

# **Australian Bushfire: Quantifying and Pricing the Risk to Residential Properties**

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## **Abstract**

A new analysis of bushfire risk to residential properties shows that in 60% of years losses occur somewhere in Australia. The evident corollary to this is that in 40% of years no losses are experienced. This statistic has remained reasonably stable over the last century despite large increases in population and improvements in technology and firefighting resources. This stability was similarly demonstrated by the 40% probability of a major event, here arbitrarily defined as the loss of more than 25 homes within a period of 7 days, a time window of some relevance to reinsurance contracts.

The annual average number of houses lost is estimated to be 83 homes and when this is combined with current asset values for home and contents, the Annual Average Damage is valued at \$33.5 million. The 1 in 100 year event equates to a likely loss of AU\$0.7 billion and the 1 in 250 year event, AU\$1.1 billion. These figures are approximately equal to the present value of the insured losses from Tropical Cyclone Tracy and the Newcastle earthquake.

When the Annual Average Damage is adjusted for the annual volatility of losses, as would typically be the case when risk is judged from a reinsurance perspective, the national bushfire risk premium amounts to \$62.4 million. A complete costing for bushfire would need to include loss of life, the fixed cost of maintaining and supporting state fire fighting services, the opportunity cost of the volunteers engaged in firefighting activities as well as any contributions from Federal Government. This same general approach could be easily adapted to other perils in order to establish an objective ranking of the threat posed by the various natural hazards.

## **Introduction**

In its relatively short recorded history, Australia has witnessed first hand the impact of a wide range of geological and meteorological perils. In recent decades, tropical cyclones, earthquakes, floods, bushfires and hailstorms have all taken their toll (Table 1). Just which of these presents the largest threat in Australia is by no means a new question and not necessarily one that is well posed. As might be expected, the answer is very much dependent upon whether the concern is for loss of life, insured losses or wider economic losses to individual communities or the nation (Blong, 2004).

The focus here is on direct losses to residential property only – those assets that would normally be covered under a Home and Contents insurance policy. The study represents the beginning of an attempt to rank national bushfire risk alongside other natural hazards. It exploits modeling techniques that are increasingly used by the insurance sector to price catastrophe risks. For these risks, the absence of sufficient historical data means that future event losses must be simulated from synthetic hazard catalogues that faithfully reproduce the frequency and magnitude attributes of the peril along with descriptions of building vulnerability and the value at risk. Risk is interpreted here as the financial liability of future event losses and not the probability of a damaging event.

**Table 1:** Nine largest insured losses (Source: Insurance Disaster Response Organisation, 2003)

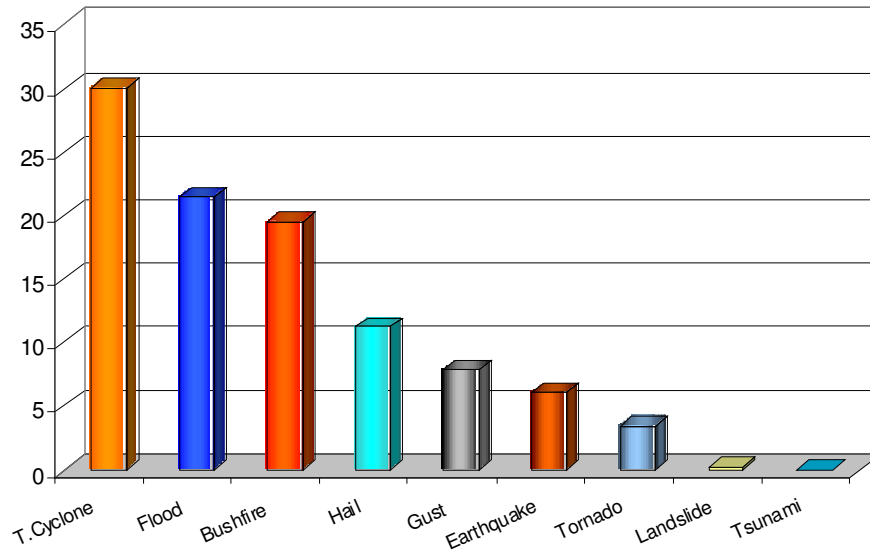
Event	Insured loss (AU\$ million) 2003 AU\$
Sydney hailstorm, 1999	1,700
Newcastle earthquake, 1989	1,124
Cyclone Tracy, 1974	837
Sydney hailstorm, 1990	384
Canberra fires, 2003	350
Brisbane floods, 1974	328
Ash Wednesday fires, 1983	324
Brisbane hailstorm, 1985	299
Sydney windstorm, 1991	226

While Table 1 is useful for illustrating the range of possible hazards that can afflict Australia, a more useful database is *PerilAUS*. This database was developed by Risk Frontiers and contains records of nearly 5,000 hazard events in Australia from 1900 to 1998. The database was compiled by painstaking examination of early newspapers and official records. For almost 1,200 events, it is possible to estimate the number of buildings destroyed, with damaged buildings being described in terms of *house equivalents* destroyed. Here one *house equivalent* could equal two homes each 50% destroyed or 10 homes each of which experienced damage amounting to 10% of their replacement value. During bushfires, as compared with some other perils such as hailstorms, say, homes are more often than not completely destroyed.

In the case of bushfire, the *PerilAUS* database has benefited from CSIRO records and newspaper reports (contributed by P. Cheney, CSIRO Div of Forestry and Forest Products). For more complete details on methodology, the reader is referred to Blong (2003).

Using data from *PerilAUS*, Figure 1 illustrates the relative importance of the various hazards over the last century in respect of their contribution to home destruction. At least during this time, tropical cyclones have been most destructive, accounting for almost one third of the total losses. Floods and bushfires each contribute about another 20%, as do thunderstorms if gust, hail and tornado are combined. Earthquake accounts for about 7%, a proportion that is heavily dependent upon a single event - the 1989 Newcastle earthquake. For long return period events such as damaging

earthquakes, the historical record is an inadequate sample on which to judge the future. The case of tropical cyclone is similarly conflicted as a forward analysis needs to consider new building standards using more rigorous wind loading codes introduced in the 1980s following Tropical Cyclone Tracy. These codes should dramatically reduce the vulnerability of newer homes. To a much lesser extent, this is also true for earthquakes.



**Figure 1:** Percentage of building damage to residential properties in the 20<sup>th</sup> century attributed to different perils. (Source: Chen, 2004.)

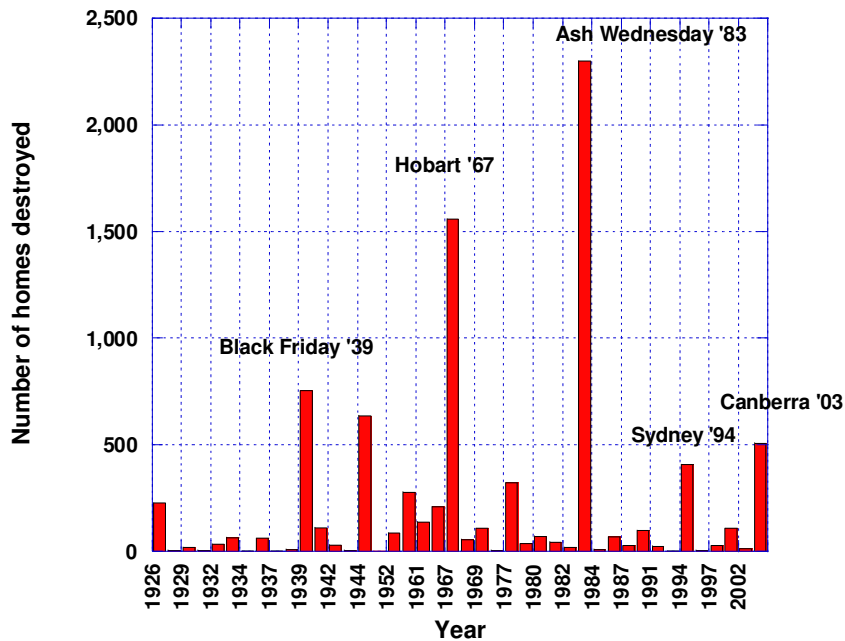
Some brief background to the insurance industry in terms of catastrophe risk is warranted. In Australia, insurers cede most of this risk to the international reinsurance market. (For example, reinsurance companies contributed nearly 90% of the AU\$1.7 billion in claims paid to policyholders after the 1999 Sydney hailstorm.) Thus the price of Australian catastrophe risk is determined by these international companies in relation to their worldwide exposure, risk appetite, expenses, and desired return on capital and investments (Walker, 2003). This pricing is passed on to policyholders by local insurers and accounts for some 20% of a typical Home and Contents policy premium of AU\$660 (Insurance Council of Australia, 2004, pers. com.).

In what follows, we will attempt to quantify the national bushfire risk to residential properties; the aim is not to calculate this as a reinsurance cost, a task beyond the scope of this paper, but merely to exploit techniques used by the industry in order to provide a consistent pricing methodology. In the future this type of analysis could be extended to other threats and thus the relative risk of the various hazards judged more objectively.

## Bushfire Losses

In comparison with rare damaging earthquakes or tropical cyclones, *PerilAUS* contains a wealth of information on bushfire losses. Figure 2 shows the times series of residential home destruction going back as far as 1926. The database goes back further than 1926 but is incomplete for some periods.

Our interest in this time series is two-fold. It allows us first to estimate the annual probability of experiencing a non-zero loss due to bushfire somewhere in Australia, and secondly, to capture the distribution of homes destroyed given a loss. Then by recombining this information together with current asset values, the distribution of future losses (in today's dollars) can be estimated. In reality, this amounts to assuming that the data (Figure 2) constitutes a stationary series, a point to which we shall return in later discussion.



**Figure 2:** Annual number of domestic dwellings lost to bushfires since 1926.

### Annual probability of a loss

In relation to the first of the above two tasks, Table 2 lists two relevant statistics and how these change when calculated between the given start date and 2003. The first of these is the probability of having a non-zero loss to residential homes in any year and

this can be seen to have remained relatively stable over time at around 60%. The corollary of this is that in 40% of years, bushfires cause no home losses. It might be argued that the shorter time span is more relevant going forward but this needs to be considered in the light of the increasing statistical confidence associated with longer time periods.

**Table 2:** Statistics of bushfire loss probabilities (Source: *PerilAUS*, Risk Frontiers). The first column has been adjusted to account for years where data are missing.

Start Year	1900	1926	1939	1967	1983	1990
Annual probability of a loss	57%	54%	49%	59%	62%	64%
Annual Probability of a major event	40%	43%	41%	38%	38%	36%

The second statistic in Table 2 only counts annual losses that exceed a lower threshold of 25 homes and which occur within a seven-day period. At current average asset values (AU\$440,000 for average home and contents), an event loss of 25 homes would exceed AU\$10 million, the lower limit for consideration in the Insurance Disaster Response Organisation database. The 7-day time window has some relevance for reinsurance contracts but is introduced here merely to confirm that the stability of the probability of any loss shown above also holds true for larger events. Table 2 shows that the annual probability of having a significant event loss (as opposed to a large annual loss) has remained remarkably constant at around 40%.

### Number of homes destroyed

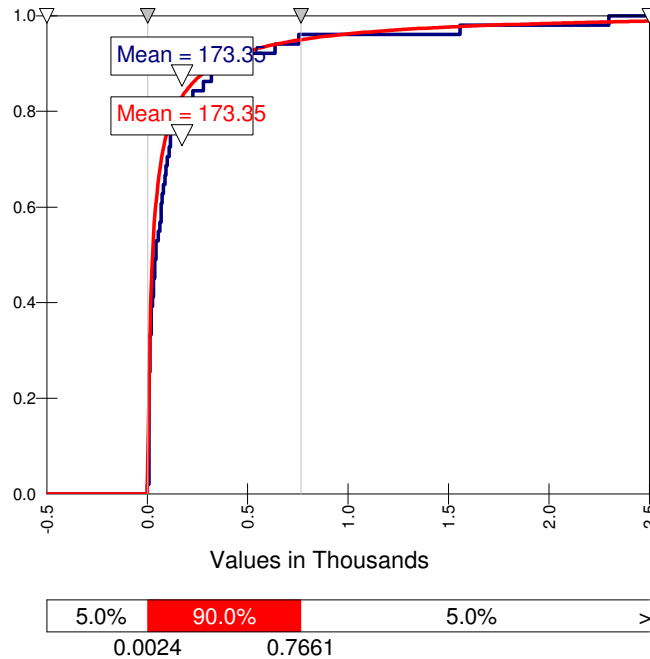
Figure 2 provides a useful guide to the distribution of past losses. But what does this really mean? This author interprets it as the legacy of fires that ‘got away’; it’s a legacy of losses that takes no account of the many more bushfires that were successfully controlled by fire authorities and/or resident action and which resulted in no damage to property. The action of residents in successfully defending their homes in any such conflagration is assumed to be already embedded in the data.

Just how many houses are at risk given an event that penetrates a community is really a function of the spatial disposition of homes with respect to the bushland-urban boundary. This is something ignored in an earlier analysis by Ahern and Chladil (1999) whose work has been instrumental in influencing town planning, at least in NSW. The general pattern of damage observed in the Canberra 2003 fires, for example, accords poorly with the Ahern and Chladil results (Chen and McAneney, 2004).

So what we are looking at is a perimeter effect: the same fire with a given width of the firefront impacting upon the urban fringe (e.g. Canberra or Southern California in 2003) has the potential to destroy many more homes than in the case of a small hamlet with a few houses strung out either side of a rural road. Even in the Ash Wednesday fire, the efforts of the Country Fire Authority were laudatory despite resources that

were 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 these 7 responsible for major house loss (Leonard et al. 2003). Again it is these few fires that get out of control that are responsible for most losses.

Figure 3 shows the distribution fitted to the loss data shown in Figure 2. The fitted function has the same mean as the input data of 173 homes destroyed in a year given a loss.

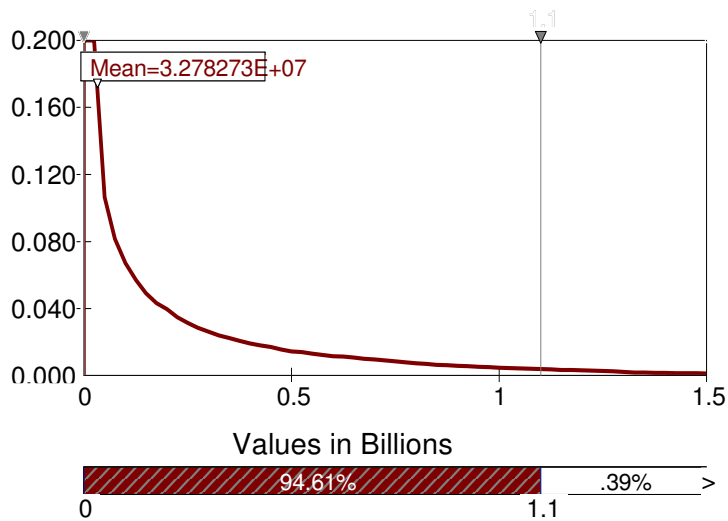


**Figure 3:** Cumulative distribution of actual (blue) and modeled (red) number of homes destroyed in years when actual losses occur. The vertical axis shows the probability of the actual loss being less than or equal to the number of homes on the x-axis. The bar graph shows the 5- and 95-percentile numbers of homes destroyed.

### ***Modeling Bushfire Losses***

Bushfire losses were simulated assuming an underlying Poisson process for the likelihood of fire damage with an annual probability of occurrence of 0.6 (Table 2). A Poisson process adopts a fixed probability of occurrence and assumes that the occurrence of a bushfire is unrelated to bushfires in earlier years. This distribution was multiplied by the distribution of annual losses of homes (Figure 3) after imposing an upper limit on annual home destruction of 3,500 residences. (This is an arbitrary value that requires further investigation but for the moment serves as a reasonable constraint on the variance. Within wide limits, the results are not sensitive to its exact value.) The annual average loss estimated from this calculation is 83 homes.

Then using an average asset value of AU\$440,000 for home and contents, we simulate the distribution of annual losses (Figure 4). This asset value was deduced from the average insurance premium for home and contents after making some adjustment for under insurance - 25% for home and 50% for contents.



**Figure 4:** The loss exceedance curve for future bushfire losses. The y-axis gives the annual probability that losses will equal or exceed the dollar sum on the x-axis.

Figure 4 is a descending cumulative distribution of possible losses. It shows the annual exceedance probability of increasing losses, that is, the probability that losses will equal or exceed any given dollar loss on the x-axis. It shows a 1 in 100 chance of an annual loss in excess of AU\$0.7 B and a 1 in 250 chance of this exceeding AU\$1.1 B. After updating each of these for inflation, the calculated losses are roughly equal to the insured losses in 1974 Cyclone Tracy in the first instance while the latter comparable to those from the 1989 Newcastle earthquake (cf. Table 1).

Let's return now to the modeled annual average loss from bushfire over all years. Is 83 homes a significant risk? To get a better feeling for this, Risk Frontiers has used satellite imagery to estimate the number of addresses within different distance categories from large areas of continuous bushland, i.e. those areas where the opportunity exists for large bushfires to get out of control (Chen and McAneney, 2005). Nationally some 340,000 addresses were found to be located immediately adjacent to the forest or within the next 50 m. A priori, these are the properties most at risk.

So again, what is the risk? Well given the information above, it would take some 4,100 years to burn through this number (340,000) of homes. On this basis the risk appears low but at this juncture it is difficult to compare this result with other threats. In what follows a more objective way of quantifying this risk is introduced. It is an approach that could easily be extended to other perils.

## **Pricing the National Bushfire Risk**

Reinsurance premiums are priced on the basis of a simulated Annual Average Damage (AAD) – sometimes called the *Pure Risk Premium* – plus compensation for uncertainty or volatility calculated simply as a multiple ( $\alpha$ ) of the standard deviation ( $\sigma$ ) of likely losses. *viz.*:

$$\text{Premium} = \text{AAD} + \alpha\sigma \quad (1)$$

Kreps (1990) provides the theoretical basis underlying this formula as well as showing the functional dependence of coefficient ( $\alpha$ ) on a number of financial and business variables. Catastrophe insurance premiums for a number of reinsurers active in the Australian market is consistent with a value of  $\alpha$  of about 0.2 (Walker, 2003). This value is used here.

In reality, of course, pricing also depends on a negotiated outcome contingent upon a number of other business considerations including the history of losses or surpluses, the entry of new capital into the reinsurance market as well as the willingness of reinsurers to maintain existing business relationships. Actual contracts include attachment points and limits as well as complex layering. We ignore these realities; our intention is not to duplicate actual reinsurance behaviour but merely to exploit equation (1) as a consistent means of pricing Australian bushfire risk.

Substituting now the appropriate moments of the distribution of simulated losses (Figure 4) in Equation (1), we obtain:

$$\text{'Bushfire Risk Premium' (AU\$ million)} = 33.5 + 0.2(144.4) = \$62.4$$

where the inverted commas again remind us that this is a notional insurance premium that ignores many complexities of real reinsurance programmes.

## **Concluding Comments**

The loss history (Figure 2) indicates that some home destruction can be expected in some 60% of years, a statistic that has remained remarkably constant despite large increases in population, improvements in fire fighting technology and understanding of bushfire physics. This is not surprising given that the propensity for fires to escalate once started will be largely a function of the surface water budget, ambient temperatures and windspeed, and fuel load. Of these variables, only the latter is subject to human intervention through controlled burnoff practices.

Our second result is that the modeled losses based on the distribution of the number of homes destroyed over the last 70-odd years amount to an average annual loss of 83 homes. Given current average asset values, this amounts to an Annual Average Damage of \$33.5 million and a bushfire risk premium of \$62.4 million. This is not the true cost to the nation as one must also consider loss of life, the cost of maintaining

fire services and the opportunity cost of the many volunteers involved in such activities and who might otherwise be engaged in wealth creating activities. These costs are likely to dwarf the 'premium' calculated here.

The question remains as to whether or not our modeled losses are a valid representation of future losses. We believe these to be the best available indicators of what may happen. This belief hinges on the fact that we are only simulating losses likely once a fire gets out of control of fire authorities and especially if it enters the urban boundary where there is a possibility of very large losses. Just how many homes will be lost in such situations will depend upon the disposition of homes *vis-a-vis* the bushland boundary. It will be largely independent of the total population. And our best estimate of this potential is the range of possibilities already present in the historical record.

We have also invoked the results of Chen and McAneney (2004 and 2005) to show that with some 340,000 homes around major capital cities to be most at risk should an extreme fire invade their properties. At an annual average loss of 83 homes, it would take some 4,100 years to destroy this number of homes. So the risk to any particular home is low, but this is poor consolation to those directly affected and, moreover, we do not know the equivalent 'burn rate' for other perils.

Some will argue that with better knowledge of how to minimise the vulnerability of individual homes to bushfire (Leonard and McArthur, 1999) reduced losses will inevitably follow. However the widespread application of these methods remains untested and the Canberra fires remain a stubborn reminder that fire catastrophes will continue to occur. Moreover they 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. The recent tragic losses on the Eyre Peninsula are yet another reminder that peoples' behaviour in crisis situations is not always predictable.

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