# Australian Bushfire Losses: Past, Present and Future

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### Abstract

This study reviews and extends previous analyses of the bushfire risk to the built environment in Australia. The most salient result is that the annual probability of building destruction has remained almost constant over the last century despite obvious demographic and social changes as well as improvements in fire fighting technique and resources. Most historical losses have taken place in extreme fires with an average return period of a decade or two and which when repeated are likely to overwhelm even the most professional of fire services. Because of these observations and despite predictions of an increasing likelihood of conditions favouring bushfires under global climate change, we suspect that building losses are unlikely to alter dramatically in the near future.

By evenly spreading the risk over the entire bushland-urban interface, we calculate the annual chance of a random home being threatened by a bushfire to be of the order of 1 in 3000, a factor of three lower than the ignition probability of a structual house fire. The probability of destruction is lower still at around 1 in 5000. Thus the incentive for individuals to mitigate and reduce the bushfire danger even further is low. In particular, without strong political leadership and regulatory pressure preventing development adjacent to bushland, the prospects for further significant loss events, such as the Ash Wednesday fires, in which 2300 homes were destroyed and 75 people lost their lives, will remain unchanged.

## Introduction

Australia is sometimes called the most fire-prone country on earth and certainly the threat of bushfires (wildland fires) casts a malevolent shroud over many communities. In extending and updating material previously reported by McAneney (2005), this paper reviews the bushfire threat to the built environment in Australia especially the risk at the bushland-urban interface. It briefly considers the role of climate, particularly that of the El Niño-Southern Oscillation phenomenon, in modulating building losses and the likely impact of global warming on this nation's fire risk.

The study draws upon Risk Frontiers' database of historical building losses - *PerilAUS* - the most comprehensive record of its kind in Australia. It was compiled by painstaking examination of official records and early newspapers and records of nearly 5,000 hazard events from 1900 to 2003. For almost 1,200 events, it is possible to estimate the number of buildings destroyed with damaged buildings (including commercial premises) normalised to *residential house equivalents* (RHE) using relative building costs and floor areas for different types of buildings. In principle, one RHE could equal two residential homes each 50% destroyed or 10 homes experiencing damage amounting to 10% of their replacement value. Outcomes from bushfires, however, tend to be binary in nature with buildings either being completely destroyed or surviving relatively unscathed. In what follows, we will loosely refer to RHE simply as homes or buildings destroyed.

## Historical losses

Figure 1 shows annual numbers of buildings (RHEs) destroyed by bushfire since 1926. The average annual toll is 84 buildings each year. Of the more extreme events, some 2300 homes were lost in the 1983 Ash Wednesday fires in Victoria and South Australia; in 1967, another 1300 in Hobart, Tasmania, and, more recently, in 2003, 500 in Canberra. On five occasions since 1926, more than 500 buildings have been destroyed. Thus the average return period for these extreme loss events or mega-fires is of the order of 15 years, although we concede that there may well have been other equally dramatic fires in which few houses were lost due to remote location, changing weather conditions, good management or providence. We return to this point in later discussion.

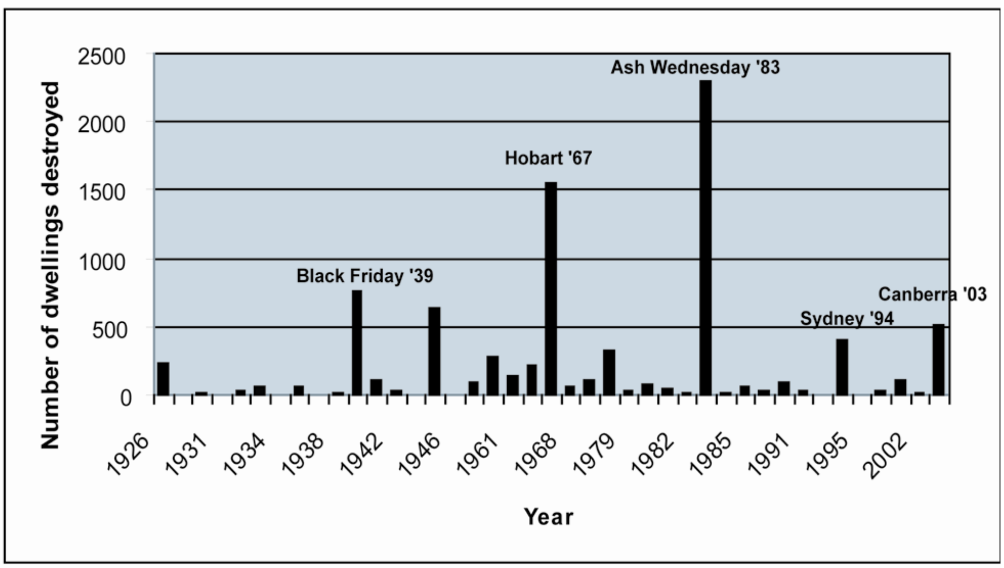


*Figure 1:* Annual number of dwellings lost to bushfires since 1926. (Source: *PerilAUS*, Risk Frontiers.)

## Bushfires losses in perspective

How important are bushfire losses in relation to other natural hazards? Figure 2 answers this question: in terms of total building losses over the past century, tropical cyclones have been most destructive, accounting for some 30% of losses, with floods and bushfires each responsible for another 20% as are thunderstorms when losses from hail, wind gust and tornado are combined. Earthquakes account for only 7%, a proportion heavily dependent upon a single event – the 1989 Newcastle earthquake (Blong 2004). (For long return period loss events such as earthquakes and tsunami, 100 years of data is too short to gauge their relative importance with any confidence.) We remind the reader that consideration of loss of life would produce a different ranking of perils.

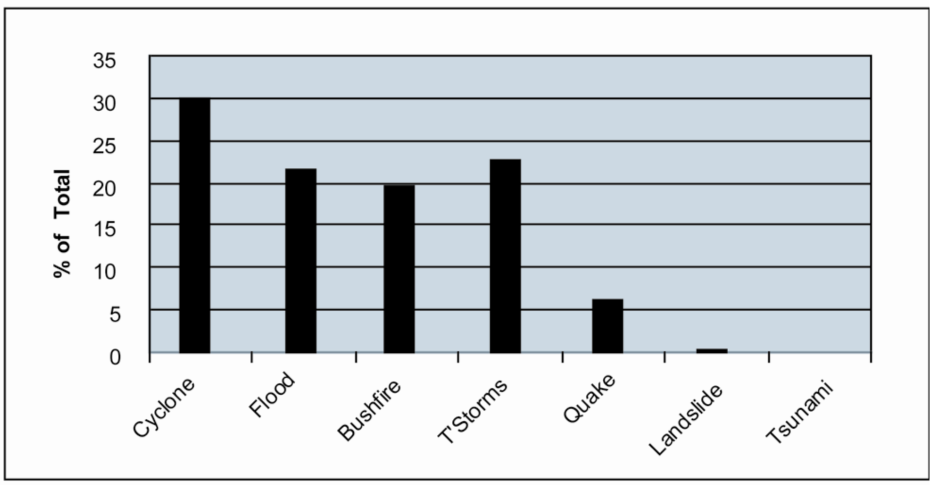


*Figure 2*: Percentage of the accumulated building damage between 1900 and 2003 attributed to different perils. "T'storms" represents thunderstorms including wind and hail damage. (Source: *PerilAUS*, Risk Frontiers)

Another source of information is the Insurance Council of Australia's (ICA) database of significant insured losses (>$A10 million) due to natural hazards since 1967. These losses have recently been indexed to account for changes in inflation, population and wealth (Crompton et al. 2006) in much the same way as has been done for the US hurricane record (Pielke and Landsea 1998). Indexed figures approximate likely losses if a historical event were to reoccur with today's exposure. Seventeen bushfire events are recorded on this database with the 1983 Ash Wednesday event making the top 10 (Table 1). It what follows, we argue that a reoccurrence of such losses in the future is inevitable.

*Table 1:* The 10 largest insurance disasters ranked by the indexed loss as if the historical event were to re-occur in 2006. (Cyclone losses have been adjusted where appropriate for changes in building codes introduced to improve the wind resistance of new construction in cyclone threatened regions.)

| Rank | Year | Peril | Location | Original Loss ($M) | Current Loss (2006) ($M) |
|---|---|---|---|---|---|
| 1 | 1989 | Earthquake | Newcastle | 862 | 4300 |
| 2 | 1974 | Cyclone | Darwin | 200 | 4060 |
| 3 | 1999 | Hail | Sydney | 1700 | 3310 |
| 4 | 1974 | Cyclone-Flood | Brisbane | 68 | 1790 |
| 5 | 1983 | Bushfire | VIC, SA | 176 | 1610 |
| 6 | 1990 | Hail | Sydney | 319 | 1480 |
| 7 | 1985 | Hail | Brisbane | 180 | 1430 |
| 8 | 1976 | Hail | Sydney | 40 | 740 |
| 9 | 1986 | Hail | Western-Sydney | 104 | 710 |
| 10 | 1984 | Flood | Sydney | 80 | 670 |

## Role of climate and global climate change

Damaging bushfires are obviously more common in times of drought and in many parts of Australia this condition is influenced by the El Niño-Southern Oscillation (ENSO) phenomenon. (An El Niño (La Niña) event is taken to occur when sea surface temperatures in the region of the Pacific known as “Nino 3.4” ($5^{o}$N-$5^{o}$S and $120^{o}$W-$170^{o}$W) are greater than or equal to 0.4C warmer (cooler) than the long-term average during August, September, and October (Pielke and Landsea 1999)). Of the 17 bushfire events featured in the ICA database, none occurred during La Niña seasons, while seven took place during Neutral and the other 10 during El Niño seasons. (A season is taken from July 1 to 30 June to include the Southern Hemisphere summer.)

Looking to the future, the impact of global climate change on ENSO phenomenon, especially the relative frequency of El Niño, La Niña and Neutral phases, is unknown. What we have examined is the bushfire risks to New South Wales under different $CO_2$ emission scenarios by means of a high resolution regional climate model driven at the boundaries by data from a transitory coupled climate model (Pitman et al. 2007). By 2050, this study shows the $95^{th}$ percentiles of the commonly used Forest Fire Danger Index (FFDI) to increase by around 25% compared with the present day under both relatively low and high emission scenarios. This index – effectively an expression of the difficulty of bushfire suppression - increases even more dramatically by 2100 under higher emission rates. These simulated increases in FFDI are largely driven by background changes in air temperature and humidity, variables that create the setting for wild fires. Days of high winds, not captured in the analysis, but which determine the rate of spread of the fire front, will further amplify the bushfire hazard.

In concluding that bushfire occurrence in Australia is likely to increase under global warming, our results are consistent with earlier studies. More days of elevated fire risk will undoubtedly mean increased burning of bushlands; but, will this imply increased building losses? We consider this question now.

## Temporal changes in bushfire losses

It is instructive to look at how building losses have changed over time. Figure 1 displays the historical evidence and shows no obvious trend. Table 2 shows that the likelihood of home destruction has remained remarkably stable over the last century with some building destruction expected in 60% of years. This same stability is also exhibited for the bigger events with an *annual* probability of losing more than 25 or 100 homes in a single week remaining around 40 and 20% respectively. (The time duration of one week has relevance to reinsurance treaties.)

*Table 2:* National bushfire building loss probabilities calculated between the start year and 2003. Data in the first column (1900) has been adjusted to account for missing data. The first row gives the frequency of any (non-zero) loss while the second and third includes only those events that have resulted in more than 25 or 100 homes destroyed within a single week. 1926, 1939, 1967 and 1983 were each years with significant losses. (Source: *PerilAUS*, Risk Frontiers.)

| Start Year | 1900 | 1926 | 1939 | 1967 | 1983 | 1990 |
|---|---|---|---|---|---|---|
| Annual probability of a non-zero loss | 56% | 53% | 48% | 57% | 57% | 57% |
| Annual probability of losing >25 homes in 1 week | 39% | 40% | 42% | 41% | 38% | 36% |
| Annual probability of losing >100 homes in 1 week | 18% | 19% | 22% | 19% | 19% | 21% |

That the statistics on home destruction has remained obstinately invariant over time is an intriguing and important result. If we consider just one variable that might influence risk, we note that Australia's population has increased from around 3.75 to 20 million over the last century and 63% of people now live in capital cities rather than just 33% in 1900 (Trewin 2006). *A priori*, we might have expected bushfire losses to increase with population and the fact that this is not so is presumably a testament to the activities of firefighters in keeping building losses in check. However the constancy of the figures over time still remains to be explained.

One possibility is that resources into fire fighting and education have increased over time to exactly balance the presumably increasing risk. In other words, the political processes that govern the allocation of resources have established some sort of quasi-equilibrium between inputs and outcomes. Attractive as this thesis may be, it seems implausible, especially given that in the early part of last century, there was little systematic attempt to learn from fire experience (Collins 2006).

More credible is the argument that large losses occur rarely and under extreme weather conditions when fires get out of control and converge to create so-called mega-fires. Once a fire exceeds a certain scale, there is very little that can be done to stop it until it either runs out of fuel or weather conditions change. This is easily demonstrated by reference to Figure 1 where we see that just four such events have accounted for the majority of losses in the last 50 years.

The risk is particularly high at the edges of towns or cities where suburbs adjoin bushland and where there is the potential for large numbers of homes to be destroyed. This being the case, building losses will be a function of the width of the fire front and if and how this front intersects populated areas, the disposition of homes vis-à-vis the bushland and whether or not homes are defended. This is borne out in Figure 3 by the wide dispersion in the spatial distribution of homes destroyed in major Australian bushfires. The medium distance (50-percentile) from the bushland edge for Duffy, Canberra, is about three times that of Como-Jannali (145 m versus 45 m) and the proportion of homes destroyed in the first 50 m ranges between 10% (Duffy, Canberra) and 80% (Otway Ranges, Victoria). The former impacted a modern leafy suburb on the edge of the nation's capital while the latter mainly rural areas and small townships.

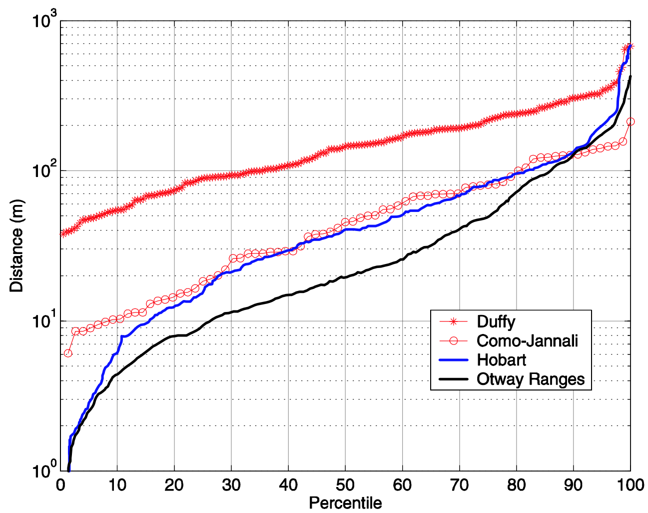


*Figure 3:* Cumulative distribution of homes destroyed in major bushfires in relation to distance from nearby bushland. The Otway ranges curves (648 samples) from the Ash Wednesday fires and the Hobart fires (Tasmania) are from Ahern and Chladil (1999) are also shown. (Source: Chen and McAneney 2004.)

Quantifying the fire hazard at the bushland-urban interface is essential for developing rational planning regulations (how far from the bushland should houses be built?) and fair and realistic insurance premiums. A useful rule of thumb that emerges from Figure 3 is that the maximum distance at which we have seen homes destroyed under Australian conditions is about 700 m. We now examine the pattern of home destruction given the incidence of an extreme event incident on the suburbs.

## Fire penetration at the urban boundary

The most recent example of an extreme fire loss event is the January 18, 2003 Canberra fires. We focus on the damage experience in the suburb of Duffy, which we adopt as a worse case scenario given that most homes were undefended following enforced evacuations by the police. The cumulative distribution of home destruction in relation to distance from the bushland has already been shown in Figure 3.

Using aerial and satellite images of bushfire damage in Duffy (Figure 4) and for Como-Jannali, near Sydney in 1994, Chen and McAneney (2004) found the probability of houses burning down decreased linearly with distance from the bush boundary (Figure 5). In both these and other cases of severe bushfires, around 50 to 60 per cent of homes within the first 50 m were destroyed — a remarkably consistent figure given the varying circumstances of the fires.

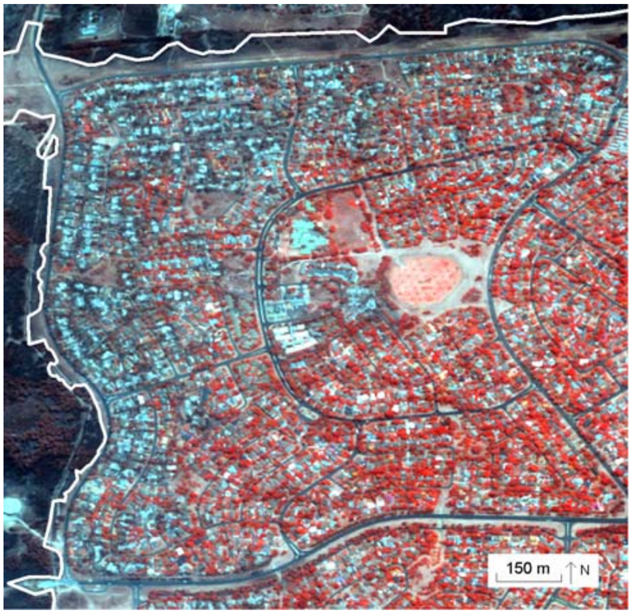


*Figure 4:* A false-colour Quickbird image (with near infrared, green and blue bands) for the fire-damaged suburb of Duffy, Canberra. Healthy vegetation is shown in red, whereas burnt vegetation to the north and west appears as grey. White lines indicate the bushland boundary. The predominant wind direction was along the diagonal from the upper left-hand corner. Patterns of damage were consistent with most houses being set ablaze by wind-borne embers rather than radiant heat or direct contact with the fire. (Source: Chen and McAneney 2004.)

It is important to reinforce the fact that most homes were undefended in the Canberra fires as a number of studies have found that suppression activity by residents during and immediately after fires is important in saving homes (e.g. Wilson and Ferguson 1986). In situations when these efforts prove fruitless and/or warning time is insufficient, we may reasonably take this experience (Figure 5) as an upper limit under extreme fires.

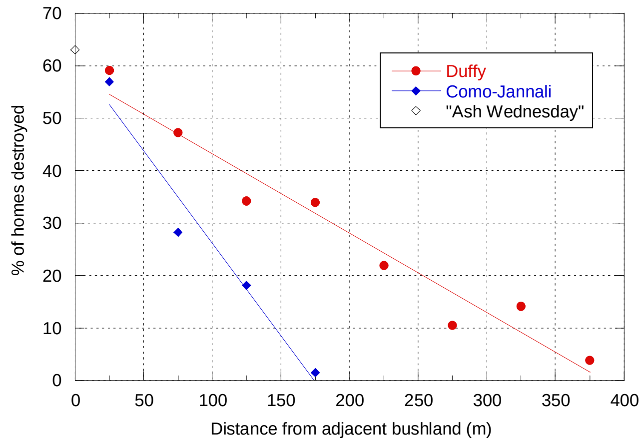


*Figure 5:* Percentage of homes destroyed at different distance ranges (interval=50 m) in the 2003 Canberra fires, the 1994 Como-Jannali fires in Sydney and the 1983 Ash Wednesday fires in Victoria and South Australia. In four different suburbs (Fairhaven, Airey's Inlet, Macedon and Mount Macedon, the delineation of bushland boundaries was difficult and so post-fire aerial photographs were used to estimate the percentages of homes destroyed for areas immediately adjacent to bushland. The figure plotted is an average of these. (Source: Chen and McAneney 2004.)

## Buildings at risk

While distance is not the only variable determining the relative bushfire threat to homes, Figure 5 shows that it is demonstrably the most important and has the virtue of being relatively easy to measure. So here we use distance as a surrogate metric to answer a pretty basic but important question: how many properties in Australia are at risk? And what is the likelihood of home destruction on average?

To answer this, we need accurate locations of property addresses and maps of the distribution of bushland. For the former, Chen and McAneney (2005) employed the latest G-NAF (Geocoded National Address File) street address database, Australia's most authoritative geo-located address database, together with medium-resolution Landsat 7 ETM+ images to classify bushfire-prone vegetation - forests and pine plantations. The focus was on identifying large areas of continuous bushland, i.e. areas that might allow large fires to develop and, on occasions, get out of control. For this reason, small, scattered and discontinuous areas of vegetation (<0.5 $km^2$) were eliminated.

Given the locations of addresses and bushland, the calculation of shortest distance between them is then straightforward. A total of 8.2 million (or 75% of) national addresses primarily in major capital cities and surrounding areas have been analysed. (Another 5% of national addresses are located north of Brisbane in sub-tropical and tropical regions, where the bushfire risk to buildings is low.) Seven distance ranges were categorised (Figure 6) with Group 1 comprising the first row of addresses immediately adjacent to bushland and those up to 50 m beyond the first row. 80% of addresses lie beyond 700 m, the maximum extent to which we have seen damage. Here we concentrate on Group 1 as the most at-risk addresses. Because of the medium resolution satellite imagery used, there could be either one or two rows of homes to Group 1, meaning that we have somewhere between 334,600 and 167,300 homes sitting near the forest boundary.

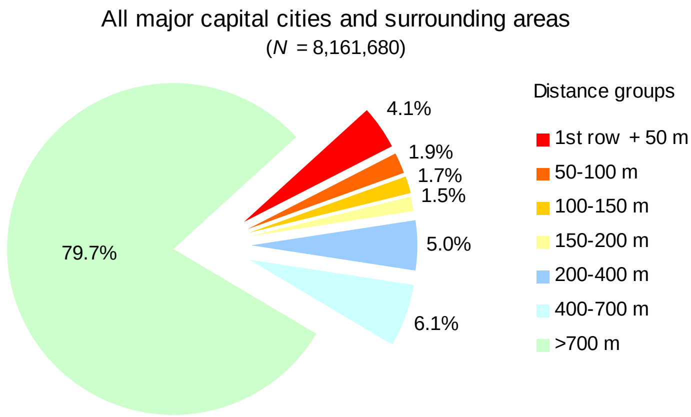


*Figure 6:* Percentages of addresses falling within different distance ranges from bushland in Australia (Chen and McAneney 2005).

Having estimated numbers of at risk addresses, we now exploit Figures 3 and 5 to calculate the probability of a random home on the bushland-urban boundary being threatened by the arrival of a fire front associated with an extreme fire. These calculations follow those of McAneney (2005) and Bob Leicester and Justin Leonard (Bushfire CRC, pers. comm.)

First, Figure 3 allows us to estimate the numbers of homes destroyed within the first 50 m during so-called mega-fires during the last 50 years as 2500. (This assumes that the Otway Ranges curve in Figure 3 is reasonably representative of all of the Ash Wednesday fires.) Figure 5 tells us that given such an extreme event, the probability of home destruction in the first 50m is around 60% (Figure 5), and thus we estimate a total 4200 homes to be have been directly threatened by the fire front. And finally, by dividing this figure into the national numbers of addresses at risk (scaled up to adjust for the 20% of national addresses that were not analysed), we arrive at rough upper and lower bounds for the arrival of a fire front at a random position on the bushland-urban boundary to be 2.0% and 1.0% in 50 years. A mid-range figure around 1.5% seems reasonable.

Thus the current annual probability of a random home being threatened with home destruction by the arrival of a bushfire front *when this risk is spread equally over the entire bushland-urban boundary* is around 1.5% in 50 years or roughly 1 in 3000. This probability is much lower than the average ignition frequency of structural house fires, which for Australia is around 1 in 1000 (SCRCSSP, 2006). We explore the implications of these figures in the following discussion.

## Discussion

This paper extends previous efforts to estimate the risk to the built environment from bushfires in Australia. Using Risk Frontiers' *PerilAUS* database of building damage, we see very clearly (Figure 1) that most building damage occurs during infrequent extreme events, the most recent example being the 2003 Canberra fires. Of special interest is the urban-bushland interface where the potential always exists for large losses and where the average annual likelihood of a random home being threatened by a bushfire is around 1 in 3000. Given a 40% chance of survival, the probability of destruction is around 1 in 5000. Locally this risk may vary enormously from the average due to position, slope and aspect in relation to dangerous wind directions and occupier behaviour.

The fact that the average risk to a home seems low, even compared with the likelihood of experiencing a structural house fire, may partially explain why many people ignore advice about how to reduce their fire risk even further. From community and political perspectives, however, the prospect of losing thousands of homes in a single event and, worse still, large loss of life –75 people were killed in the Ash Wednesday fires – remains unpalatable and underscores on going efforts to control and mitigate against bushfires. Insurers take a similarly jaundiced view about the prospects of large correlated losses.

We find it curious that the probability of building destruction has remained so stable in the face of significant demographic changes and improvements in fire fighting capacity over the last century. This result is best explained by infrequent mega-fires that have occurred about 5 times in the last 75 years and that can exhaust the resources of even the most professional fire services. Even in the Ash Wednesday fire, the efforts of the Country Fire Authority were laudatory despite resources considered primitive by today's standards: of some 95 fires, 88 were contained within 100 hectares, while 7 burnt out extensive areas of bushland, with only 5 of those 7 responsible for major house loss (Leonard et al. 2003). A somewhat banal conclusion might be that large event losses can only be avoided if every fire that has the possibility of impacting a populated area is extinguished while it is still small enough to be manageable. However there is a limitation to the most generous of resources.

The recent Canberra fires remain a stubborn reminder that fire catastrophes will continue to occur and the stability of past losses already referred to gives little hope that another Ash Wednesday can be avoided. Such events will occur for a variety of reasons that will vary from one fire to another: worse droughts, limited resources, failure of owners to mitigate their individual risk, high fuel loads, poor decision-making or even poor outcomes to good decisions given the uncertainties of conditions in the field (McAneney 2005). The actual loss in a mega-fire is a random variable that depends upon a host of variables including whether or not it intersects a populated area, the disposition of threatened houses and human intervention.

Global climate change adds a further level of uncertainty to the above picture both by increasing the likelihood of conditions that lead to bushfires and through unknown influences on the ENSO cycle. Nonetheless we believe that the near future impacts of global climate change are unlikely to be as dramatic as the combined changes of all of the other factors that have so far failed to materially affect the likelihood of loss over the last century. This is not to ignore the threat posed by global climate change, but, at least in the case of fire in Australia, the main menace will continue to be the extreme fires. This threat can only be diminished by improved enforcement of planning regulations that restrict where and how people live with respect to distance from the forest. This is a political choice that must be made in the knowledge that the risk on average, even for those living at the urban-bushland interface, is relatively low.

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