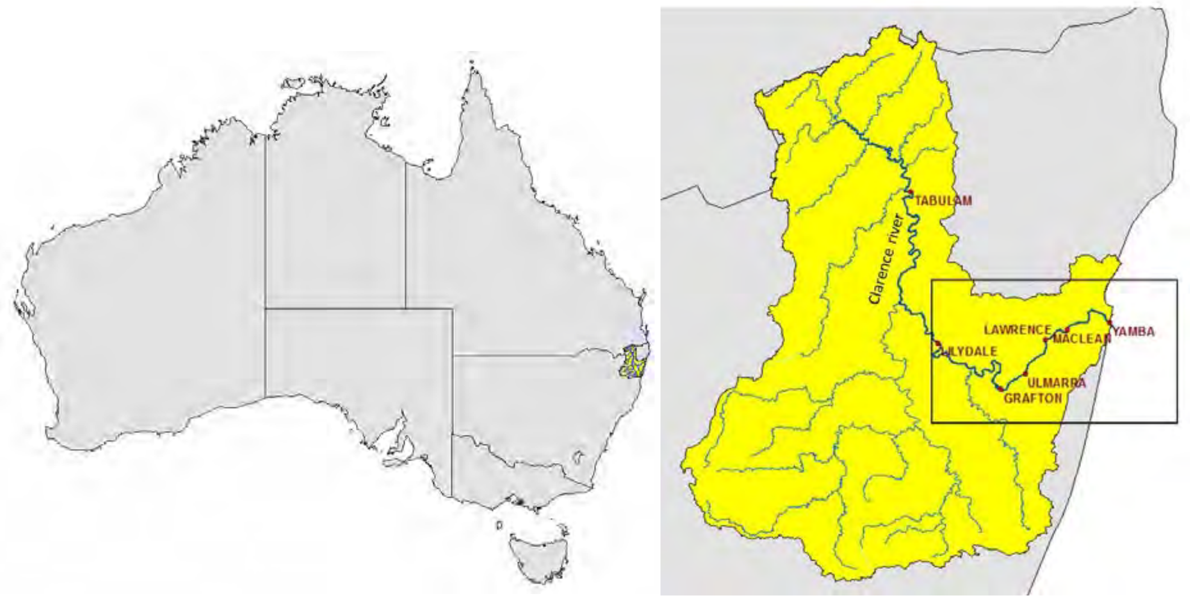
ABSTRACT

Floods are among the most important natural disasters in Australia. The average annual cost of floods in the last 40 years has been estimated to amount to $377 million, with the 2010–2011 Brisbane and south-east Queensland floods alone leading to $2.38 billion in economic damage and 35 confirmed deaths. Flood forecasting systems are the most important tools to limit this damage but are prone to a considerable degree of uncertainty.

During the last decades, significant research focusing on the monitoring of the global water cycle through satellite remote sensing has been performed. The strength of remote sensing is the opportunity to provide information at large spatial scales including areas that are difficult or impossible to monitor using on-ground techniques. For these reasons it is believed that the use of remote sensing data can improve the quality of operational flood forecasts.

Operational flood forecasting systems typically consist of a hydrologic model, which estimates the amount of water entering a river system, and a hydraulic model, which models the flow of water inside the river system. Remotely sensed soil moisture data is being used to improve the hydrologic model results (i.e. the modeled hydrograph into the river network), while remotely sensed water levels and/or flood extent data are being used to improve the hydraulic model results (i.e. the modeled water velocities, depths, and floodplain extents).

The project focusses on two test sites, the Clarence River in New South Wales and the Condamine-Balonne River in Queensland. Figure 1 shows an overview of these test sites.



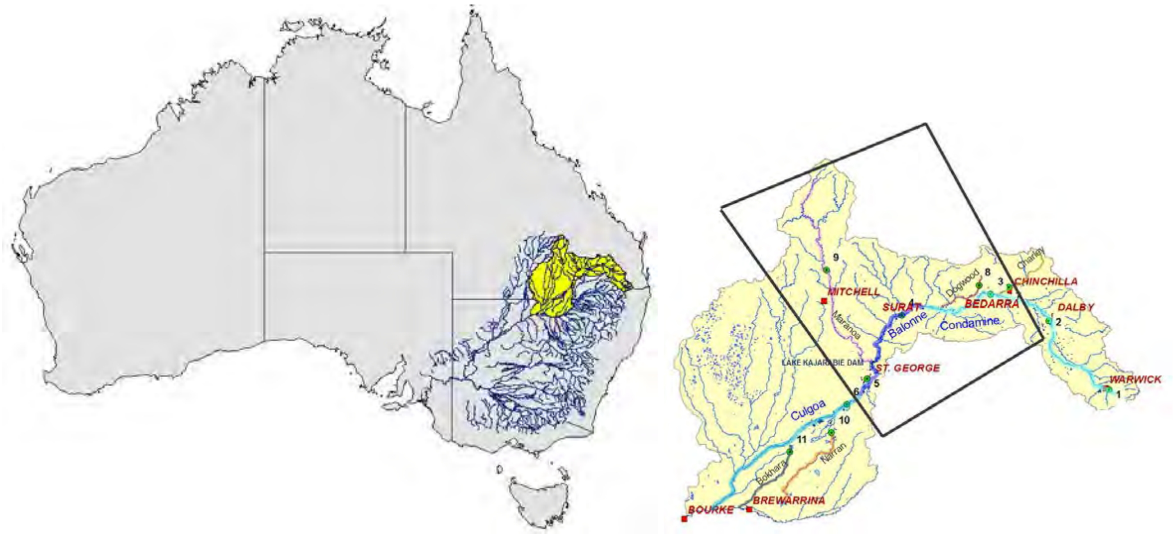


FIGURE 1. OVERVIEW OF THE TEST SITES. TOP LEFT HAND SIDE: LOCATION OF THE CLARENCE RIVER BASIN. TOP RIGHT HAND SIDE: DETAILED OVERVIEW OF THE CLARENCE RIVER BASIN. BOTTOM LEFT HAND SIDE: LOCATION OF THE CONDAMINE-BALONNE RIVER BASIN. BOTTOM RIGHT HAND SIDE: DETAILED OVERVIEW OF THE CONDAMINE-BALONNE RIVER BASIN.

This presentation will provide an overview of our preliminary analysis on the effectiveness of using RS data to calibrate and validate hydrologic and hydraulic models for flood forecasting. In particular, the impact of using RS soil moisture and RS water extents on the accuracy of the calibration and validation of a hydrologic and of a hydraulic model, respectively, will be discussed using the Clarence catchment as study site.

A preliminary streamflow simulation experiment has been conducted in the Clarence River basin upstream of Lilydale. The study basin was delineated into six sub-catchments and the streamflow was simulated at the outlets of the six sub-catchments through a semi-distributed hydrologic model based on the GRKAL rainfall-runoff model and the linear Muskingum flow routing model. The model parameters were estimated using two calibration schemes: 1) a single-objective calibration using streamflow measurements and 2) a multi-objective calibration using both remotely sensed surface soil moisture (SMOS) and streamflow measurements. Only discharge at Lilydale (outlet of the study basin) was used for calibration, while the other five internal gauges were only used for validation. Data from 2010 to 2011 was used for calibration while data from 2012 to 2014 was used for validation.

The result at Lilydale indicates that the calibration with soil moisture data results in a slight degradation in streamflow simulation during the calibration period compared with the calibration without soil moisture data, e.g. the NS decreases from 0.81 to 0.76. However, during the validation period, calibration with soil moisture data gives slightly better forecasts, e.g. the NS increases from 0.70 to 0.71. This means that minimising errors in soil moisture may lead to sub-optimal streamflow simulation in calibration period, but can lead to a more robust parameter set which has the potential to improve the future forecasts. The results at the five internal locations indicate a potential to improve forecasts in ‘ungauged’ areas. Four of the five locations were improved through incorporating remote sensing soil moisture data in the calibration period, and the improvements were retained at three locations. Figure 2 gives an example of simulated hydrographs at Lilydale and two upstream gauges in both calibration and validation periods.

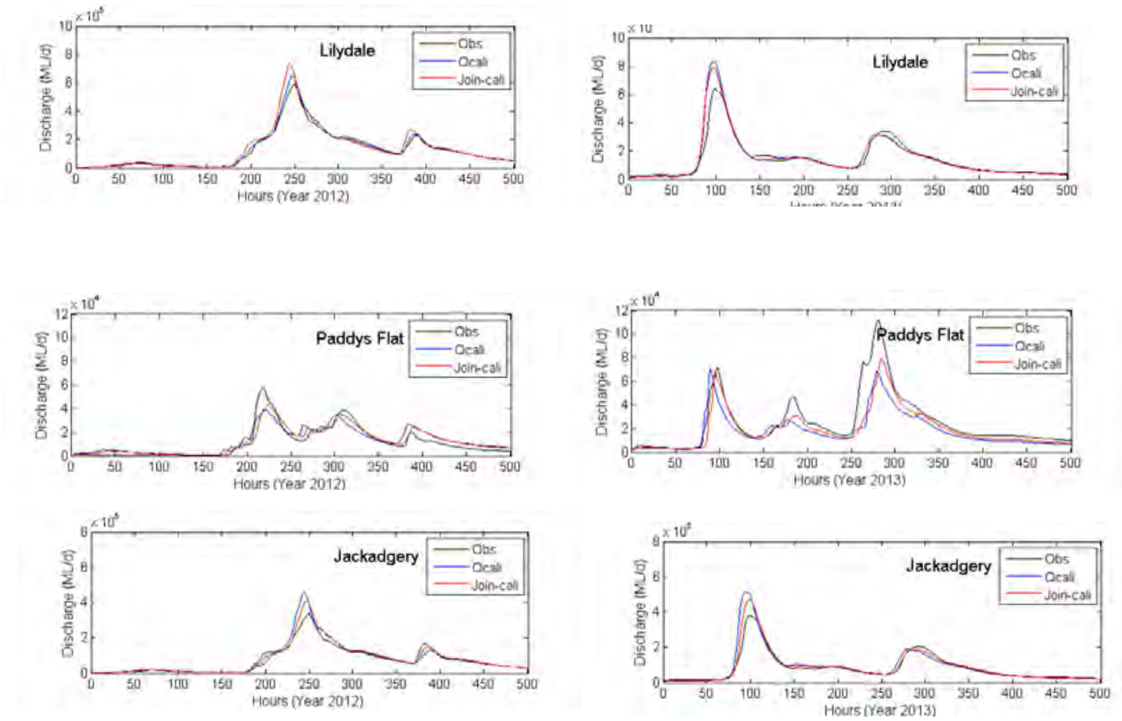


FIGURE 2. STREAMFLOW SIMULATIONS AT THREE LOCATIONS. THE LEFT ONES ARE IN CALIBRATION PERIOD AND THE RIGHT ONES ARE IN VALIDATION PERIOD.

A preliminary comparison on the use of field and RS data for the calibration and validation of hydraulic models for flood forecasting has been completed using the January 2013 flood event in the Clarence catchment as case study.

The hydraulic model is based on LISFLOOD-FP (Bates et al., 2010) and it uses the finite difference method to solve the inertial approximation of the shallow water equations. The measured discharge hydrograph at Lilydale and tidal levels at Yamba were used as upstream and downstream boundary conditions respectively.

The results of the model were firstly compared with the water levels measured by ten gauging stations. The RMSE, when averaged over the ten gauging stations, was 0.30 m. As an example, Figure 3 shows the measured and modelled water level hydrographs at Grafton and Maclean. Despite providing rather satisfactory results at local level, a comparison with RS-derived flood extent observations pointed out that the model failed the prediction of the flood extent in the relevant urban area of Grafton. Figure 4 shows the modelled and observed flood extent at Grafton on January 29th at 12pm.

These results underlined the limits of a punctual model-measurements comparison and highlighted that more coherent and explicative modalities of comparison are possible thanks to the intrinsically two dimensional features of RS observations.

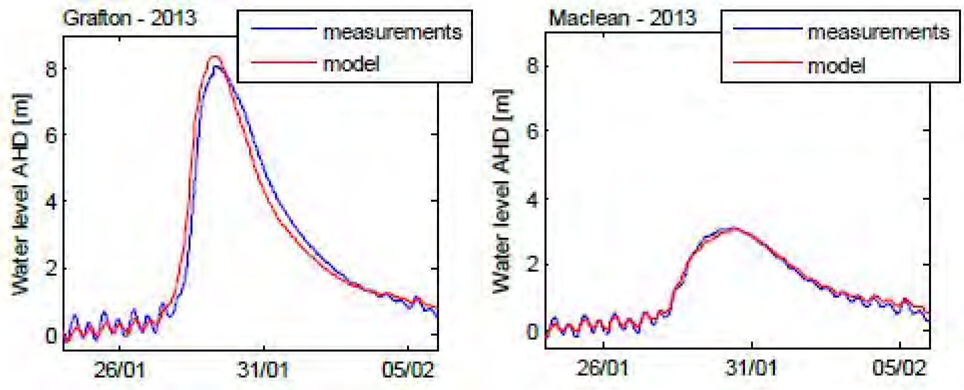


FIGURE 3. EXAMPLES OF MODELLED AND MEASURED WATER LEVEL HYDROGRAPHS.

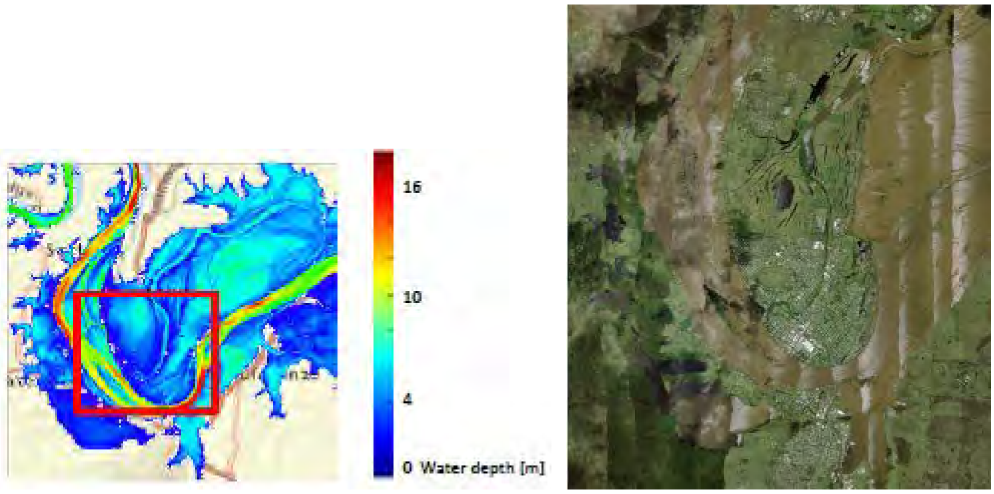


FIGURE 4. MODELLED AND OBSERVED FLOOD EXTENT: GRAFTON, JAN 29TH, 12PM.

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INTEGRATED ECONOMIC ASSESSMENT OF FLOOD MANAGEMENT OPTIONS FOR ADELAIDE

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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ABSTRACT

The extent of damages caused by floods can be great. It is estimated that 80 per cent of the overall cost of Australian natural disasters is the consequence of flooding and this, on average, costs approximately $600 million per annum (Gentle et Bureau of Transport Economics, 2001; Productivity Commission 2015). These average figures do not reflect the severity of the impact that some floods can cause. For example, the magnitude and extent of the recent (2011) Queensland floods was vast, with an overall cost estimates above $6.8 billion.

There is a growing recognition that Australia's disaster funding arrangements are not efficient and do not create the right incentives for managing risks (Productivity Commission 2015). There is underinvestment in disaster mitigation and overinvestment in post-disaster interventions. Across Australia, flood maps have become a major mitigation strategy. Other mitigation strategies include structural solutions such as levees, dams, diversion channels, floodgates, and detention basins as well as non-structural solutions such as early warning and evacuation systems and community education programs. The structural solutions are typically capital intensive and costly. On the other hand, the assessment of flood mitigation benefits generally tends to be partial and focused on tangible and direct benefits. As a result, investment decisions can be suboptimal.

For optimal and equitable investment in mitigation, it is important to understand the full range of costs and benefits and also how these costs and benefits are distributed among different segments of the community. Therefore, it is important that cost and benefit assessment methods depict an adequate picture of the costs and benefits of possible risk mitigation measures. Otherwise, even simple option evaluation procedures such as cost-benefit analysis are not precise. A panel of experts convened under the European Union's 'Costs of Natural Hazards' (CONHAZ) project identified key areas for improvement in cost/benefit assessment and these include the need for more focus on non-structural measures, and indirect and intangible costs (Meyer et al. 2013). Intangible values, normally excluded from benefit cost analysis, can be significant or even the most dominant set of values in some cases.

The purpose of this presentation is to address the shortcoming in relation to intangible values in the context of flood mitigation option analysis for the Brown Hill and Keswick catchments in Adelaide. The catchments include both rural and urban areas and involve local government councils for Adelaide, Burnside, Mitcham, Unley and West Torrens. This analysis focuses on a set of flood mitigation options that are currently under consideration following a public consultation. Previous analysis done on these options suggests that the benefit-cost ratios appear unfavourable. However, the analysis was done without the inclusion of intangible values. In this presentation we argue why intangible values should be included and provide estimates that show how our understanding of the costs and benefits of mitigation options would change with the inclusion of intangible values to account for the health, environmental and social impacts of floods. Intangible values relevant in the context of natural hazards in general are shown in Table 1.

Health	Environment	Social
Mortality, morbidity, injury, stress/anxiety, pain, trauma, grief, increased vulnerability among flood survivors	Wildlife loss, ecosystem degradation, water quality problems, invasive species	Recreation values, amenity values, safety, social disruption, cultural heritage, animal welfare, loss of memorabilia

TABLE 1: INTANGIBLE VALUES IMPACTED BY NATURAL HAZARDS

Health effects range from loss of life (or mortality), to physical injuries and psychological distress, all of which are direct intangible impacts. There is research evidence showing that floods cause numerous psychological effects that are adverse to health. A study conducted by the UK Department of Environment, Food and Rural Affairs (Defra 2005), indicates that a large proportion of flood-affected respondents (80 per cent) suffer from anxiety when it rains while two thirds (65 per cent) have reported increased stress levels. More than half have reported sleeping problems (Defra 2005). Other effects include morbidity, trauma and loss of trust in authorities (Merz 2010).

Floods can also have direct and indirect impacts on natural assets and ecosystem services; and these effects generally lead to the loss of intangible values. In some cases the effects of floods can be beneficial. These effects also depend on the speed of flooding and whether wildlife has the chance to escape. For example, the Queensland floods of 2010/11 had adverse impacts on marine and terrestrial biodiversity, including some threatened species such as the cassowary, but had positive effects on freshwater systems such as those on the Murray River (Reid 2011). Water quality problems generated by floods include water contamination and hypoxic blackwater events that are detrimental to fish (Whitworth et al. 2012).

Even small floods can cause disruptions to traffic in urban environments, and these disruptions can add up to significant damages especially if the floods occur regularly (ten Veldhuis and Clemens 2010). Larger floods can cause massive population displacement causing prolonged social disruption. Other social intangible costs include: loss of recreational opportunities and amenity values; increased risk of loss of life; loss of cultural heritage and memorabilia; and harm to animals.

In the context of flooding the study catchments, the relevant intangible values are the following: mortality; morbidity and other health related problems; social disruption; recreational values; and cultural heritage. Estimates for these intangibles are generated and used in the analysis of mitigation options.

The mitigation options considered are based on alternatives identified in the current Stormwater Management Plan (SEM 2016), which is the result of collaboration among the councils and involves mitigation works in the four major watercourses serving the catchments, namely, Brown Hill, Keswick, Glen Osmond and Parklands Creeks. The options all provide protection against100-year ARI floods.

We show that the inclusion of intangibles changes the cost-benefit ratios and the attractiveness of options greatly. Further, as results depend on cost and benefit estimates, we undertake sensitivity analysis to provide a sense of the dependence of proposed best choices to the variability in both cost and benefit estimates. The presentation concludes by drawing recommendations for improving the choice of flood mitigation options.

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IMPROVED PREDICTIONS OF AUSTRALIAN EXTREME SEA LEVELS THROUGH A COUPLED WAVE-SURGE MODEL

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Brisbane, 30 August – 1 September 2016

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ABSTRACT

In order to protect life and property coastal planners and emergency managers require accurate estimates of flood risk. Providing reliable predictions of extreme sea levels for this purpose represents a significant challenge due to the range of complex processes that vary from beach to beach, town to town, and state to state around the entire Australian continent. As a result, a reliable comprehensive dataset of extreme sea levels for the entire coastline does not yet exist. Recent technological advances have allowed us to develop a high-resolution numerical model capable of analysing ocean dynamics to better understand how storms will impact local beaches on an Australia-wide scale. The advanced, high-resolution (in the coastal zone ~100m) 3D finite element hydrodynamic model (SCHISM) coupled with the state-of-the art WWMIII wave model included the effects of wave breaking on top of storm surges caused by wind and pressure. Simulations of multiple extreme sea level events, ranging from Southern Ocean winter storms to destructive tropical cyclones revealed that including waves in the simulations raised surge levels between 10–50 per cent, depending on local water depths and coastline orientation. To illustrate the robustness of the coupled wave-surge model we present results from Cyclone Yasi (2011), the largest and most intense storm to impact Queensland since 1913. The cyclone caused extensive damage to property and infrastructure costing $800 million over more than 500 km of coastline. A storm surge of 5.5 m was simulated in Cardwell with waves exceeding 12 m offshore and 6 m near the coast. Wave effects raised water levels by up to 35 per cent, highlighting the benefits of a coupled wave-surge model that includes wave setup effects.

INTRODUCTION

Extreme sea levels result from the combined effects of a range of factors including astronomical tides, long-term sea-level variability, storm surges due to pressure and wind, and wave breaking processes that include wave setup and run up. Wave setup is a rise in water level near the shore due to the transfer of momentum from breaking waves to the water column resulting in a slope of the water surface (Longuet-Higgins and Stewart, 1964). This component when added to already high water levels during storm conditions can significantly increase the risk of flooding, erosion, and structural damage in coastal areas.

A majority of the Australian coastline is exposed to ocean surface waves (Short and Woodroffe, 2009) and during storm conditions waves breaking at the shoreline undoubtedly play an important role in generating extreme sea levels. This has motivated a number of recent studies aimed at better improving wave setup understanding and including the effects in storm surge numerical modelling studies (e.g. McInnes et al., 2009a; McInnes et al., 2009b; Soomere et al., 2013; O'Grady et al., 2015). Many of these studies have often been undertaken at the state or local level to inform planning and emergency management and a comprehensive Australia-wide assessment of the importance of waves for extreme sea levels still does not exist.

The approach that we have undertaken here is to utilise recent advancements to numerical models and a new Australian supercomputing facility to run a high resolution unstructured coupled wave-surge model for the whole of Australia.

METHODOLOGY

Coupled surge-wave model simulations were undertaken for historically significant storms that were recorded to cause damaging storm surges. The contribution of wave setup was then extracted from the model output by a comparison between coupled and uncoupled model runs.

Cyclone Yasi was chosen as a test case to investigate the ability of a coupled wave-surge model to simulate storm surges and wave setup effects. TC Yasi made landfall near Mission Beach in northern Queensland on the night of 2 February 2011 as a Category 5 cyclone with estimated wind gusts up to 285 km/hr (79 m s-1). Yasi was the largest and most intense storm to impact Queensland since 1913. The cyclone caused extensive damage to property and infrastructure costing $800 million over more than 500 km of coastline.

Numerical Model

The SCHISM hydrodynamic model was fully coupled with the Wind Wave Model III (WWM-III), a wave spectral model developed by Hsu et al. (2005) but since significantly updated by Roland et al. (2009). SCHISM is a full 3D finite element hydrodynamic modeling system that has successfully been applied to simulate circulation and storm surges in a broad range of coastal environments (Zhang and Baptista, 2008; Bertin et al., 2014; Bertin et al., 2015). The SCHISM-WWMIII modelling system is capable of two-way information exchange between the hydrodynamic model and wave model providing feedback into the hydrodynamic model and wave model at each time step during the whole simulation (Roland et al., 2012).

The unstructured triangular grid (containing ~800,000 nodes) allows the model to change resolution from coarse resolution in the open ocean (kilometres scale) to very fine resolution along the coast (metres scale) without the need for nesting of sub grids (Figure 1).

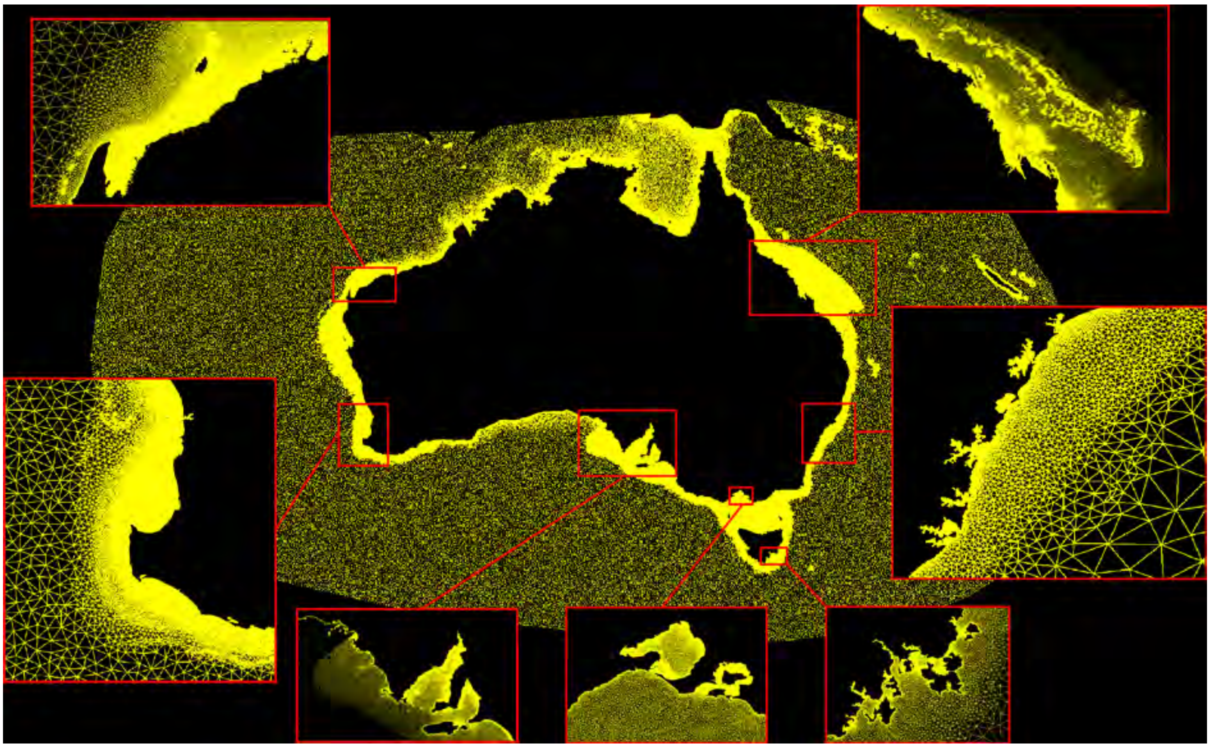

FIGURE. 1. UNSTRUCTURED MODEL GRID SHOWN FOR ENTIRE DOMAIN WITH ZOOMED IN VIEWS AT POPULATION CENTRES TO SHOW HIGHER SPATIAL RESOLUTION.

Atmospheric forcing

Atmospheric forcing for the model was derived by blending reanalysis model data (Japanese Reanalysis JRA55) (Ebita et al., 2011; Japan Meteorological Agency, 2013) with parametric representations of wind and pressure fields (eg. Holland, 1980, 2010) near the core of the cyclone.

RESULTS

Storm Surge

Storm surges occurred between Mackay and Cairns when Yasi made landfall with higher values limited to the areas between Mission Beach (2 m) and Townsville (1.6 m). To the north of Mission Beach where the storm crossed the coast, water levels were either only slightly higher than normal or even lower than normal due to strong offshore winds compensating for the inverse barometric effect (Figure 2). The shallow bay at Cardwell dramatically amplified the storm surge water level up to 5.5 m with a slightly delayed response, peaking around 16:00 on 2 February (GMT) two hours after landfall (Figure 2). In the inner regions of the bay the surge reached 6 m. This localised surge amplification highlights the critical role of bathymetry in determining maximum water levels.

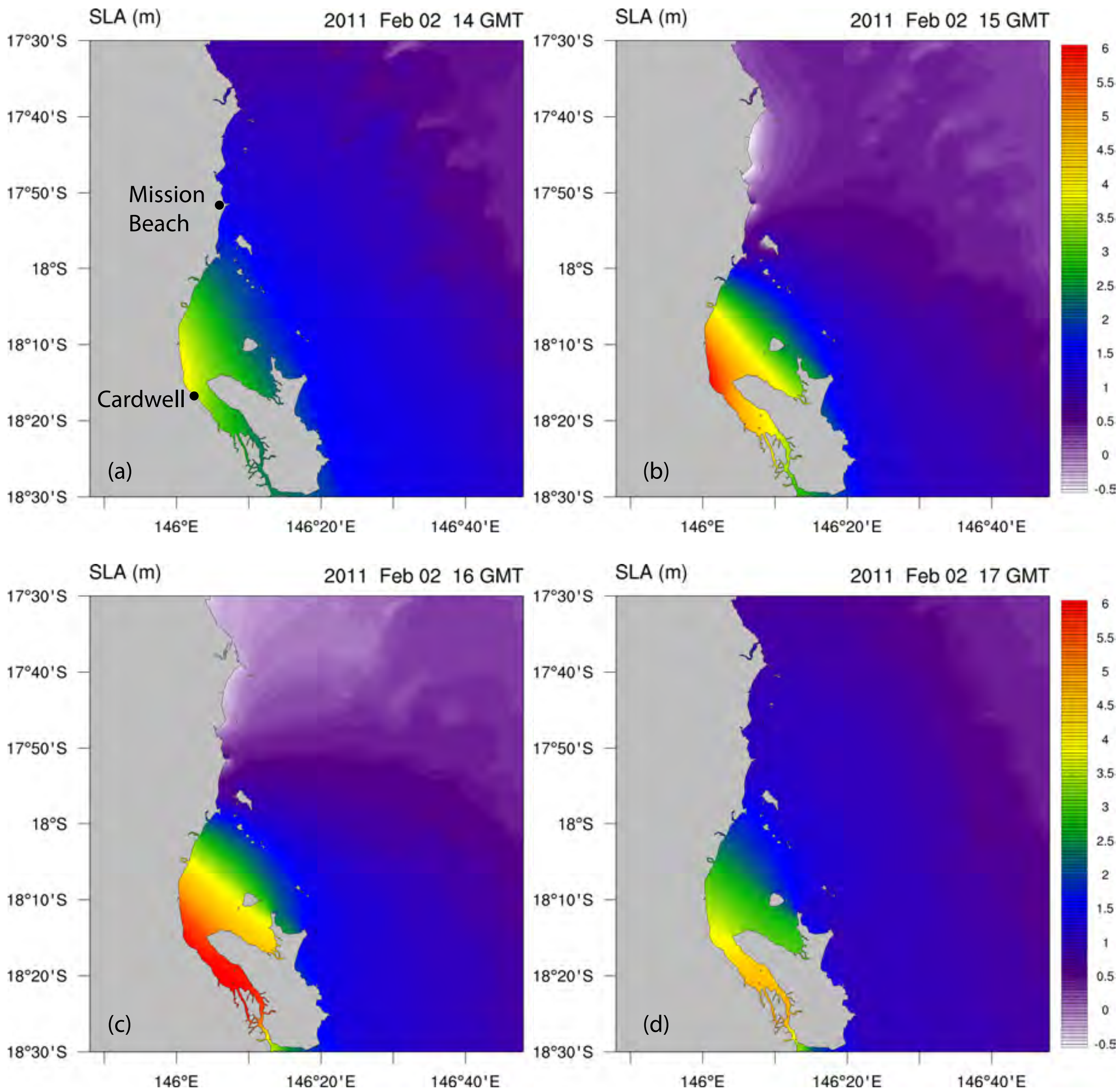

FIGURE 2. SIMULATED STORM SURGE AT CARDWELL SHOWING THE PROPAGATION OF THE SURGE INTO THE BAY FOLLOWING THE CYCLONE CROSSING THE COAST NEAR MISSION BEACH JUST AFTER 14:00 (GMT). HEIGHT COLOUR SHOWN IN METRES.

Wave setup

Cyclone Yasi caused extreme waves that reached almost 14 m on 2 February 2011 between hours 10-12 (GMT) offshore of the GBR reef system. These waves dissipated over the GBR before impacting the coast but some of the wave energy passed through the reef system and combined with locally generated waves to create significant wave heights of approximately 6 m inside of the reef. These large waves had an impact on total surge levels.

Calculating the difference between coupled and uncoupled model runs resulted in a measure of wave setup that consisted of the transfer of momentum from breaking waves into vertical change in water level. Simulations indicated that this contribution was 0.3–0.4 m over a broad area where waves impacted the coast, with peak levels around Cardwell despite the protection provided by shallow areas offshore where wave breaking occurred (Figure 3). Maximum setup levels occurred just before landfall but exceeded 0.2 m over a 10–12 hour period coinciding with large waves

(Figure 4). Two factors contributed to the amplitude of the wave setup component of the surge: wave height and the cross shelf depth profile. Along all cross shelf transects changes in wave height were inversely proportional to wave setup as expected with increased setup wherever waves transformed (or broke) and decreased in size.

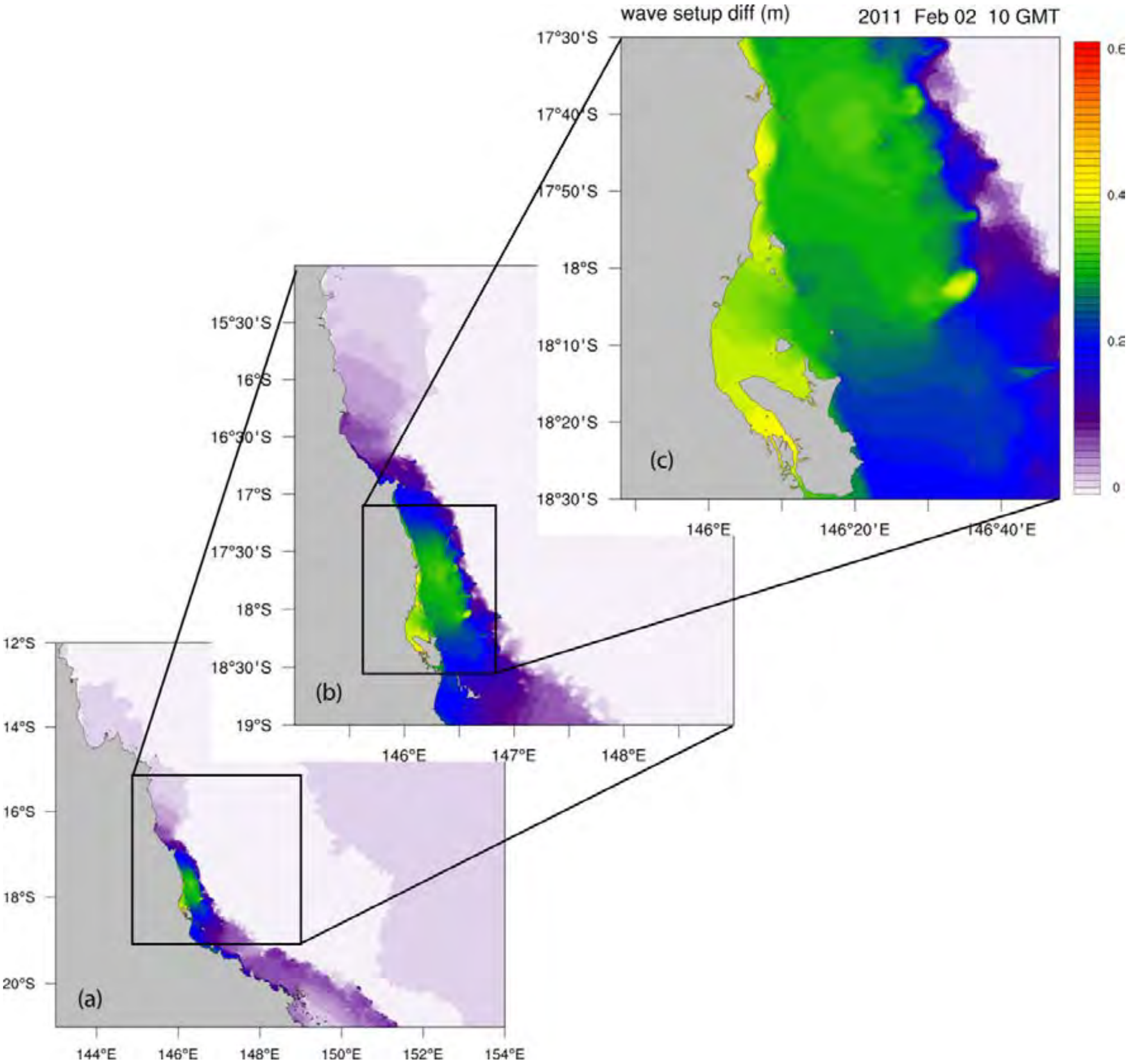

FIGURE 3. WAVE SETUP AS DEFINED BY THE DIFFERENCE BETWEEN COUPLED AND UNCOUPLED MODEL RUNS AT THREE DIFFERENT ZOOM LEVELS AROUND CARDWELL.

Maximum wave setup of 0.25–0.4 m slightly preceded maximum surges at all sites and coincided with maximum wave heights. In the hours before landfall this accounted for 30–35 per cent of the total surge (Figure 4a). Around the time of landfall the proportion of the surge related to wave setup dropped to around 20 per cent due to the increase in surge from the strong winds and decrease in pressure (Figure 4a, hour 12-14). Following landfall the wave setup component dropped below) 0.2 m but the percent contribution oscillated between 5 and 30 per cent depending on site and time owing to the persistence of waves and changes in wind direction and intensity (and thus amplitude of the storm surge).

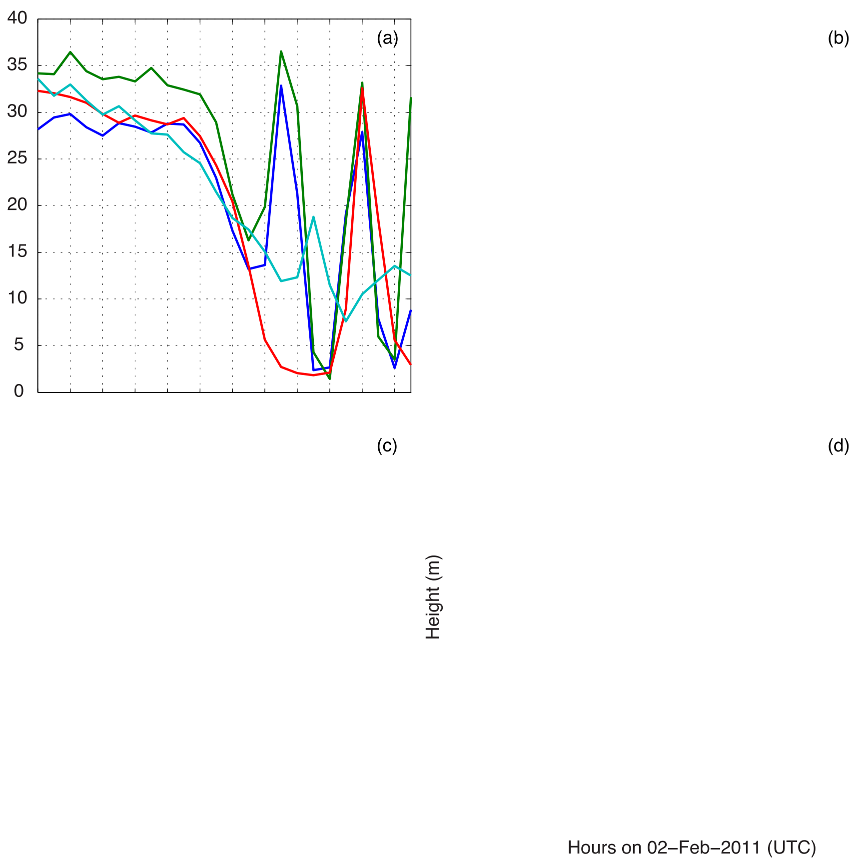

FIGURE 4. TIME SERIES OF STORM SURGE COMPARED WITH WAVE SETUP AND WAVE HEIGHTS AT 10 M DEPTH FOR ALL SITES.

DISCUSSION AND CONCLUSIONS

Recent technological advances have allowed us to develop a high-resolution numerical model capable of analysing ocean dynamics to better understand how storms will impact local beaches on an Australia-wide scale. The advanced, high resolution 3D hydrodynamic model (SCHISM) coupled with the state-of-the art WWMIII wave model included the effects of wave breaking on top of storm surges caused by wind and pressure.

This experiment indicated that wave setup for TC Yasi contributed up to 35 per cemt of total surge height and was 6-10 per cent of wave heights at 10 m depth. This supports the commonly applied engineering approach of applying a 10 per cent factor for waves in estimates of water levels, but we believe that our estimates of wave setup are conservative and in reality could be higher. Sensitivity studies indicated that increasing the resolution to better represent reality did generally result in increased wave setup and surge levels. Another important factor included the orientation of the coastline to waves and wind. Our experiments showed, for example, large variations in setup and surge over the scale of tens to hundreds of kilometres that was mostly related to the relative intensity and direction at which Cyclone Yasi impacted the coast.

The results suggest that coupling a wave and surge improves the accuracy of storm surge predictions and provides a useful tool to determine areas of the Australian coastline are more susceptible to flooding and erosion from extreme waves.

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A SPATIAL DECISION SUPPORT SYSTEM FOR NATURAL HAZARD RISK REDUCTION POLICY ASSESSMENT AND PLANNING

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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EXTENDED ABSTRACT

The challenges facing environmental policymakers grow increasingly complex and uncertain as more factors that impact on their ability to manage the environment and its risks need to be considered. Due to a large number of influencing environmental and anthropogenic factors, natural hazard risk is difficult to estimate accurately, and exaggerated by large uncertainty in future socioeconomic consequences. Furthermore, resources are scarce, and the benefits of risk reduction strategies are often intangible. Consequently, a decision support system assisting managers to understand disaster risk has great advantage for strategic policy assessment and development, and is the focus of this extended abstract.

The spatial decision support system (SDSS) presented is being developed in collaboration with several South Australian government departments and funded by the Bushfire and Natural Hazards CRC. It integrates multiple hazard models with a land use model which includes information on population and building stock to consider long term spatial and temporal dynamics of natural hazard risk. The integrated SDSS operates at a 100m resolution with a time-step of one year and can be used to model 20–50 years into the future. Hazards included in the SDSS include riverine flood, coastal inundation, bushfire, heatwave and earthquake. Each is modelled dependent on the relevant physical properties of the hazard and include the impacts of climate change on hydro-meteorological, bushfire and heatwave hazard. The land use model is driven by land use demand (population and jobs), and allocates land accordingly.

The SDSS conceptualises and subsequently models risk as the combination of the natural hazard, exposure and vulnerability (UNISDR, 2009). The modelling of risk across these three factors, simulating their spatial and temporal dynamics, improves understanding of long-term risk. It also allows for consideration of risk reduction options to be implemented across each of the factors targeting specific aspects of the risk. Figure 1 highlights the overall architecture of the system, showing external drivers influencing exposure and hazard dynamics (socioeconomics and climate), along with risk reductions options on different components of risk, and a series of indicators calculating risk in terms of average annual loss, and the economic effectiveness of risk reduction options.

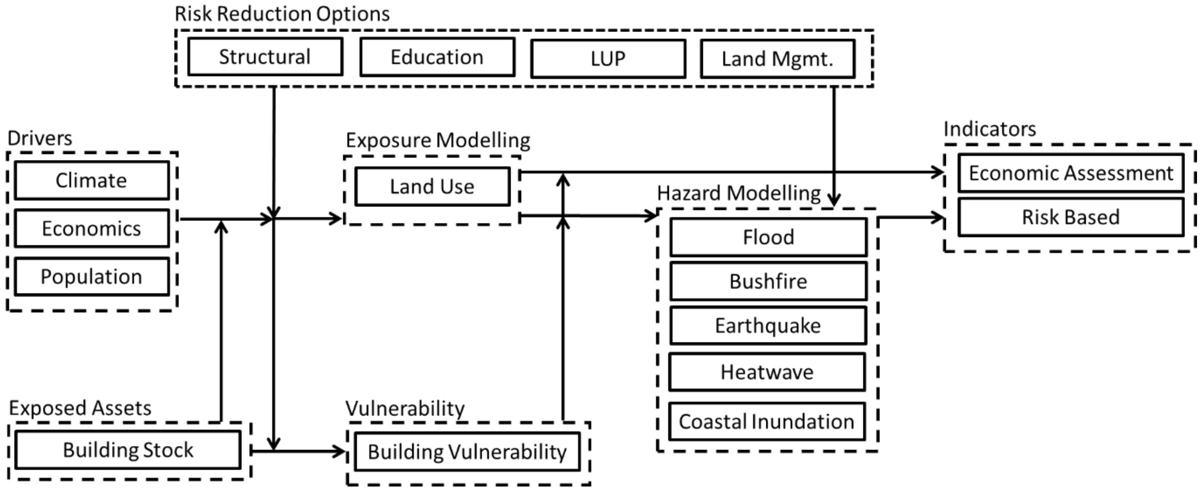

FIGURE 1. OVERALL ARCHITECTURE OF PROPOSED SPATIAL DECISION SUPPORT SYSTEM

Within the SDSS, exposure is considered dynamically with the inclusion of a land use allocation model (RIKS, 2015) and building stock information retrieved from the NEXIS database (Dunford et al., 2015). The land use allocation model operates on a square grid of 100m cells. The model is cellular automaton (CA) based and calculates the state of each cell within the overall growth of the region of interest (Greater Adelaide for this study), driven by population and economic demands (White and Engelen, 1993). The CA model stochastically allocates the land use demands at an annual time step based on the land uses at the previous time step and the spatially dependent, attractive and repulsive forces that land uses exert on each other within a close neighbourhood. There are three additional site specific factors that influence the potential for a land use to change, namely suitability, zoning status and accessibility (van Delden et al., 2007).

Suitability relates to the physical aptness of a cell to support a particular land use and its activities. Examples of this include soil type or slope. Suitability is represented as one map per land use function modelled. Zoning, similarly represented as one map per land use function, specifies when a cell can or cannot be changed to a particular land use for various planning periods and how strict or flexible the policy is. Accessibility expresses the ease with which the activities associated with each land use can fulfil their requirements for transportation, mobility or any other infrastructure need based on each cell's proximity to networks (van Delden and Hurkens, 2011).

A suite of hazard models is also included, as shown in Figure 1. For bushfire, coastal inundation, riverine flood and earthquake, average annual direct loss is calculated using appropriate processes and input data to capture the nature of the hazard. For example, bushfire hazard likelihood and intensity is considered using three factors; ignition potential (a function of land use, road proximity and vegetation), suppression capability (the probability of first wave attack success), and fire behaviour (a function of climate, slope and fuel load). Hydro-meteorological hazards are considered using a digital elevation model and inundation depths for various return periods and future climate scenarios. Earthquake hazard is calculated by a using a probabilistic set of a 100 events calibrated on historical earthquake events in the region. For each of these hazards direct losses are considered by taking the magnitude outputted from the hazard models and converted using vulnerability curves for the building stock dependent on its construction type. By using these curves, for specific hazards and construction types, relative damage indices can be multiplied by the building stock's value providing an output of direct monetary loss. Heatwave hazard is considered in terms of increased mortality. This is achieved by calculating the number of excess deaths, using relationships between percentage of excess deaths and excess heat factor, as well as population and mortality rate projections, for climate-affected time series of daily temperatures at a number of locations, which are then spatially interpolated.

Risk reduction options are also considered across hazard, exposure and vulnerability. For hydro-meteorological hazards, structural measures such as levies and sea walls can be implemented to alter flow and inundation paths, whereas vegetation management (planned burns) can be used to influence fuel loads in the calculation of bushfire intensity. Spatial planning measures can also be implemented, reducing exposure to all hazards. In addition, changes to building codes and retrofitting can be considered by altering the vulnerability curves that relate hazard magnitude to damage.

Along with the technical development of the modelling platform is an integrated and participatory development and use process. This process brings together the knowledge of scientists, IT specialists, and end users to develop a problem-specific model platform, along with modellers, facilitators and stakeholders, to explore the application of the platform to a problem of interest, exploring policy options, indicators and future scenarios. Figure 3 highlights the iterative loop between the development and use cycles.

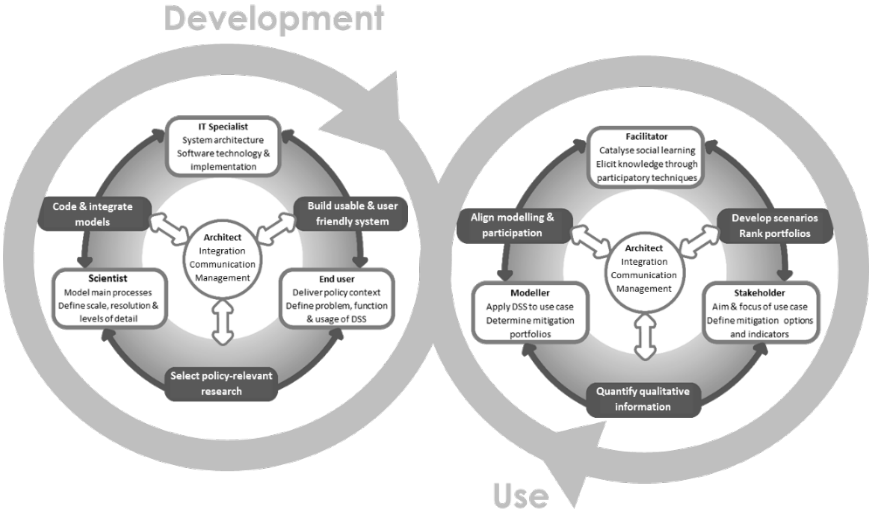

FIGURE 2. DEVELOPMENT AND USE CYCLE

This development and use process has been applied to Greater Adelaide, developing the modelling platform through end user engagement with the State Mitigation Advisory Group (SMAG) and applying it to consider future risk profiles. Five scenarios were developed considering the future of Greater Adelaide. These scenarios were developed by initially considering the risk reduction options at the avail of decision makers, grouped into resilience or mitigation focused options. These foci were used as framing axis for the scenarios, shown in Figure 4. The two foci were further discussed considering the factors that contributed to their success or failure, and these factors were then used as the building blocks of the scenario storylines.

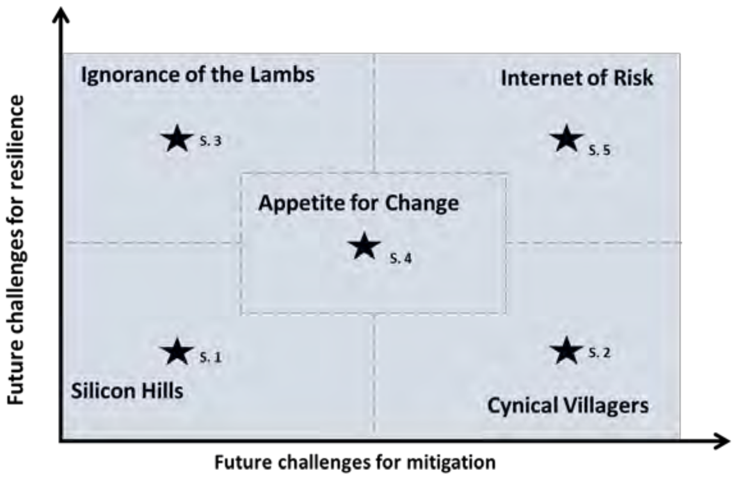

FIGURE 3. SCENARIOS DEVELOPED

The five scenarios were quantified and presented to the stakeholder group, highlighting the five plausible futures for Greater Adelaide in terms of socioeconomic development through the land use model outputs, and also risk profiles across the various modelled hazards. Figure 5 highlights the changes in rural residential land uses between 2013 and 2050, along with the calculated damage from 1 in 500 riverine flood events in 2050 for illustration purposes.

This extended abstract provides a brief overview of the SDSS, and its development and application for Greater Adelaide. The SDSS is able to account for long-term risk through considering the dynamics in hazard, exposure and vulnerability, along with a use process that emphasizes the exploration of plausible futures and what impacts various trends have on risk profiles. The analysis of risk reduction can be coupled with cost-benefit analysis and socioeconomic environmental values and impacts to provide a more holistic view of the utility of various mixes of risk reduction options. Given risk management has very strong social and environmental dimensions, it is hoped the SDSS can lead to more transparent and robust policy settings and decision making.

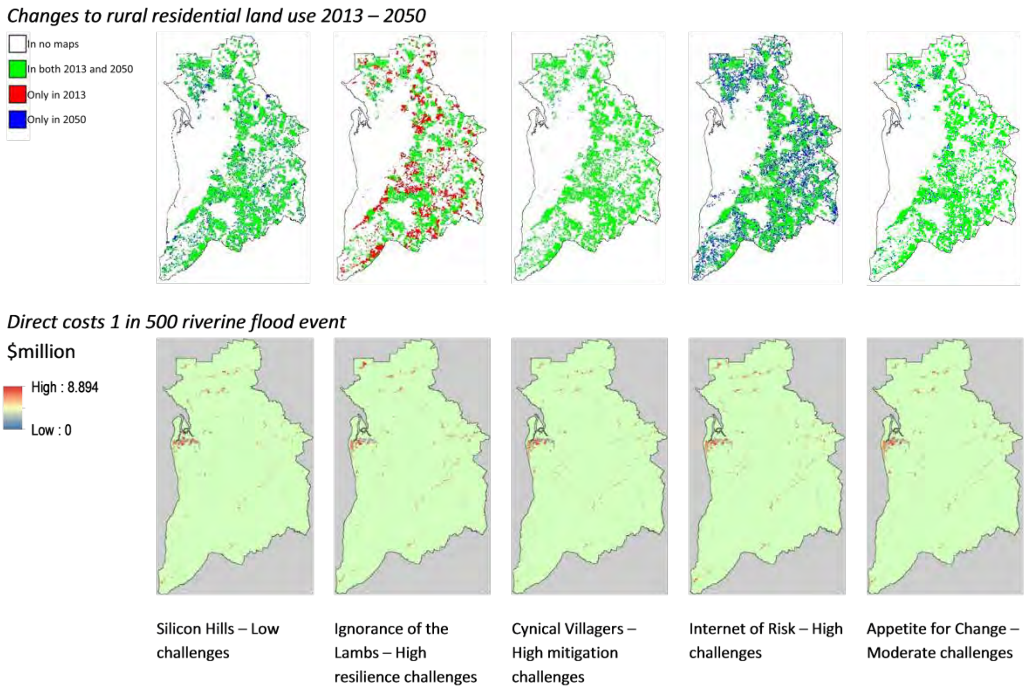

FIGURE 4. SELECTED MODEL OUTPUTS FOR THE FIVE SCENARIOS.

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THINK LONG TERM: THE COSTS AND BENEFITS OF PRESCRIBED BURNING IN THE SOUTH WEST OF WESTERN AUSTRALIA

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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Wildfires are a worldwide phenomenon that can cause significant damage to ecosystems, life and property (Gill 2005; Bowman et al. 2009). Every year in Australia large, uncontrolled fires burn in a variety of landscapes destroying economic, environmental and social assets (Williams et al. 2011). But wildfires are also a natural, inevitable and vital element of the Australian environment that cannot (and should not) be eliminated (Pyne et al. 1996; Pyne 2006). Hence fire management must be an integral part of land and ecosystem management (Bradstock et al. 2012b; Burrows and McCaw 2013).

In recent years, the frequency and severity of large wildfires have increased in most of the vegetated landscapes around the world (Bowman et al. 2009), including Australia. For instance, the fires of Black Saturday on February 2009 caused the highest loss of life and property from a wildfire in Australian history (Teague et al. 2010). The total cost of the Black Saturday fires was estimated to be AU$4.2 billion (Attiwill and Adams 2013). These large fires and losses occur despite advances in fire-fighting technology, greater suppression capacity, considerable suppression efforts, and record expenditures in wildfire suppression (Toman et al. 2011; Attiwill and Adams 2013).

Indeed, the costs of wildfire management, and in particular the costs of wildfire suppression, have increased substantially in the last few decades in many parts of the world (Morgan et al. 2007; Cochrane et al. 2012; Gude et al. 2013; Thompson et al. 2013a). In countries like the US and Australia, fire suppression expenditures have reached record highs (Morgan et al. 2007; Thompson et al. 2013a). These increases in suppression costs have been attributed to the cumulative effects of: (1) the increase in the number, size and intensity of wildfires due to changes in weather patterns, (2) the continuous expansion of the wildland-urban interface (WUI), and (3) decades of fire exclusion and aggressive suppression that resulted in extensive fuel build-ups in fire-prone landscapes (Liang et al. 2008; Stetler et al. 2010; Stockmann et al. 2010a; Cochrane et al. 2012; Thompson et al. 2013b). And this increasing trend in suppression expenditures is expected to continue. However, increasing suppression capacity alone will not solve the problem of the increasing fire threat (Marino et al. 2014). There is a risk that Australia will continue to increase its fire-fighting capacity and suppression expenditures without improving its management of fire in the landscape (Morgan et al. 2007). As the likelihood of suppressing bushfires decreases with growing fire intensity and size, it becomes increasingly important to apply effective policies that reduce the risk of mega–fires.

With more severe wildfire impacts and suppression expenditures at record highs, other strategies need to be implemented for the management of wildfires. A strategy available to fire managers is managing fuel levels through prescribed burning (Mercer et al. 2008; Stockmann et al. 2010b; Toman et al. 2011). The purposeful application of fire to the landscape in mild weather conditions is used in many fire-prone landscapes for wildfire management and protection of human assets (Fernandes and Botelho 2003; Penman et al. 2011). More recently it has been used for the protection of ecological assets and ecosystems restoration (Bradstock et al. 2012a; McCaw 2013). However, the increased focus on prescribed burning to mitigate potential wildfire effects has generated considerable debate (Penman et al. 2011; Ryan et al. 2013). Much of this debate revolves around the efficacy of prescribed burning in reducing wildfire extent and severity (Fernandes and Botelho 2003), but little attention has been given to the economic impacts of prescribed burning programs and the trade-offs in the allocation of resources between different fire management activities. Despite much land being prescribed burned in some parts of Australia, there has been almost no evaluation of the costs and benefits of the practice. Without the help of sound economic analyses, it is not clear which option yields the best returns on investment.

Most of the literature that applies economic analysis to fire management has focused on one single aspect of the problem in isolation: the costs, the benefits or the losses. A very small number of studies have dealt with the three aspects simultaneously. This study aims to fill these gaps in research and provide a framework through which the trade-offs between prescribed burning, wildfire suppression and wildfire damages can be brought to light and interpreted. Through the application of economic analysis to fire management in the south-west of Western Australia (WA), the main goal is to appraise the impacts of changing the prescribed burning strategy under different scenarios. This study seeks to provide improved understanding about the implications of different uses of limited resources in fire management, taking into account the following facts: (1) prescribed burning costs change with the size and location of treatments (Berry et al. 2006; Calkin and Gebert 2006), (2) varying the size and the location of the treatments can strongly affect their efficiency (Fernandes and Botelho 2003), and (3) the assets protected differ in nature and value (Ganewatta 2008).

We used an economic model in conjunction with a wildfire simulator to test different prescribed burning strategies (varying the amount and the location of the burns) and identify the strategy that yields the highest returns to society under different scenarios. The economic model used for this study is the cost plus net value change (C+NVC) model, a monetary-based framework that minimises the total sum of pre-suppression costs, suppression costs and net fire damages (Venn and Calkin 2011), similar to a benefit-cost analyses. The C+NVC is the commonly accepted model for evaluating bushfire management programs (Ganewatta 2008; Gebert et al. 2008). The simulator used for this study is the AUSTRALIS Bushfire Simulator developed at the School of Computer Science and Software Engineering, the University of Western Australia. We conducted a short-term analysis (one year) and a long-term analysis (15+ years) in order to evaluate the impact of short-term and long-term decisions in fire management and examine the differences between the two approaches.

We found that for a short-term analysis, there is not a significant difference in the economic results when the level of prescribed burning is varied over a wide range of values (using the current spatial strategy that the Department of Parks and Wildlife has in place). What changes in the short term are the proportion of management costs and the proportion of damages for different prescribed-burning rates. At low levels of prescribed burning, the vast majority of the costs arise from the damages sustained and the amount of money that has to be spent in suppression. At higher levels of prescribed burning (>10%), expenditure in prescribed burning and in suppression costs are approximately the same, and the proportion of damages is reduced. Damages then account for 2/3 of the C+NVC, while management costs correspond to 1/3 of the total C+NVC. But in any case, damages are always much larger than management costs, being twice or three times larger than suppression and prescribed burning expenditures together. Compared to a no-prevention strategy (0% prescribed burning), short-term investments in prescribed burning in the south-west of WA generate a benefit of AU$0.7 to AU$1.5 per dollar invested. The issue with a short-term analysis is that it cannot be used to answer a key question for fire managers: what would be the cost to society of not prescribed burning for several years?

A long-term analysis can answer this question and in fact it shows an entirely different outcome. The long-term analysis shows that not doing any prescribed burning for several years can be very costly for the south-west forest region, with large increases in damages and in suppression expenditures, much higher than indicated by the short-term model. In addition, the long-term analysis shows a more clear-cut answer. It suggests that at a 0% or at a 5% prescribed-burning rate there are substantial benefits that can be gained from increasing the amount of area prescribed burned per year in the south-west forest region. However, there are still several near-optimal options when a rate of 10% or higher is applied in the long term. The results from the long-term model indicate that prescribed burning may generate between AU$10 and AU$47 benefits every year per dollar invested compared to a no-prescribed-burning scenario.

The model shows that with the current prescribed-burning program that the Department of Parks and Wildlife have in place, applying the treatment to an average of 6% to 7% of their managed land in the region, they are already generating substantial benefits for society. If no prescribed burning was applied in the south-west forest region, average annual suppression expenditure would be around four times higher than the current level and damages would be around five times higher. On average, the current prescribed-burning program generates AU$31 million savings per year in suppression expenditures and AU$169 million savings in damages compared to a no-prescribed-burning scenario.

The optimal rate obtained from the long-term model suggests an increase in prescribed burning in the region to the levels applied in the 1960s and 1970s. However, increasing prescribed burning to these levels will come at an additional cost that may be high. In addition, in today's context in the South West forest region, this would be an exceptionally high level of prescribed burning and it may not be possible for several reasons: climate change (Bradstock et al. 2009; Cary et al. 2012; Barbero et al. 2015), the accumulation of fuels in the south-western forests of WA for the past 50 years (Boer et al. 2009), fire exclusion policies and the expansion of the WUI (Mutch et al. 2011), have all contributed to create a landscape in which the application of high rates of prescribed burning is increasingly difficult (Burrows and McCaw 2013; McCaw 2013). Nevertheless, this study emphasises the importance of keeping a minimum level of prescribed burning per year in the south-west forest region.

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YOU OWN THE FUEL, BUT WHO OWNS THE FIRE?

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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The statement 'Whoever owns the fuel owns the fire' was coined during the 1994 Sydney bushfires[1] and is attributed to Phil Cheney,[2] the then Project Leader for Bushfire Behaviour and Management in CSIRO and a former Director of the National Bushfire Research Unit. Cheney and Sullivan[3] say: 'The landholder effectively owns the fuel and so determines whether the fire can spread and how intense it will be. In other words, the landholder owns the fire.'

This quote, or variants with the same meaning, have been used by fire managers, agencies, scientists, and politicians, and in enquiries and parliamentary proceedings, including:

(i) the Queensland Rural Fire Service (2001);[4]

(ii) the Commissioner of the NSW Rural Fire Service (2003);[5]

(iii) the House of Representatives *Select Committee on the Recent Australian Bushfires* (2003);[6]

(iv) the Chief Officer of the Tasmanian Fire Service (2013) who said 'if you own the land, you own the fuel on that land and therefore own the risk';[7]

(v) Dr Kevin Tolhurst (AM) Associate Professor with expertise in bushfire science and management (2013);[8]

(vi) the Western Australian Fire and Emergency Services Commissioner (2014) who said 'If you own the fuel, you own the risk;'[9]

(vii) the Queensland Minister for Police, Fire and Emergency Services (2014);[10] and

(viii) The recent *Report of the Special Inquiry into the January 2016 Waroona Fire in Western Australia*.

Thus, the understanding represented by the saying 'Whoever owns the fuel owns the fire' has become widespread and influential across a wide spectrum of bushfire management in Australia.

The statement implies a duty on public and private landowners to manage fuel on their land to reduce the likelihood of bushfires, however started, from spreading to neighbouring properties. Governments and private citizens sometimes go to extensive efforts to manage fuel so that 'their' fire is more easily contained, and where fire does escape from areas with natural, untreated levels of accumulated fuel, including publicly managed natural areas, there are inevitable questions about

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1 Phil Kopperberg, 'The Politics of Fire Management' (2003) *3rd International Wildland Fire Conference*, 3-6 October 2003, Sydney, Australia.

2 T. Vercoe, 'Whoever owns the fuel owns the fire' (2003) Liftout number 65, *Australian Forest Grower*.

3 P Cheney & A Sullivan, *Grassfires: fuel, weather and fire behaviour* (CSIRO Publishing, 2008).

4 D Ockwell & Y Rydin 'Analysing dominant policy perspectives: the role of discourse analysis' in J. C. Lovett & D. Ockwell (Eds), *A handbook of environmental management* (Edward Elgar 2010), 168-197.

5 Kopperberg, above n. 1.

6 Hansard (2003) *House of Representatives Select Committee on the Recent Australian Bushfires*, Wednesday, 9 July 2003, Katoomba.

7 ABC News (29 May, 2013) 'Fuel reduction burns debate after Tasmanian bushfires', http://www.abc.net.au/worldtoday/content/2013/s3769981.htm

8 K. Tolhurst, 'Bushfire risk is not someone else's problem' (2013) *Australian Forest Grower*.

9 ABC News (16 April, 2014) 'Emergency services call for law change to compel agencies to reduce fire risks', http://www.abc.net.au/news/2014-04-16/proposed-changes-to-wa-fire-management-laws/5394976

10 Media Statement, Minister for Police, Fire and Emergency Services (4 April 2014) http://statements.qld.gov.au/Statement/2014/4/4/operation-cool-burn-activated

fuel treatment practices and claims for compensation.[11] However, as far as we are aware, the notion 'Whoever owns the fuel owns the fire' has not been interpreted from a legal perspective.

This paper will review the Australian law to identify who is legally responsible for the fire. It will be argued that the correct legal position is that 'if you own the ignition source, you own the fire'—that is, liability has always fallen on those that start the fire, not on the 'owners' of the fuel that sustain the fire. That legal consequence could have dramatic implications for prescribed burning policies as it will be shown that liability for starting a prescribed burn is clear-cut whereas liability for allowing fire to spread in untreated fuel is unheard of.

Whilst we review the law, we do not analyse, and therefore do not question, the importance of bushfire fuel for fire behaviour. Fire intensity[12] and rate of fire spread[13] are generally positively related to amount of fuel consumed and level of fuel 'hazard' respectively, when other factors are held constant.

The law

Historically there was strict liability for the spread of fire;[12] that is a person was liable if fire escaped from their property regardless of the care that they took to contain the fire. The High Court has moved the law away from special rules relating to different hazards or the status of various plaintiffs and defendants[13] and today the former rules of strict liability are '... absorbed by the principles of ordinary negligence'.[14] These principles require that a person seeking compensation must establish that there was a legal duty on a person to take some action and a failure by that person to take 'reasonable care'.

In *Goldman v Hargrave* the Privy Council had to consider liability for the 1961 Western Australia bushfires. The question for the Supreme Court of Western Australia, the High Court of Australia and ultimately the Privy Council was whether the landowner was liable in negligence for the spread of a fire that he did not start. In the Supreme Court, the trial judge found that there was no liability 'for anything which happens to or spreads from his land in the natural course of affairs, if the land is used naturally'.[15] The High Court came to a different conclusion. Windeyer J said:

In my opinion a man has a duty to exercise reasonable care when there is a fire upon his land (although not started or continued by him or for him), of which he knows or ought to know, if by the exercise of reasonable care it can be rendered harmless or its danger to his neighbours diminished.[16]

On appeal, the Privy Council agreed finding that there is 'a general duty upon occupiers in relation to hazards occurring on their land' but what may be expected to control that hazard depends on many factors.

… the standard ought to be to require of the occupiers what it is reasonable to expect of him in his individual circumstances. Thus, less must be expected of the infirm than of the able bodied: the owner of a small property where a hazard arises which threatens a neighbour with substantial interests should not have to do so much as one with larger interests of his

11 See Legislative Council General Purpose Standing Committee No. 5 *Wambelong fire* (Parliament of NSW, 2015).
12 *Beaulieu v Finglam* (1401) YB 2 Hen. IV.
13 *Safeway Stores v Zaluzna* (1987) 162 CLR 479; *Imbree v McNeilly* (2008) 236 CLR 510.
14 *Burnie Port Authority v General Jones* (1994) 179 CLR 520, [43].
15 *Hargrave v Goldman* (1963) 110 CLR 40, [6] (Taylor and Owen JJ).
16 Ibid, [25] (Windeyer J).

own at stake and greater resources to protect them: if the small owner does what he can and promptly calls on his neighbour to provide additional resources, he may be held to have done his duty: he should not be liable unless it is clearly proved that he could, and reasonably in his individual circumstance should, have done more.[17]

The duty to make an effort to extinguish a fire, or to call for assistance, is now reflected in modern legislation.[18]

However, these cases involve liability to deal with a fire once started. In the absence of a fire, the fuel per se does not pose a threat to the neighbours. Allowing vegetation to grow or dead fuel to accumulate may increase the risk that fire, once started, will spread but the vegetation and dead plant material is not itself the risk.[19] That is, it is not the vegetation that causes the harm to the neighbour, but the fire.

Even if it is the vegetation that is the risk there may be no duty on a landowner to take steps to control it for the benefit of his or her neighbour. In *Spark v Osborne*, dealing with the spread of prickly pear, Higgins J in the High Court of Australia said:

I know of no duty imposed by the British common law… on a landowner to do anything with his land, or with what naturally grows on his land, in the interests of either his neighbour or himself. If he use the land, he must so use it as not thereby to injure his neighbours… But if he leave it unused, and if thereby his neighbours suffer, he is not responsible. So long as he does nothing with it, he is safe. It is not he who injures the neighbour. It is Nature; and he is not responsible for Nature's doings.[20]

Spark v Osborne is an old case that today would likely be judged in accordance with the modern law of negligence.[21] In modern law, determining whether or not a duty of care exists depends on more than mere foreseeability of risk, rather it requires consideration of all the 'salient features' that define the entire relationship between the plaintiff and the defendant.[22] Even if we assume there is some legal duty to control the build-up of fuel then liability can only be established if there is a negligent failure to take reasonable care.

The perception of the reasonable man's response calls for a consideration of the magnitude of the risk and the degree of the probability of its occurrence, along with the expense, difficulty and inconvenience of taking alleviating action and any other conflicting responsibilities which the defendant may have.[23]

The 'expense, difficulty and inconvenience of' fuel treatment may be very high. Planning and conducting prescribed burns requires multiple resources and suitable weather conditions, and requires strict compliance with legislative provisions. Other fuel treatment activities may be less risky but can incur significant costs.

This does not mean that in the right circumstances liability could not be established against a landowner or occupier who fails to take reasonable steps to undertake bushfire fuel treatment, but such an action would be a novel development of the law and would no doubt be both costly and time consuming.

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17 *Goldman* v *Hargrave* [1967] AC 645, [25].

18 See, for example, *Emergencies Act 2004* (ACT) ss 120 and 121; *Rural Fires Act 1997* (NSW) ss 63 and s 64; *Country Fire Authority Act 1958* (Vic) s 34; and *Bushfires Act 1954* (WA) s 28.

19 *Stannard v Gore* [2012] EWCA Civ 1248.

20 *Sparke v Osborne* (1908) 7 CLR 51.

21 *Goldman* v *Hargrave* [1967] AC 645, [23].

22 For a discussion of those relevant features, see *Caltex Refineries (Qld) Pty Limited v Stavar* [2009] NSWCA 258, [103]-[105] (Allsop P).

23 *Wyong Shire v Shirt* (1980) 146 CLR 40, 48 (Mason J).

On the other hand, liability for starting a fire is unquestioned. Liability has been established for fires started by negligence of farmers, train operators and electricity suppliers, and where fires have been deliberately lit and then allowed to escape, regardless of whether the fires were lit for cooking, land clearing or 'hazard reduction'.[24] Therefore, when it comes to fires that are 'introduced' to the land, the situation is clear; a person lighting a fire will have a duty to take reasonable steps to contain that fire and, given the risk, 'the standard of "reasonable care" may involve "a degree of diligence so stringent as to amount practically to a guarantee of safety".'[25]

When it comes to accidental fires liability has been established since at least 1868.[26] Since 1977 electricity supply authorities have settled claims for fires caused by their assets[27] culminating in the largest class action settlement in Australian history.[28] The authors can find only one reported case where the presence of fuel was an issue. In *Dennis v Victorian Railways Commissioner*[29] the defendant was being sued for a fire caused by a steam engine that was 'properly constructed and managed'. Williams J, on behalf of the Supreme Court of Victoria, said 'there is an obligation on the part of the defendant to use reasonable care to prevent ignition of the dry grass and herbage on its property through the agency of the sparks which escape from the engines';[30] i.e. the defendant owed a duty to ensure that its activities did not cause the ignition of the grass. The presence of the grass itself was not a breach of duty save that the defendant was operating a steam engine that, with the best care would still produce sparks, and so they were under a duty to prevent the ignition of their grass from their steam engine.

Where a prescribed burn is planned, the landowner or agency conducting the burn will have a duty to ensure the fire is contained. Given the risk if fire escapes they will have to consider a variety of factors including the weather, the availability of firefighting resources and the special vulnerabilities of anyone likely to be affected by the fire. They have the ultimate control as they can elect not to light the fire. State agencies may enjoy some extra legal protection from liability in negligence when implementing state policy[31] whereas private landowners must exercise 'a degree of diligence so stringent as to amount practically to a guarantee of safety'.[32]

Conclusion

What this review of the law reveals is that a person who introduces fire into the landscape, whether intentionally or accidentally, is under a duty to control that fire. Liability for starting a fire is well established and is recognised by the care that must go into planning and igniting prescribed burns and the limited opportunities for burning when all relevant factors are considered.[33]

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24 Michael Eburn, *Australian Bushfire Cases: Annotated Litigation 1867-2011* (Bushfire CRC, u.d) <http://www.bushfirecrc.com/resources/external-resource/australian-bushfire-cases-annotated-litigation-1867-2011> accessed 3 July 2016.

25 *Burnie Port Authority v General Jones* (1994) 179 CLR 520, [41] (Mason CJ, Deane, Dawson, Toohey and Gaudron JJ).

26 *Macdonald v Dickson* (1868) 2 SALR 32.

27 See for example *Wollington v State Electricity Commission* [1979] VR 115.

28 *Matthews v AusNet Electricity Services Pty Ltd & Ors* [2014] VSC 663.

29 (1903) 28 VLR 576.

30 Ibid, 579.

31 See for example *Civil Liability Act 2002* (NSW) ss 40-46; see also *Southern Properties (WA) Pty Ltd v Executive Director of the Department of Conservation and Land Management* [2012] WASCA 79.

32 Above, n 25.

33 *Southern Properties v Executive Director of the Department of Conservation and Land Management [No 2]* [2010] WASC 45, [152]-[188] (Murphy J (at first instance)).

The alternative, of doing nothing, is legally much safer. Whilst there is a duty to attempt to control a fire once it is started, what can be expected might be very limited and may amount to no more than calling triple zero. Liability for failing to reduce fuel loads, and so possibly contributing to fire spreading from one property to another, is theoretically possible, but so far unheard of and would be difficult to establish.

In short if you own the ignition source you own—are responsible for—the fire, but so far there is no legal precedent to say that if you own the fuel that carries a fire from one property to another, then you own or are responsible for the fire.

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PREVENTING FLOOD RELATED FATALITIES – A FOCUS ON PEOPLE DRIVING THROUGH FLOODWATER

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Brisbane, 30 August – 1 September 2016

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INTRODUCTION

Floods are the leading cause of natural disaster fatalities worldwide. In 2013, 44 per cent of natural disaster fatalities were caused by floods (International Federation of Red Cross and Red Crescent Societies, 2013). Flash floods, in particular, have the highest average mortality rate per event (Jonkman, 2005). Approximately 180 people have died in Australia over the last 15 years (Haynes, et al., 2016; Peden, 2016). A large number of these fatalities occurred when people drove their vehicles into floodwaters, ignoring road closures and warning signs.

Despite numerous campaigns on the dangers of floodwaters in recent years, people continue to put themselves at risk each year. In the June 2016 flood in New South Wales (NSW) alone, approximately 350 flood rescues occurred. Many of these rescues (approximately 50 per cent) included people stranded in or on the roofs of their cars, who may have otherwise been added to the number of fatalities. This flood event also resulted in the loss of multiple lives.

Following the major flood event on the east coast of Australia in May 2015, where several lives were also lost, the Law Crime and Community Safety Council (LCCSC) Ministers sought the Community Engagement Sub-committee (CESC) of the Australia-New Zealand Emergency Management Committee (ANZEMC) to explore the issue. A working group was established consisting of representatives from the Commonwealth, state and territory governments, and from the research industry. The project was funded by the Commonwealth Attorney-General's Department (AGD), with the resultant report prepared by the NSW State Emergency Service (SES) and the working group on behalf of ANZEMC. As at 11 July, the report has not been endorsed by ANZEMC CESC or AGD.

METHOD

A literature review analysed research on behaviour and decision-making, and how they can be influenced, drawing on examples from public health and road safety as well as flooding. Both flash flooding and slower riverine flooding were considered, given that the differences between these flood types may trigger different behaviour and decisions.

The review also surveyed Australian and international interventions targeting a reduction in the number of flood fatalities. The types of interventions considered included engagement and education, engineering, emergency management, encouragement and enforcement. Empirical evaluation of success was included where available.

The sources for the review included peer reviewed research, conference proceedings, media clips and reports, and information from government agencies.

The findings of the review were considered in a series of meetings held during the project and a workshop for the project working group in March 2016.

DISCUSSION

The literature identified the following particularly high risk trends for the period 1900-2015:

- Eastern states in coastal catchments, between Wollongong (NSW) and Maryborough (Queensland) (Coates, 1999; Fitzgerald, et al., 2010), with NSW and Qld accounting for 74% of fatalities (Haynes, et al., 2016). These areas generally have very little warning time of flooding.

- Within 20 kilometres of home (Haynes, et al., 2016), with only 1% of flood fatalities during the period involving people who were not familiar with the area (Haynes, et al., 2016).
- Summer, particularly January to February (36%) (Haynes, et al., 2016), in the late afternoon to night (39%–45%) (Haynes, et al., 2016; Peden, 2016), and more frequently on a Friday (Peden, 2016)
- 75–80% of flood fatalities were males (Coates, 1999; Queensland University of Technology, 2010; Haynes, et al., 2016), with a similar over-representation of males fatally attempting to drive through floodwaters (Haynes, et al., 2016).
- 0–29, and over 60 (Coates, 1999; Coates & Haynes, 2008; Fitzgerald, et al., 2010; Becker, et al., 2011; Haynes, et al., 2009; Wright, et al., 2010; Drobot, et al., 2007; Haynes, et al., 2016; Peden, 2016).
- 4WD drivers, with approximately 35% of flood related fatalities associated with 4WDs (Haynes, et al., 2016).
- Workers including, emergency services personnel such as fire, police, ambulance and SES (Live Leak, 2011; Fox4, 2015), as well as doctors, utility maintenance workers, mail delivery personnel, farmers, miners and many government workers (Becker, et al., 2015; Gissing, 2015; Becker, et al., 2011) where they 'needed to get to work' and did not have the discretion to cancel their trip, even if they perceived the risk was high (Ruin, et al., 2009; Ruin, 2008).

Similar trends have been observed internationally (Ashley & Ashley, 2008; French, et al., 1983; Jonkman & Kelman, 2005; Kundzewicz & Kundzewicz, 2005; Diakakis & Deligiannakis, 2013; Doocy, et al., 2013; Petrucci & Pasqua, 2012; Coates & Haynes, 2008; Fitzgerald, et al., 2010; Coates, 1999). Contributing factors to these trends include exposure, propensity for particular occupations (Coates, 1999; Coates & Haynes, 2008; Fitzgerald, et al., 2010; Jonkman & Kelman, 2005; Jonah, 1986), greater confidence in their driving ability (Matthews & Moran, 1986), type of cars they drive, when and why they drive, identity, broader social influences such as peer and/or passenger influence, a tendency for risk-taking behaviour (Jonah, 1986; Maples & Tiefenbacher, 2009), voluntary exposure to floodwater, as well as a perception that such large vehicles are more stable and safe (Franklin, et al., 2014; Maples & Tiefenbacher, 2009; Petrucci & Pasqua, 2012; Becker, et al., 2011; League, 2009; Wilson, 2015).

Fatalities are not isolated to the areas of Australia listed above, with Northern Territory having a heightened risk per capita (Haynes, et al., 2016).

Additionally, it is important to note that near misses are usually absent from statistics, with the exception of recorded flood rescues, self-reports and insurance records where available. This may mean the potential risks associated with flooding are underestimated, and may also skew the groups identified as most at risk.

Why are people driving through flood water?

The majority of people who died attempting to drive through floodwater were 'en-route' (Haynes, et al., 2016). It is easy to feel safe inside a vehicle and not fully appreciate the risks of floodwater (Diakakis & Deligiannakis, 2013; Jonkman &

Kelman, 2005). The following excerpts demonstrate some of the misconceptions about driving through floodwater (Footprints Market Research, 2015):

- 'I'm a local, I know the roads and how they flood.'
- 'My vehicle can handle the water – It's a 4WD, heavy, has high clearance and snorkel.'
- 'It's the small cars and soccer mums that don't know what they're doing.'
- 'If I can walk through it, I can drive through it.'
- 'The car manual says it can handle this depth.'
- 'I'll follow in the wake of a truck.'

Behaviour and decision-making during natural disasters is complex—it involves interaction between environmental information, social processes and individual factors, including beliefs, knowledge, willingness, attitudes, perceptions and skills (Lindell & Perry, 1992; Grothmann & Reusswig, 2006; Sorensen, 2000; Bandura, 1997; Tobin & Montz, 1997; Pearson & Hamilton, 2014). Blood alcohol level, which impairs judgment, is obviously another factor (Diakakis & Deligiannakis, 2013), with an estimated 37 per cent of vehicle-related flood fatalities involving alcohol (Peden, 2016). Higher-order thinking is influenced by conscious intentions and can be disengaged through distraction, or high or very low levels of arousal (Kahneman, 2012; Strack & Deutsch, 2004). Arousal can be triggered by stressful situations, for example, a flooded road (Tobin & Montz, 1997; Benight, et al., 2007; MacLean, 1990; Thomas, 2012). This helps to explain contradictions between how people think they might behave and how they actually behave (Wright, et al., 2010). When higher-order thinking is disengaged, the number of potential actions considered by a person is reduced (Lambert, et al., 2003; Baumeister & Heatherton, 1996). Appealing to rationality is generally not a successful way to intervene in this situation; instead, a person's motivational system needs to be considered (Redshaw, 2004), which is developed well before the decision about driving through floodwater (Dufty, 2014).

Motivations include internal, external, social, situational and organisational influences (Bearman, et al., 2009), such as attachment, reputation (good or rebellious), control, desire for pleasure and avoidance of pain (Darnton, 2008), the need for self-enhancement, identity (Grawe, 2007; Freud, 1922), social norms, values, experience and understanding (Andreasen, 1995; O'Neill, 2004; Abraham, et al., 2011; Michie, et al., 2011; Triandis, 1977; Ajzen, 1991). While there is unlikely to be a single psychological theory or behavioural model that explains why people drive through floodwater, the research shows that the timing of interventions is particularly important—both in targeting the motivational system and enabling the brain to process concepts.

Changing risky behaviour

Trying to ensure safe behaviour in disasters is a challenging and long-term pursuit which, ultimately, is about minimisation rather than eradication. People still smoke, eat junk food and speed, and realistically, they are also likely to continue to enter floodwater. However, there have been dramatic changes in attitudes and perceptions towards these kind of behaviours as a consequence of successful interventions and enforced regulation.

Behaviour change literature and campaigns, including health behaviour and road safety, show that a holistic approach to changing risky behaviours, using multiple intervention techniques and targeting different audiences, is more effective than using an intervention in isolation. The goal is to make the decision *not* to drive through floodwater the easiest decision.

Education and engagement

Communication generally occurs through a spectrum of education and engagement activities, ranging from mass media campaigns to locally based community engagement activities. Message consistency is a critical component of successful education and engagement interventions. In the context of driving through floodwater, this may mean working with the media, vehicle manufacturers, schools, workplaces (including emergency service workplaces), driver education and advertising bodies to ensure that the messages and imagery used by these different sources support the desired overall messaging, and work collaboratively towards the development of a safe social norm (Goode, et al., 2011; Gissing, et al., 2015).

Also important is helping people to develop alternatives to driving into floodwater (e.g. using alternative routes or re-scheduling travel plans), rather than simply warning them against risky behaviour. In addition, research shows that involving the public in the development of interventions (e.g. development of messaging) produces benefits, including the fostering of trust, social norms, and ownership of choices made (Burningham, et al., 2008; Parker & Handmer, 1998; Parker, 2000; Handmer, 2000; Covello & Allen, 1988; CSIRO, 2000).

Media campaigns and community engagement are more effective when used together, and in conjunction with other types of interventions, and are most successful where they target a number of different audiences using a variety of methods (e.g. Montague, et al., 2001; McGuire, 1985; Australian Institute of Criminology, 2014). Evaluation is critical if organisations are to make a greater impact by learning from their successes and mistakes.

Engineering interventions

The range of engineering interventions implemented in Australia and internationally to prevent people driving through floodwater includes barricades and signage, vehicle design and lighting, road design to enhance the safety of motorists (e.g. road surfaces, fences and vegetation to prevent cars being washed off causeways), vehicle design with mechanisms to avoid the threat, and appropriate land-use planning to avoid the 'need' of people to drive through floodwater (VicRoads, 2003; Main Roads Western Australia, 2006; Department of Transport and Main Roads, 2010; Australian Standard 1742.2, 2009; Austroads, 2015). The scope of such engineering interventions is expanding rapidly, in line with new technologies. For example, some organisations (including Melbourne Water and Toowoomba Regional Council) have installed advanced warning systems that, when activated, communicate information to approaching vehicles and pedestrians, trigger road closure barriers and assist remote site monitoring,.

The high cost of many engineering interventions is clearly an issue, particularly where the effectiveness is uncertain. The success has been varied, partly because barricades may be removed and warnings ignored by motorists, even while flooding is still occurring. However, in certain high-risk locations, engineering solutions may be determined as most appropriate through a floodplain risk management process (Commonwealth of Australia, 2013). This process can also assist in avoiding risk in the future.

Enforcement

Examples of effective interventions using engagement and education in combination with enforcement include speeding, seat belts and drink driving. There are a number of provisions in each jurisdiction of Australia that would allow for penalties for disobeying flood signs or barriers in order to drive through floodwater, with penalties ranging from small fines to imprisonment (Eburn, 2016). The effectiveness of these penalties relies on the extent to which they can be enforced (e.g. not all signage is enforceable – 'water over road'). The presence of police, official personnel (e.g. SES) and penalties have been identified as strong deterrents to driving through floodwater. However, while enforcement may appear to offer a reliable way of influencing behaviour, it may be accompanied by high financial and political costs. In the USA there is legislation to allow for charging for flood rescue. However this may cause resistance and discourage people from seeking assistance due to fear of costs, placing those in need of rescue at greater risk (Eburn, 2016).

Work health and safety legislation (e.g. Work Health and Safety Act 2011) and policy have been effective in supporting behavioural change, which could target the substantial number of workers who drive through floodwater. Change may be achieved, for example, by workplaces acknowledging flood threats and allowing employees to arrive late or arrange alternative workplaces.

Encouragement

Positive reinforcement is often more effective than punishment in shaping decision-making and behaviour. In relation to floodwater, this may include reduced insurance premiums for safe driving, acknowledgement or reward in the workplace for flood safe behaviours, and monetary reward and community involvement through competitions (Federal Emergency Management Agency, 2016; Lahrmann, et al., 2012).

Emergency planning and response

Emergency planning can help eliminate the need for sudden and stressful fleeing and facilitate safe road use (Kelman, 2005). Involvement of the community in the development and implementation of planning can increase its benefits (Mostert & Junier, 2009; World Health Organisation, 2014; Comrie, 2011; Webber & Rae, 2015).

Emergency services generally use rescue as a response when other mechanisms fail. There are differing levels of flood rescue capability across Australia but, regardless of which state or territory, flood fatalities often occur before rescuers can respond. Rescuers cannot be everywhere at all times—they are a finite resource, conditions do not always allow rescue, and rescuers are placed at risk. Therefore, increasing rescue capability is not the simple solution.

CONCLUSION

People entering floodwater is a national issue. More than 180 people died in floods in Australia during the past 15 years. Driving a motor vehicle into floodwater was the leading cause of these fatalities and, in many cases drivers ignored road closure and warning signs when entering the water. There are a number of trends associated with those at higher risk.

Research shows that people's willingness to drive into floodwater, even after receiving warnings not to, is the result of a number of factors including attitudinal belief, social norms, past behaviour and risk perception.

Long-term behaviour change is required to achieve reduction of flood fatalities from driving into water. This may involve collaboration with key national stakeholders and ongoing coordination and collaboration between Australian jurisdictions on flood safe behaviour, as well as consistent and longitudinal evaluation of measures put in place or piloted – beyond general metrics of 'hits, likes and shares' – to strengthen the evidence base to support flood safe behaviour.

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DEVELOPMENT OF FLOOD MITIGATION STRATEGIES FOR AUSTRALIAN RESIDENTIAL BUILDINGS

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
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INTRODUCTION

Globally floods cause widespread damage and loss of life and property. An analysis of global statistics conducted by Jonkman (2005) showed that floods (including coastal flooding) caused 175,000 fatalities and affected more than 2.2 billion people between 1975 and 2002. In Australia, floods cause more damage on an average annual basis than any other national disaster (HNFMSC, 2006). The fundamental causes of this severity of damage and the key factors contributing to flood risk, in general, are the vulnerable buildings constructed within floodplains and land-use planning.

Recent events in Australia (2011, 2013 and 2015) highlighted the vulnerability of housing to flooding which originates from inappropriate development in floodplains. While there is a construction standard issued by the Australian Building Code Board (ABCB, 2012) for new construction in some types of flood-prone areas, a large proportion of the existing building stock has been built in flood-prone areas across Australia (HNFMSC, 2006). Flood losses from the recent events highlight the requirement of implementing effective and efficient mitigation measures to reduce losses in future.

The Australian Government has developed the National Strategy for Disaster Resilience that defines the role of government and individuals in improving disaster resilience (NSDR, 2011). The strategy also emphasises the responsibility of governments, businesses and households to assess risk and take action to reduce the risk by implementing mitigation plans (Productivity Commission, 2014). Therefore, an in-depth understanding of the effects of floods on building stock is required for the development of risk mitigation and adaptation strategies, in particular considering the limited financial resources available. In this respect, reliable information about the costs and benefits of mitigation are crucial to inform decision-making and develop policies, strategies and measures to prevent or reduce the impact of flood.

The Bushfire and Natural Hazards Cooperative Research Centre project entitled 'Cost-effective mitigation strategy development for flood-prone buildings' (BNHCRC, 2016) is examining opportunities for reducing the vulnerability of new and existing Australian residential buildings. It addresses the need for an evidence base to inform decision-making on the mitigation of the flood risk posed by the most vulnerable Australian building types. This project investigates methods for upgrading existing residential building stock in floodplains to increase their resilience to future flood events. The project also aims to make assessments of the reduction in damage losses that will result from the implementation of a range of mitigation measures developed by the project.

COMPLETED PROJECT ACTIVITIES

A summary of the activities which have been completed is presented below.

Development of building schema

This research requires a building vulnerability classification, or schema. The classes identified within the schema have to represent the variety of housing within the nation's residential building stock and, more specifically, the variation in vulnerability across the nation's building stock. Furthermore, the schema must identify specific classes for which the project will develop mitigation strategies.

In this research, a literature review has been conducted which reviewed building schemas developed nationally and internationally for a range of uses within different projects. The reviewed schemas are from the USA (FEMA, 2007a), Germany (Schwarz and Maiwald, 2008), Philippines (Pacheco et al. 2013), New Zealand (NIWA, 2010), Australia (Wehner et al. 2012) and UNISDR Global Assessment Report (Maqsood et al. 2014).

Based on the literature review a schema was proposed that represents a fundamental shift from describing the complete building as an entity to one that focuses on sub-components (Maqsood et al. 2015a). The proposed schema divides each building into its major components (i.e. foundation, ground floor, upper floors [if any] and roof) enabling the vulnerability of each of these components to be assessed separately (Figure 1). Each storey type is then classified using the following six attributes.

- Construction period (pre-1960 or post-1960)
- Fit-out quality (standard or low)
- Storey height (3.0m or 2.7m or 2.4m)
- Bottom floor system (slab-on-grade or raised timber or raised particleboard)
- Internal wall material (masonry or plasterboard or timber)
- External wall material (brick veneer or weatherboard or masonry)

With the exclusion of combinations that are invalid in an Australian context, the schema defines 60 discrete storey types based on the above-listed attributes. Additionally, the schema proposes six roof types based on the material and pitch of the roof.

This approach facilitates the development of vulnerability models for taller buildings, buildings with basements, buildings with mixed usages and those with different construction materials used at different floor levels. Therefore, the new approach provides a mechanism to represent building stock in a better way and to improve the quality of flood risk assessment.

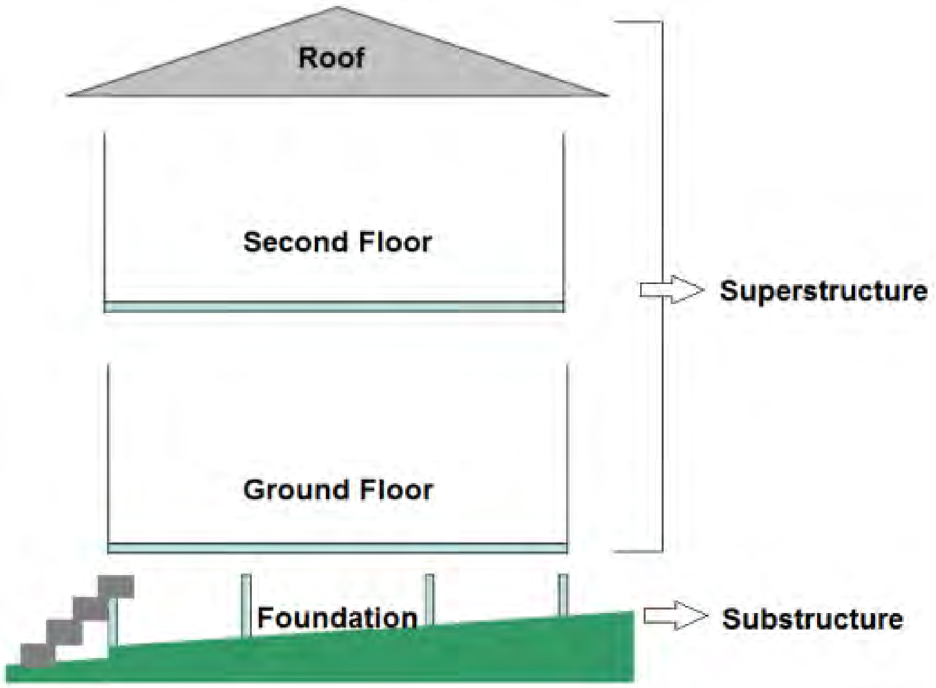


FIGURE 1: BUILDING STRUCTURE DIVIDED INTO MAIN COMPONENTS (MAQSOOD ET AL. 2015A)

Literature review of mitigation strategies

A literature review has been conducted to identify mitigation strategies used in several countries and for various severities of flooding (Maqsood et al. 2015b). The review has considered literature available through peer-reviewed journals, international conferences, research reports and guideline documents, and a summary of the review is provided here.

Bouwer et al. 2011 classified the different types of retrofit or mitigation measures into nine basic categories in which a distinction was made between mitigation measures that focus on hazard reduction and those that focus on vulnerability reduction. The use of insurance to recover from a disaster and to provide incentives for mitigation works was studied by Kunreuther (2006) and Crichton (2008). The use of spatial zoning and land-use changes was presented by Burby et al. 2000 and Poussin et al. 2012. Another widely used broader classification of mitigation measures is based on whether the strategies utilise engineering and administrative methods to reduce flood risk or modify the flood characteristics and human occupancy of the floodplain. These are broadly divided into structural and non-structural approaches (Brody et al. 2010) or hard and soft measures (Productivity Commission, 2014). Both approaches have benefits and limitations. Mitigation strategies that have been applied in Australia and internationally to minimise vulnerability and future losses of residential buildings can be summarised below (Maqsood et al. 2016).

- Elevation
- Relocation
- Dry floodproofing
- Wet floodproofing
- Flood barriers

Development of costing modules for selected retrofit options

Out of 60 possible types, five typical storey types have been selected for the remainder of the research which represent most common residential types in Australia. These are a subset of the schema proposed earlier in this paper. Key characteristics of these storey types are presented in Table 1. Further, based on the characteristics of the selected storey types, a floodproofing matrix has been developed which excludes the mitigation options noted in Section 2.2 that are invalid and considered to be inappropriate in the Australian context (see Table 2). As part of this project costing modules are being developed by quantity surveying specialists to estimate the cost of implementing all appropriate mitigation strategies for these five storey types. A summary of mitigation measures considered for the costing is provided below.

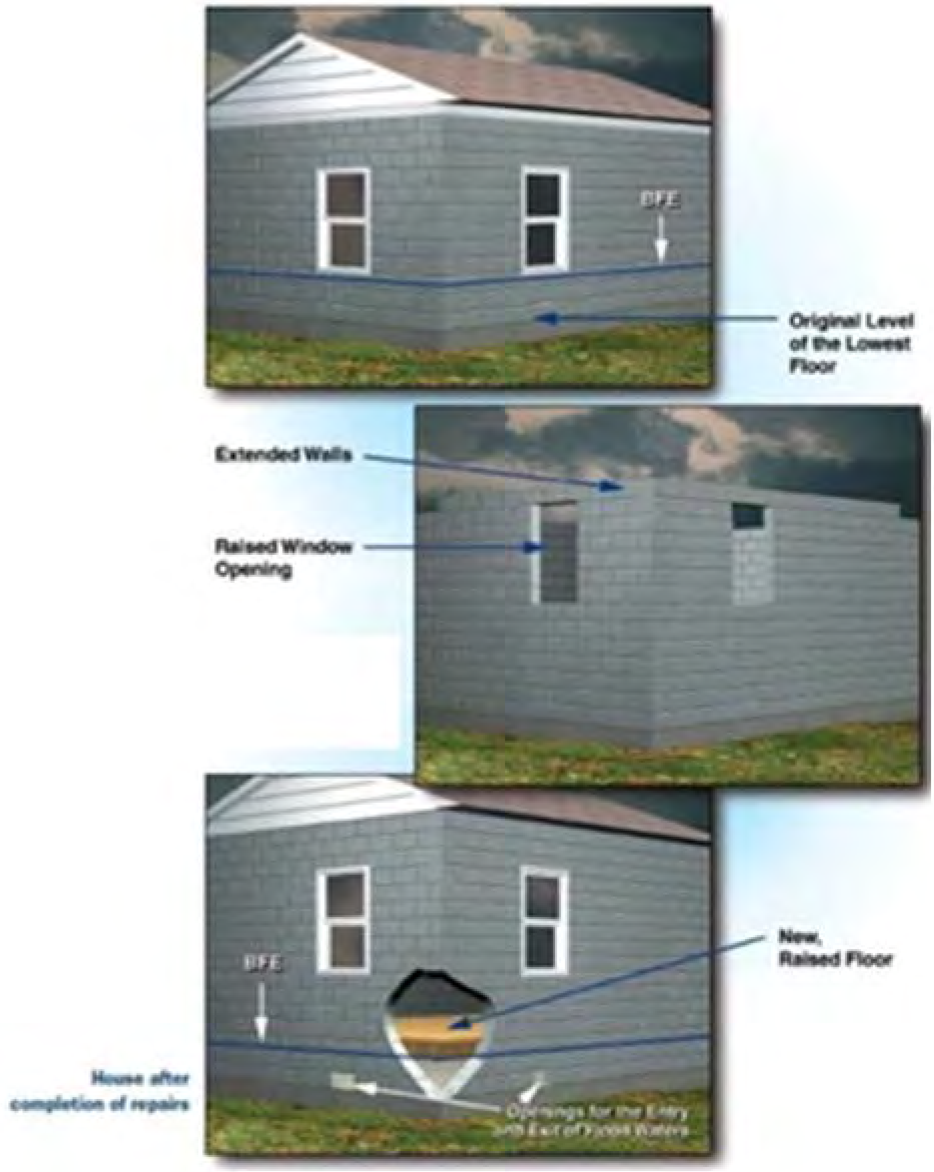
Elevating a structure is one of the most common mitigation strategies which aims to raise the lowest floor of a building above the expected level of flooding. This can be achieved by (i) extending the walls of an existing structure and raising the floor level, (ii) changing the use of ground floor and constructing a new floor above the existing one, (iii) through raising the whole structure on new substructure. Figure 2 shows the three techniques to elevate a building. The applicability of these techniques for the five selected storey types is presented in Table 2.

Relocation of a building is the most dependable technique, however, it is generally the most expensive as well (USACE, 1993). Relocation involves moving a structure to a location that is less prone to flooding or less exposed to flood-related hazards such as erosion or scouring. Relocation normally involves placing the structure on a wheeled vehicle, then transporting it to a new location and setting it on a new foundation (FEMA, 2012). In the present study this is found to be appropriate only for Building Type 1 which is a lightweight timber frame building with weatherboard exterior walls.

Storey Type	Construction period	Bottom floor system	Fit-out quality	Storey height	Internal wall material	External wall material	Photo
1	Pre 1960	Raised timber	Low	2.7m	Timber	Weatherboard	
2	Pre 1960	Raised timber	Low	3.0m	Masonry	Solid masonry	
3	Pre 1960	Raised timber	Low	2.4m	Masonry	Cavity masonry	
4	Post 1960	Raised timber	Standard	2.4m	Plasterboard	Brick veneer	
5	Post 1960	Slab-on-grade	Standard	2.4m	Plasterboard	Brick veneer	

TABLE 1: CHARACTERISTICS OF SELECTED STOREY TYPES

(A) Technique 1: extending the walls of an existing structure and raising the floor level



(B) Technique 2: changing the use of ground floor and constructing a new floor above the existing one

(C) Technique 3: raising the whole structure on new substructure

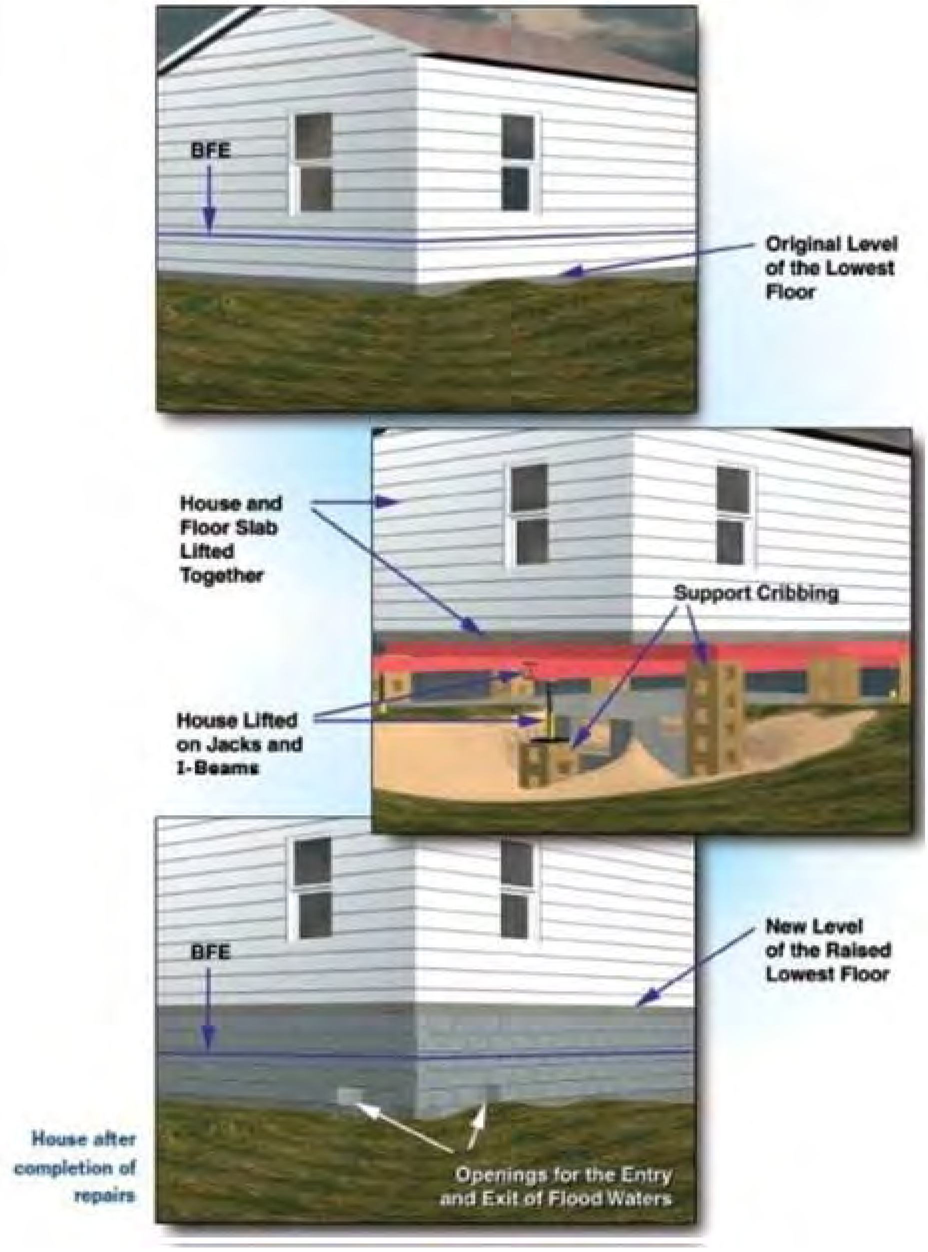


FIGURE 2: TECHNIQUES FOR ELEVATION (FEMA, 2000)

Building Type	Elevation (Extending the walls)	Elevation (Building a second storey)	Elevation (Raising the whole house)	Relocation	Flood barriers (permanent)	Flood barriers (temporary)	Dry flood-proofing	Wet flood-proofing
1	N/A				N/A	N/A	N/A	
2	N/A		N/A	N/A				
3			N/A	N/A	N/A	N/A	N/A	
4	N/A		N/A	N/A	N/A	N/A	N/A	
5	N/A		N/A	N/A				

TABLE 2: FLOODPROOFING MATRIX

Dry floodproofing consists of measures to seal the portion of a structure that is below the expected flood level to make it substantially impermeable to floodwaters. Such an outcome is achieved by using sealing systems which include wall coatings, waterproofing compounds, impervious sheeting over doors and windows and a supplementary leaf of masonry (FEMA, 2012). Dry floodproofing is generally not recommended in flood depths exceeding one metre based on tests carried out by the US Army Corps of Engineers as the stability of the building becomes an issue above this threshold depth (USACE, 1988; Kreibich et al. 2005). Dry floodproofing may also be inappropriate for light timber frame structures (Building Type 1), structures with raised timber floors (Building Type 1, 3 & 4) and structures which are not in good condition and may not be able to withstand the forces exerted by the floodwater (FEMA, 2012).

Wet floodproofing includes modifying the building by (i) replacing existing building components/materials with more water-resistant materials, (ii) adapting to the flood hazard by raising key services and utilities to a higher level, and (iii) installing flood openings to equalise the hydrostatic pressure exerted by floodwaters on the interior and exterior of the building and thus reducing the chance of building failure. With this technique, as the building components below the flood level are wetted, all construction material and fit-outs should be water-resistant and/or can be easily cleaned following a flood (USACE, 1993; FEMA, 2007b). This strategy can be used for all storey types.

Flood barriers considered in this research are those built around a single building and are normally placed some distance away from it to avoid any structural modifications to the building. There are two kinds of barriers: permanent and temporary. An example of a permanent barrier is a floodwall which is quite effective because it requires little maintenance and can be easily constructed and inspected. Generally, it is made of reinforced masonry or concrete and has one or more passageways that are closed by gates. There are also several types of temporary flood barriers available in the market which can be moved, stored and reused. Examples of temporary flood barriers are shown in Figure 3. Flood barriers may be inappropriate for structures with raised floors (Building Type 1, 3 & 4) because of the high cost of barriers for height more than 1 m.

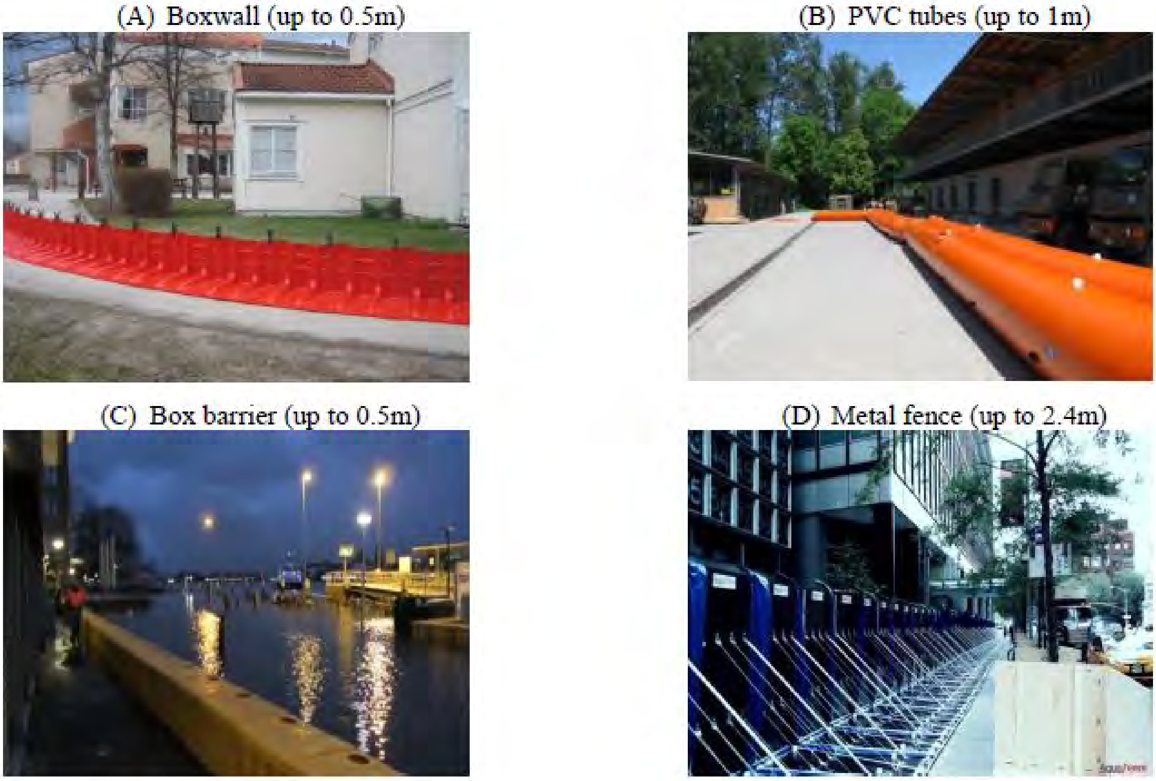


FIGURE 3: EXAMPLES OF TEMPORARY FLOOD BARRIERS (BLUEMONT, 2015)

FUTURE PROJECT ACTIVITIES

A brief overview of the future activities of the project is given below.

Experimental testing of selected building materials

In this project the strength and durability implications of immersion of key structural elements will be examined in slow water-rising conditions to ascertain where deterioration due to wetting and subsequent drying needs to be addressed as part of repair strategies. An analysis will be conducted to identify research gaps in building material susceptibility to flood water in Australia. This research will also entail experimental testing of preferred material types to ascertain their resilience to flood water exposure in FY 2016-17.

Vulnerability assessment for current and retrofitted building types

The vulnerability of selected storey types to a wide range of inundation depths will be assessed. It will also be supplemented by both a significant range of flood vulnerability research by Geoscience Australia which includes flood vulnerability models for a range of usage (e.g. residential, commercial, industrial) and a body of damage survey activity in Australia.

Benefit versus cost analysis

Retrofit options entail an investment that will realise a benefit over future years through reduced average annualised loss. Decisions to invest in reducing building vulnerability, either through asset owner initiatives or incentives provided by government or the insurance industry, will depend upon the benefit versus cost of the retrofit. In this research all retrofit options will be assessed in future years through a consideration of a range of severity and likelihood of flood hazard covering a selection of catchment types.

OUTCOMES

The result will be an evidence base to inform decision-making by government and property owners on mitigation of flood risk by providing information on the cost-effectiveness of different mitigation strategies and optimal solutions for different cases of building and catchment types. The work will provide information on the optimal retrofit types and design levels in the context of Australian construction costs and catchment behaviours by the end of the project in 2020.

SUMMARY

Economic losses due to floods have been increasing during the last decades due to vulnerable construction types and because of rapid urban development in floodplains which increases exposure to flooding. The increase in loss emphasises the need to improve flood risk management and to reduce future flood losses.

Flood risk management not only includes the measures taken by government but also includes mitigation measures adopted by private property owners to reduce the potential losses. These measures include elevating structures above the expected flood level, relocating the structure outside the floodplain, dry floodproofing to make the structure water tight, wet floodproofing by using water-resistant materials and installing flood barriers to keep water away from the building. These efforts have a significant potential to reduce flood damage to buildings and contents particularly in low to moderate flood levels losses (Kreibich and Thieken, 2008).

This project within the Bushfire and Natural Hazards CRC aims to conduct a comprehensive analysis of mitigation options and evaluate each of them through cost benefit analyses for use in Australian conditions. The result will be a clear understanding of cost and benefits involved in implementing any of these mitigation measures. This evidence base will facilitate and encourage governments and property owners to make informed and optimal decisions to reduce flood risk.

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