

WATER TRANSFORMED:

SUSTAINABLE WATER SOLUTIONS FOR CLIMATE CHANGE ADAPTATION

MODULE A

ADAPTING TO CLIMATE CHANGE

This online textbook provides free access to a comprehensive education and training package that brings together the knowledge of how countries, specifically Australia, can adapt to climate change. This resource has been developed formally as part of the Federal Government's Department of Climate Change's Climate Change Adaptation Professional Skills program.

CHAPTER 1: UNDERSTANDING THE RISKS AND ADAPTING TO CLIMATE CHANGE

LECTURE 1.3: REDUCING RISKS TO THE BUILT ENVIRONMENT & INFRASTRUCTURE – FROM BUSHFIRES

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Peer Review

Principal reviewers for this lecture were: Dr Geoff Cary - Dr Cary convenes the 'Fire in the Environment' course at ANU where he is a senior lecturer. Dr Cary is a member of the Bushfire CRC where he leads projects on the importance of climate change for fire management and carbon dynamics.

Dr Justin Leonard - Dr Leonard is currently leading CSIRO Sustainable Ecosystems' Bushfire Urban Design project. Dr Leonard researches the design of buildings in bushfire prone areas to improve their survival prospects during bushfire events, and provide understanding of infrastructure loss, relative risk and design improvements for risk mitigation.

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The Natural Edge Project (TNEP) is an independent non-profit Sustainability Think-Tank based in Australia. TNEP operates as a partnership for education, research and policy development on innovation for sustainable development. TNEP's mission is to contribute to, and succinctly communicate, leading research, case studies, tools, policies and strategies for achieving sustainable development across government, business and civil society. Driven by a team of early career Australians, the Project receives mentoring and support from a range of experts and leading organisations in Australia and internationally, through a generational exchange model.

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Adapting to Climate Change

Lecture 1.3: Reducing Risks to the Built Environment and Infrastructure – from Bushfire

Educational Aim

This lecture points out the fact that there has already been an increase in the frequency and intensity of bushfires due to climate change in many parts of the world,¹ and overviews the climate change science literature which suggests that there will be increasing risks from bushfires due to their greater intensity and frequency in the future.² This lecture illustrates that risks from bushfires to the built environment involve more than simply buildings, as history shows that bushfires can disable electricity infrastructure³ as well as reducing water quality in dams,⁴ reservoirs and rivers.⁵ In Australia, from the time of white settlement, up to and including the 1939 'Black Friday' fires, the destruction of buildings and the built environment in bushfires was looked on as inevitable, with surviving infrastructure and buildings being viewed as 'miraculous escapes'. Seventy years later, much more is known about how to reduce the risks of damage from bushfires to the built environment, infrastructure and water quality. This lecture discusses the lessons from this research based on peer reviewed research published before the February 2009 Victoria bushfires.

Learning Points

1. Many landscapes around the world have evolved with bushfires. Bushfires are a natural phenomenon, helping landscapes to re-generate. In Australia, some plants are so well adapted to particular fire regimes, that bushfires are both an advantage and, in some cases, a necessity for survival. Some plants have seed capsules that need to be burnt to release seeds before they germinate. Bushfires enrich the soil with ash which assists plant regrowth. Experts try to manage fire regimes in ways that maximise biodiversity while reducing fire fuel loads which can, in dry conditions, enable bushfires to get out of control and lead to natural disaster, loss of life and significant costs. 'Wildfires' are bushfires which burn uncontrollably or in an unintentional way. Wildfires can cause deaths, injuries and millions of dollars in damage. From now on in this lecture, when we refer to bushfires, we mean wildfires. Hence the two terms will be used interchangeably.

¹ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

² IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

³ The Nous Group (2007) *16 January 2007 electricity supply interruptions in Victoria: What happened and why and Opportunities and recommendations*, Executive summary, The Nous Group, [www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/\\$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf](http://www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf), accessed 21 October 2008.

⁴ Chafer, C. (2008) *Wildfire, Catchment Health and Water Quality: A Review of Knowledge Derived from Research Undertaken in Sydney's Water Supply Catchments 2002-2007*, Catchment Operations and Major Projects Division, Sydney Catchment Authority, Penrith, www.ewatercra.com.au/newbushfire/downloads/1000012.pdf, accessed 7 December 2008.

⁵ Wallbrink, P. et al (2004) *Impacts on water quality by sediments and nutrients released during extreme bushfires: Report 1*, Sydney Catchment Authority - CSIRO Land & Water Collaborative Research Project, CSIRO Land and Water Client Report, www.clw.csiro.au/publications/consultancy/2004/nattai_catchment_fire_erosion.pdf, accessed 7 December 2008.

2. Many factors influence the risk of wildfires, including weather,⁶ fuels, terrain, land management and suppression activities.⁷ The latest climate science shows that the frequency and intensity of bush/forest fires has already increased due to climate change in many parts of the world, including North America,⁸ Southern Europe,⁹ and countries in temperate and tropical Asia¹⁰. The Intergovernmental Panel on Climate Change (IPCC) predicts that the frequency and intensity of bushfires on average will increase this century in many parts of the world.¹¹ If we take Australia as an example, modelling by the Bushfire Cooperative Research Centre has shown an increased fire risk due to climate change is likely in south-eastern Australia over the coming decades (see Table 1.3.1).¹²
3. Bushfires can damage civil infrastructure and the built environment in many ways, in addition to burning down homes and buildings:
 - For example, bushfires can damage above-ground fixed line transmission and distribution infrastructure and services,¹³ as was the case with the 2007 Victorian bushfires, which halted a third of Victoria's electricity supply and cost the Victorian economy AUD\$500 million.¹⁴
 - Bushfires can also lead to temporary closure of coal power plants if their associated coal mine ignites due to ember attack.¹⁵
 - As a final example, bushfires burn vegetation enabling greater levels of soil erosion, which can then lead to degradation of dam water quality, as was the case with the 2003 Canberra bushfires. The silt and ash of the surrounding forests made the dam water turbid, so Canberra's water supply was adversely affected.
4. Historically, the aspect of the built environment to which bushfires have done most of their damage has been houses and other buildings. During bushfires, structures are ignited by either direct flame contact, radiant heat from nearby flames, wind-blown burning debris/embers, or some combination thereof.¹⁶ Research shows that embers and burning debris are the major

⁶ In Australia, high fire danger generally speaking occurs when during droughts or dry summer periods, wind blows from the centre of the continent bringing hot, dry air: e.g. In south-west Western Australia, it is easterly/north-easterly, in Queensland it is west/south-west. In Northern Territory it is southerly.

⁷ Hennessy, K. (2005) *Climate Change and Fire-Weather Risk in South-Eastern Australia*, Nature Conservation Council of NSW, p1, http://nccnsw.org.au/index.php?option=com_content&task=view&id=1970&Itemid=971, accessed 2 November 2008.

⁸ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'North America', pp617-652.

⁹ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'Europe', pp541-580.

¹⁰ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'Asia', pp469-506.

¹¹ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

¹² Lucas, C., Hennessy, K., Mills, G. and Bathols, J. (2007) *Bushfire Weather in Southeast Australia: Recent Trends and Projected Climate Change Impacts*, Bushfire Cooperative Research Centre, pp2-3, www.climateinstitute.org.au/images/stories/bushfire/fullreport.pdf, accessed 4 November 2008.

¹³ Holper, P., Lucy, S., Nolan, M., Senese, C. and Hennessy, K. (2007) *Infrastructure and Climate Change Risk Assessment for Victoria*, Report to the Victorian Government, CSIRO, www.climatechange.vic.gov.au/greenhouse/wcmn302.nsf/childdocs/-FD823E8029AD4348CA25702D00156EF3-8F8E3FC6F317A487CA25702E00017C1E?open, accessed 21 October 2008.

¹⁴ The Nous Group (2007) *16 January 2007 electricity supply interruptions in Victoria: What happened and why and Opportunities and recommendations*, Executive summary, The Nous Group, p20, [www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/\\$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf](http://www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf), accessed 21 October 2008.

¹⁵ Holper, P., Lucy, S., Nolan, M., Senese, C. and Hennessy, K. (2007) *Infrastructure and Climate Change Risk Assessment for Victoria*, Report to the Victorian Government, CSIRO, www.climatechange.vic.gov.au/greenhouse/wcmn302.nsf/childdocs/-FD823E8029AD4348CA25702D00156EF3-8F8E3FC6F317A487CA25702E00017C1E?open, accessed 2 November 2008.

¹⁶ Bush Fire Info.com (undated) 'Bushfire Basics: how do burn homes burn down?', www.bushfireinfo.com/bitweaver/pages/How%20do%20homes%20burn%20down, accessed 4 November 2008; Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, p4.

means of ignition.¹⁷ A crucial factor in preventing bushfire damage is to prevent the fire from entering areas of the built environment, primarily by ensuring safe distance between unmanaged vegetation and buildings. A distance of 100m is required to reduce ember attack to an acceptable level. Distances of between 30m and 100m are usually sufficient to mitigate the effects of direct flame contact and radiant heat, depending on the circumstances.¹⁸ This was the established consensus before the February 2009 Victorian bushfires. Given the unknown behaviours (both physical and social) that led to the unprecedented loss of life in the recent 2009 Victorian bushfires, the recommended cleared distance between vegetation and buildings may change. Findings from these recent Victorian fires will be used to further inform the recommendations for setback and fuel reduced zones.

5. Managed vegetation, ground cover, and construction elements including other houses are all potential sources of embers, which is why losses were experienced 700m into the Canberra urban boundary during the 2003 Canberra fires. However, there are ways to decrease a building's flammability. Ember resistant building design and thoughtful urban design are necessary to limit the effect of fire and ember attack for many hundreds of metres into an urban interface.
6. In the past, it was assumed that when bushfires entered residential areas, they moved so fast that buildings in the path ignited explosively and burned rapidly. However, studies show that after a bushfire, there are often houses that have escaped damage while neighbouring houses are destroyed. The reason, as research has shown, is that 90 per cent of buildings survive the fire front passing, but are then ignited by embers catching on combustible components such as wooden window frames, curtains, furniture and floorboards, and burn over a few hours.¹⁹ Burning debris can enter the roof and under floor spaces, not only through window frames. Also, radiant heat from nearby burning fuel can lead to broken windows.
7. The first comprehensive study in Australia to show how buildings are affected in bushfires was by the scientist George Barrow²⁰ following the 1944 bushfire at Beaumaris on the outskirts of Melbourne. The bushfire burnt 280 hectares of land containing 118 houses. Fifty-eight houses were destroyed and eight were damaged. Barrow, performed a study of the affected houses to determine the extent to which their construction influenced, either positively or negatively, their resistance to external fire hazards. Barrow found that, *'in a fire of the type that swept Beaumaris, the chances of a house surviving are determined more by the nature of the surroundings and the details of construction than by the materials used in the walls. With two exceptions, all the really destructive fires started inside the houses, i.e., in the roof space, in rooms, or under the floors,*

¹⁷ Chen K. & J. McAneney (2004) Quantifying bushfire penetration into urban areas in Australia , *Geophysical Research Letters*, Vol. 31, L12212, doi:10.1029/2004GL020244, 2004

¹⁸ Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, pp17,19.

¹⁹ Leonard, J. (undated) 'Protecting Your Home from Bushfire', CSIRO audio transcript, www.csiro.au/csiro/content/file/pfju...html, accessed 2 November 2008; Leonard, J.E. and McArthur, N.A. (1999) 'A History of Research into Building Performance in Australian Bushfires', Conference Proceedings, Australian Bushfire Conference, Albury, July 1999, www.csu.edu.au/special/bushfire99/papers/leonard/, accessed 2 November 2008; Ramsay and McArthur (1995) cited in Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, p4.

²⁰ Leonard, J.E. and McArthur, N.A. (1999) 'A History of Research into Building Performance in Australian Bushfires', Conference Proceedings, Australian Bushfire Conference, Albury, July 1999, www.csu.edu.au/special/bushfire99/papers/leonard/, accessed 2 November 2008.

*the immediate cause of ignition in such cases being the entrance of flame, sparks and burning debris through openings such as ventilators, eaves and windows.*²¹

8. Barrow suggested that simple precautions would greatly increase the resistance of a house to fire for little or no increase in cost. These precautions include enclosing the underfloor space, covering ventilators with metal mesh, enclosing the eaves, and keeping fuel stacks (such as fire wood piles), trees and shrubs away from walls - all of which are likely to be far more effective than using non-combustible materials for walls. The suggestions by Barrow and the scientists behind studies of subsequent bushfires²² have helped identify a wide range of cost effective prevention strategies. General prevention strategies include:
- *Design of urban and rural town development:* There are two key strategies. Firstly, setting developments back sufficiently from fire-prone vegetation (typically 30-100m in Australia²³). As noted above, this is being reviewed by researchers following the findings from investigations of the 2009 Victorian bushfires. Secondly, managing the vegetation, forests and grasslands near developments, including periodically reducing the amount of vegetation contributing to ground, elevated, bark and canopy fuel, in order to reduce the fuel load.
 - *Fuel reduction programs:* The magnitude of a building's exposure to flame contact and radiant heat is also influenced by fuel load, landscape and features of surrounding buildings.²⁴ It is particularly important to reduce the fuel load in a building's surroundings.²⁵ CSIRO's studies of the 2003 Canberra bushfire found that the presence or absence of ground fuel in residential yards, front and back, was a factor in whether houses were damaged and whether the fire spread.²⁶
 - *Specific prevention strategies for houses and buildings:* These include ember proofing, protecting and securing windows, and using wire protectors for gutters to prevent leaf build up. It also involves choices of materials for and design of external structures – fences, decks, outdoor stairs – which are close to the house, ensuring that they will not provide catching points for burning debris. As with the houses, these structures may ignite during or after the fire front has passed.
9. Given the nature and extent of the risks faced by householders in bushfire prone areas, it is important that appropriate levels of bushfire protection and survival measures are included for buildings in these bush fire prone areas. However, due to a range of market failures such as imperfect individual responses, imperfect industry responses, insurance market limitations, and unpriced negative externalities, these bushfire prevention strategies for buildings need to be made mandatory in the building codes.²⁷ In March 2009, the Australian Building Codes Board published a Final Regulatory Impact Statement which analyses the likely impact of a proposal to

²¹ Barrow, G.J. (1945) 'A survey of houses affected in the Beaumaris fire', *Journal of CSIR*, vol 18, p27.

²² Leonard, J.E. and McArthur, N.A. (1999) 'A History of Research into Building Performance in Australian Bushfires', Conference Proceedings, Australian Bushfire Conference, Albury, July 1999, www.csu.edu.au/special/bushfire99/papers/leonard/, accessed 2 November 2008.

²³ Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, pp17,19.

²⁴ Ellis, P. and Sullivan, A. (2004) *The Significance of Suburban Fuels*, Client Report for Fire Management Unit, Department of Urban Services, ACT Government, CSIRO.

²⁵ Leonard, J.E. & Bianchi, R. (2004), Bushfire at the urban interface: Lessons from the Otway fires (1983), Sydney fires (1994) and Canberra fires (2003). Bianchi, R. and J. Leonard (2005), 'Investigation of bushfire attack mechanisms resulting in house loss in the ACT bushfire 2003', Bushfire CRC Report.

²⁶ Ellis, P. and Sullivan, A. (2003) *Assessment of ACT Suburban House Loss from the 18 January 2003 Bushfires*, Client Report No. 1326, CSIRO.

²⁷ Australian Building Codes Board (2009) *Final Regulatory Impact Statement – Construction in bushfire prone areas*. ABCB. <http://www.abcb.gov.au/index.cfm?objectID=D534EEF8-C439-B4AA-43876271DF9D1E09> accessed 9 March 2009

revise existing BCA requirements for construction in bushfire prone areas through the adoption of a revised version of Australian Standard AS 3959 – which governs construction of buildings in bushfire prone areas (the Standard).²⁸ Under the proposed revision of Australian Standard AS 3959, homes would be rated by a six-level scale of risk of bushfire attack. As the Australian Building Codes Board (ABCB) report explains “*Homes at highest risk will be required to be built with concrete slabs and the roof, exterior walls and decking made of non-combustible materials. Metal shutters and down pipes will replace plastic fittings and door frames must be made from fire-resistant timber. These revisions will apply to all new homes, rebuilds and additions.*”²⁹ The Victorian government announced in early March 2009, that it would adopt these new recommendations immediately to guide all rebuilding efforts from the Victorian bushfires.

10. All aspects of these bushfire prevention strategies will now be reviewed by the 2009 Victorian Royal Commission into the 2009 Victorian bushfires. To assist this review much of the rest of this lecture provides an overview of the wide range of ways buildings and infrastructure can be designed and retrofitted to reduce risks of damage from bushfires. These general prevention strategies plus others to better protect infrastructure and water quality are discussed in detail next Brief Background Information section.

Brief Background Information

Understanding the Benefits, Risks and Costs of Bushfires

Bushfires are a natural phenomenon in many parts of the world including the Mediterranean basin (Portugal, Spain, France, Greece, etc), Russia and China. In short, anywhere there is fuel and periodic dry conditions, bushfires have the potential to occur. In these parts of the world, plants have evolved and adapted to bushfires. In Australia, the flora and fauna has evolved with bushfires and has characteristics which enable the spread of fire, for example:

- Eucalypt litter is resistant and takes a long time to decay, resulting initially in a steady build up, then a longer-term stable amount, of fuel material to propel the next fire.
- The bark of many species is loosely attached to the trees and highly flammable, providing ready fuel on the ground.

As CSIRO explains,

*If we want to maintain the biodiversity in our native areas we have to accept that fire is a process that must be used to manage our native bushland. We need to accept fire for what it is – an ecological process that is a natural part of the renewal of our flora and fauna. Nothing else can replace it completely. Nothing else produces the chemicals in the ash to stimulate new growth – or in the smoke to stimulate the flowering and regeneration of particular species. Nothing else produces the heat pulse that removes growth-inhibiting toxins in the litter, or opens tightly-closed fruits to release new seed, or penetrates deep into the soil to stimulate the germination of long-buried seed. Nothing else produces the succession of plant development to which our native fauna have adapted to meet their requirements for food, shelter and reproduction.*³⁰

²⁸ Ibid

²⁹ Ibid

³⁰ CSIRO (undated) ‘Fact Sheet: Bushfire in Australia’, www.csiro.au/resources/BushfireInAustralia.html, accessed 14 November 2008.

Thus there are significant benefits to the Australian landscapes from fire. The flora and fauna in west coast USA has also evolved with bushfires. For instance, many plants in California's drier landscapes have evolved traits that allow them to regenerate after a fire. After a bushfire, the relatively barren and charred California landscapes burst into life and the landscape is covered with green shoots growing from charred stumps and with annual wildflowers. Some Californian plants have extensive root systems so they can re-sprout from above-ground parts that were damaged but not killed. Some US cone-bearing trees require fire to reproduce from seed.

But now that Australia, California, and other parts of the world have significant human settlements, and agriculture and forestry industries, uncontrolled bushfires can result in significant and costly damage and even loss of life. One of the most costly bushfires ever was in Greece, where bushfires raged in the summer of 2007 destroying forests, olive plantations, vineyards and homes. Over 70 people were killed. The estimated cost was €2 billion.³¹ If we consider California, the most costly fire in recent history in terms of quantifiable economic costs was the 1991 bushfire which swept through Oakland and other parts of Alameda County. This bushfire cost US\$1.7 billion at the time and destroyed more than 3,000 homes. The next two most expensive Californian fires occurred in late October and early November 2003 in San Diego County and San Bernardino County. These cost US\$1.1 billion and US\$1 billion in damages respectively.

In Australia bushfire disasters have also led to significant costs. The impacts of bushfires classed as 'disasters' (caused damage greater than \$10 million) between 1967 and 1999 are quantified by a report by the Bureau of Transport Economics.³² During the period, Australia experienced 23 such bushfires. In fact, bushfires, in general, are the worst type of natural disaster for human impacts, having claimed 39 per cent (223 people) of the total deaths and 57 per cent (4185 people) of the total injuries for all natural disasters, which is equivalent to an estimated cost of AUD\$654 million (48 per cent of the total estimated equivalent cost).³³ Research by John McAneney from Risk Frontiers, which takes into account a greater number of bushfire events, estimated that on average 83 houses are lost annually and the annual average damage, which is made up of current asset values for home and contents, is valued at \$33.5m (2003 dollars).³⁴ When the annual average damage is adjusted for the annual volatility of losses³⁵, the national bushfire risk premium per annum amounts to \$62.4m, which is \$71.6m in current value.³⁶ The costs of the Ash Wednesday bushfires have been costed at AUD\$967 million. The damages from the 1939 Black Friday bushfires have been costed at AUD\$750 million. Total cost of all bushfires during the period contributes 7 per cent (AUD\$2.5 billion, not necessarily including forestry losses) to the total costs of all natural disasters. Bushfires are the fourth most frequent type of natural disaster in Australia and the third most frequent type of natural event causing damage less than \$10 million (out of 6 types). There have been more bushfire disasters since the Bureau's report. For example, the 2003 Canberra bushfires caused 4 deaths and over AUD\$300 million damage.³⁷ As mentioned above, bushfires can also

³¹ Papachristou, H. (2007) *Greek August Wildfire Damage Seen at EU2 Billion, Minister Says*, Bloomberg, www.bloomberg.com, accessed 21 November 2008.

³² Bureau of Transport Economics (2001) *Economic Costs of Natural Disasters in Australia*, Report 103, Commonwealth of Australia, Canberra, pp35,44,46,48,52,109, www.btre.gov.au/info.aspx?ResourceId=199&NodeId=58, accessed 3 November 2008.

³³ The Bureau notes that these figures may be influenced by only accounting for disaster bushfires.

³⁴ K. John McAneney, 'Australian Bushfire: Quantifying and Pricing the Risk to Residential Properties', Risk Frontiers, Macquarie University, NSW

³⁵ This takes into account 1 in 100 year event that equates to a likely loss of AU\$0.7 billion and 1 in 250 year event that equates to a likely loss of AU\$1.1 billion

³⁶ This has been calculated by taking the 2003 value of \$62.4 million to the value it would be in 2008 using the consumer price index. http://www.rba.gov.au/Statistics/AlphaListing/alpha_listing_c.html

³⁷ Australian Institute of Criminology, Bushfire CRC and ACT Department of Justice and Community Safety (2004) *The Cost of Bushfires*, Bushfire Arson Bulletin, no 2, www.aic.gov.au/publications/bfab/bfab002.html, accessed 6 November 2008.

incapacitate electricity power lines.³⁸ Even those uncontrolled intense bushfires that do not cause property damage can have considerable uninsured costs, or externalities, including fire fighting costs, environmental impacts, wildlife loss, disruptions to economic and social activities and the effects of smoke on urban environments.³⁹ There are grounds for concern that the risks and costs of uncontrolled and intense bushfires could increase with unmitigated climate change. The insurance industry bears significant risk of bushfire events. Leonard and Bowditch⁴⁰ found that the insured losses in the Canberra fires in 2003 were comparable to the losses on 1983 Ash Wednesday, with approximately 516 houses destroyed. While fewer houses were lost in the Canberra fires, there has been a considerable increase in the asset value at the urban interface that needs to be considered for future policy. Insured losses from bushfires have average out to \$29.4 million per annum but are likely to increase.⁴¹

The Progression of Bushfire Risks due to Climate Change

There are a range of factors which have led to an increase in the prevalence of bushfires over the last century. For instance, an increase in global human population has resulted in more fires being started deliberately or accidentally. As the IPCC reported in its 4th assessment,⁴² a range of studies show that climate change is a factor in an increase in bushfires in North America⁴³ and Asia.⁴⁴

Since 1980, an average of 22,000 km²/yr has burned in U.S. wildfires, almost twice the 1920 to 1980 average of 13,000 km²/yr.⁴⁵ The forested area burned in the western U.S. from 1987 to 2003 is 6.7 times the area burned from 1970 to 1986.⁴⁶ In Canada, burned area has exceeded 60,000 km²/yr three times since 1990, twice the long-term average.⁴⁷

Climate change directly affects two factors - weather and the dryness of fuels - in such a way that it increases the probability of a higher frequency and higher intensity of bushfires on average in the future. Climate change is expected to further increase the risks of more frequent and intense bushfires in many parts of the world. The higher risk of bushfires over the next century is largely due to the following specific changes to climate:

- *The average weather becoming warmer and drier in already fire prone regions of the world:* In Australia, annual average temperatures over most of Australia are likely to increase by 0.1-1.5°C by 2020, 0.3-4.0°C by 2050 and 0.4-8.0°C by 2080, compared to 1990 temperatures.⁴⁸ Average annual rainfall is expected to decrease in southern, western coast and subtropical Australia by

³⁸ The Nous Group (2007) *16 January 2007 electricity supply interruptions in Victoria: What happened and why and Opportunities and Recommendations*, Executive summary, The Nous Group, p20, [www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/\\$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf](http://www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf), accessed 21 October 2008.

³⁹ Australian Institute of Criminology, Bushfire CRC and ACT Department of Justice and Community Safety (2004) *The Cost of Bushfires*, BushFIRE Arson Bulletin, no 2, www.aic.gov.au/publications/bfab/bfab002.html, accessed 6 November 2008.

⁴⁰ Leonard J.E. & P.A. Bowditch (2009) *Findings of Studies of Houses Damaged by Bushfire in Australia*, CSIRO Manufacturing & Infrastructure Technology, Melbourne, Victoria, Australia.

⁴¹ Dunn A. (2003) *Economic Impact of Bushfire on the Community*. Timber Development Association (NSW).

⁴² IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

⁴³ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'North America', pp617-652.

⁴⁴ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'Asia', pp469-506.

⁴⁵ Schoennagel, T., Veblen, T.T. and Romme, W.H. (2004) 'The interaction of fire, fuels, and climate across Rocky Mountain Forests', *BioScience*, vol 54, pp661-676.

⁴⁶ Westerling, A., Hidalgo, H., Cayan, D. and Swetnam, T. (2006) 'Warming and Earlier Spring Increase in Western U.S. Forest Wildfire Activity'. *Science*, vol 313, pp940-943.

⁴⁷ Stocks, B.J. *et al* (2002) 'Large forest fires in Canada, 1959-1997', *Journal of Geophysical Research*, vol 107.

⁴⁸ Suppiah *et al* (2007) cited in IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, see 'Australia and New Zealand', p515, www.ipcc.ch/ipccreports/ar4-wg2.htm, accessed 2 November 2008.

up to 15 per cent by 2020, up to 40 per cent by 2050 and up to 80 per cent by 2080.⁴⁹ And Southern and western coast Australia is likely to get drier than subtropical Australia.

- *The forest fire season is likely to lengthen, and the area subject to high fire danger is likely to increase significantly due to climate change:*⁵⁰ A warming, drier climate encourages wildfires through a longer summer period that dries fuels, promoting easier ignition and faster spread.⁵¹ In Canada, warmer May to August temperatures since 1970 are highly correlated with an increase in the amount of area burned.⁵² The IPCC predicts that by 2100 the period of the year for Canada where there is a high fire ignition risk will increase by 10-30 per cent, and could result in increased area burned of 74-118 per cent. The forest area burned each year has increased overall significantly between 1920 to 2000 (see Figure 1.3.1)

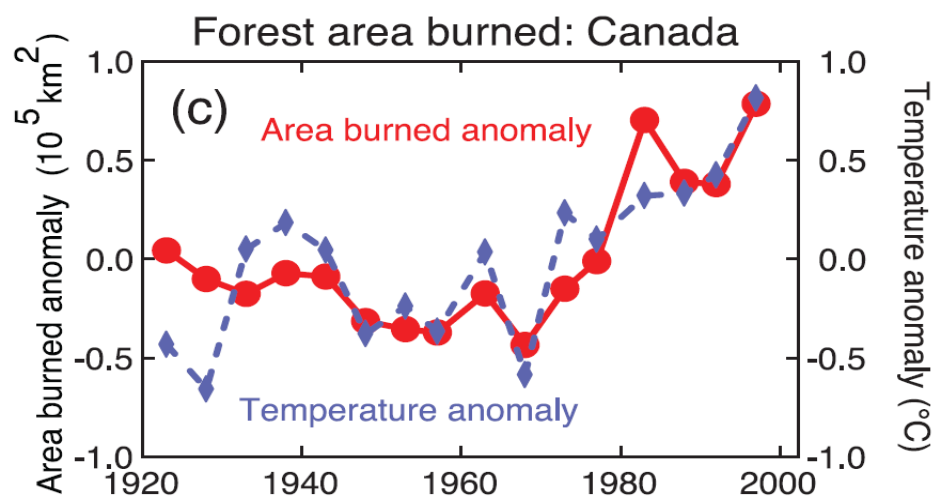


Figure 1.3.1 Forest Area Burned in Canada from 1920 to 2000

Source: Gillett, N. (2004)⁵³

- *An increase in more extreme high temperature and high fire danger days over the next century worldwide:* The McArthur Forest Fire Danger Index (FFDI) is internationally recognised but it is only used in the eastern and southern states of Australia⁵⁴ to assess whether or not there is a low, medium, or high risk of bushfires occurring. A higher FFDI indicates that the chance of fires starting is higher, and once ignited, the fires will spread more quickly, they will be more intense and more difficult to suppress. A fire danger rating of between 12-25 on the Forest Fire Danger Index (FFDI) is considered a "high" degree of danger, while if the danger rating is over 50 it is considered an "Extreme" fire danger day. In Victoria, on 7 February 2009, the FFDI reached over 120. The FFDI was also over 100 for the 2003 Canberra bushfires. (Figure 1.3.2)

⁴⁹ Smith (2004) cited in IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, see 'Australia and New Zealand', p515, www.ipcc.ch/ipccreports/ar4-wg2.htm, accessed 2 November 2008.

⁵⁰ IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'North America', pp617-652, www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter14.pdf, accessed 2 November 2008.

⁵¹ Running, S.W. (2006) 'Is global warming causing more larger wildfires?', *Science*, vol 313, pp927-928.

⁵² Gillett, N.P., Weaver, A.J., Zwiers, F.W. and Flannigan, M.D. (2004) 'Detecting the effect of climate change on Canadian forest fires', *Geophysical Research Letters*, vol 31.

⁵³ Ibid

⁵⁴ Western Australia uses the Fire Behaviour Tables rather than the Forest Fire Danger Index.

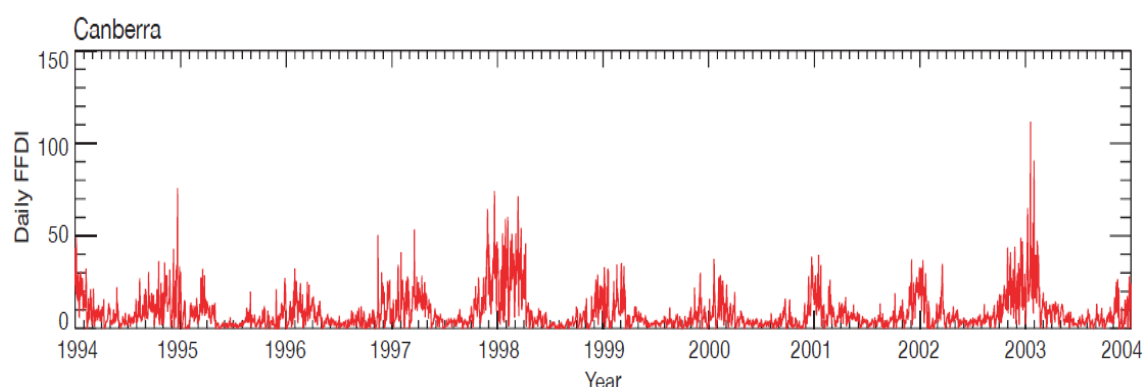


Figure 1.3.2: Forest Fire Danger Index (FFDI) for Canberra, reconstructed from daily temperature, humidity, wind and rainfall data from 1994-2004.

(Lucas et al. 2007⁵⁵).

CSIRO studies assessing the impact of climate change on the risks of bushfires have found that the number of days with very high and extreme FFDI ratings will increase by 4-25 per cent by 2020 and 15-70 per cent by 2050.⁵⁶ (Table 1.3.1) For example, CSIRO studies predict that Canberra will have an annual average of 25.6-28.6 very high or extreme fire danger days by 2020 and 27.9-38.3 days by 2050 due to climate change, compared with a present average of 23.1 days.⁵⁷

Table 1.3.1 Per cent changes in the number of days with ‘very high’, ‘extreme’, ‘very extreme’, and ‘catastrophic’ fire days due to weather in 2020 and 2050, compared to 1990

| Forest Fire Danger Index Category | 2020 | | 2050 | |
|-----------------------------------|----------------------------|---|---|--|
| | Low global Warming (0.4°C) | High global Warming (1°C) | Low global Warming (0.7°C) | High global Warming (2.9°C) |
| Very High | + 2-13% | + 10-30% | + 5-23% | + 20-100% |
| Extreme | + 5-25% | + 15-65% | + 10-50% | + 100-300% |
| Very Extreme | Little change in frequency | + 100% at many sites | + 100% at many sites | + 400-500% |
| Catastrophic | Little change in frequency | Number of affected areas increase by 160%, most with return periods of 16 years or less (frequency) | Number of affected areas increase by 160%, most with return periods of 16 years or less (frequency) | Number of affected areas increase by 180%, most with return periods of 8 years or less (frequency) |

⁵⁵ Lucas, C., Hennessy, K., Mills, G. and Bathols, J. (2007) *Bushfire Weather in Southeast Australia: Recent Trends and Projected Climate Change Impacts*, Bushfire Cooperative Research Centre, pp2-3, www.climateinstitute.org.au/images/stories/bushfire/fullreport.pdf, accessed 4 November 2008

⁵⁶ Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R. and Ricketts, J. (2006) *Climate Change Impacts on Fire-Weather in South-East Australia, Consultancy Report for the New South Wales Greenhouse Office, Victorian Department of Sustainability and Environment, Tasmanian Department of Primary Industries, Water and Environment, and the Australian Greenhouse Office*. CSIRO Atmospheric Research and Australian Government Bureau of Meteorology.

⁵⁷ Ibid.

Source: Lucas, C., Hennessy, K., Mills, G. and Bathols, J. (2007)⁵⁸

These results are consistent with those reviewed and presented by Geoff Cary in his 2002 review⁵⁹ of the effect that climate change may have on bushfires in the Australian Capital Territory region. He concluded that due to climate change, an increase in fire danger in Australia is likely to be associated with a reduced interval between fires, increased fire intensity, faster fire spread and a decrease in fire extinguishments.⁶⁰

Adapting the Built Environment and Infrastructure to the Risks from Bushfires

Bushfires can damage infrastructure and the built environment in many ways, in addition to burning down homes and buildings. We now consider strategies to adapt to, or reduce the risks of, damage from bushfires to buildings, the built environment and infrastructure.

The Causes of Bushfire Damage to Houses and Other Buildings

Bushfires are naturally occurring events in many parts of the world that experience a generally hot and periodically dry climate. Therefore, historically Europeans who migrated to Australia, USA and Southern Africa and built houses in bushfire prone regions assumed that, if a bushfire was to pass through, their houses were likely to be destroyed and that little could be done to prevent it.

This attitude, as Justin Leonard and Neville McArthur summarise,⁶¹ continued until a Royal Commission in Australia produced a set of recommendations and suggestions for defending communities following the 1939 Victoria, Australia 'Black Friday' bushfires. However, the implementation of these recommendations and suggestions was delayed by World War II until after major 1943 and 1944 bushfires. It was after one of these, the 1944 bushfire at Beaumaris on the outskirts of Melbourne, that scientist George Barrow performed the first comprehensive study in Australia to scientifically identify construction methods which influence a house's resistance to external fire hazards. Since the Royal Commission and Barrow's study, many other major Australian bushfires were investigated with the aims of further developing the understanding of house destruction and establishing strategies to prevent bushfire damage to houses and other buildings in the future (see Table 1.3.2).

Table 1.3.2 Australian bushfires involving major house loss, since 1939

| Date | Location | House loss | Research into building loss |
|--------------|-------------------------|-------------|---|
| January 1939 | Victoria | 1300* | Nil |
| January 1944 | Victoria (Beaumaris) | 927 (58) | G. Barrow, CSIR, selective survey ⁶² |
| December | Leura, NSW | 123 | Nil |

⁵⁸ Lucas, C., Hennessy, K., Mills, G. and Bathols, J. (2007) *Bushfire Weather in Southeast Australia: Recent Trends and Projected Climate Change Impacts*, Bushfire Cooperative Research Centre, pp2-3, www.climateinstitute.org.au/images/stories/bushfire/fullreport.pdf, accessed 4 November 2008.

⁵⁹ Cary, G.J. (2002) 'Importance of changing climate for fire regimes in Australia', in Bradstock R.A., Williams, J.E. and Gill A.M. (eds), *Flammable Australia: The Fire Regimes and Biodiversity of A Continent*, Cambridge University Press, Cambridge, pp26-46.

⁶⁰ Ibid.

⁶¹ Leonard, J.E. and McArthur, N.A. (1999) 'A History of Research into Building Performance in Australian Bushfires', Conference Proceedings, Australian Bushfire Conference, Albury, July 1999, www.csu.edu.au/special/bushfire99/papers/leonard/, accessed 2 November 2008.

⁶² Barrow, G.J. (1945) 'A survey of houses affected in the Beaumaris fire', *J. CSIR*, vol 18, p27.

| | | | |
|---------------|---|------------------------|--|
| 1957 | | | |
| January 1961 | Dwellingup, WA | 132 | A. G. McArthur, general survey ⁶³ |
| January 1962 | Dandenong Ranges, Victoria | 454 | Nil |
| February 1967 | Hobart | 1300+ | Forest and Timber Bureau, questionnaire. ⁶⁴ |
| 1967/68 | Dandenong Ranges, Victoria | 53 | |
| November 1968 | Blue Mountains | Some | R. Cole, CEBS, selective survey ⁶⁵ |
| January 1969 | Lara | 251* | Nil |
| February 1977 | Western District, Victoria | 116 | CSIRO/CFA, rate of spread only ⁶⁶ |
| January 1983 | Victoria, SA (Mount Macedon, Victoria) (Otway Ranges, Victoria) | 1511 (234) (729) | A. Wilson, in-depth survey ⁶⁷ CSIRO, in-depth survey ⁶⁸ |
| January 1994 | Sydney and surrounds | 202 | CSIRO, in-depth survey ⁶⁹ |
| January 2009 | Victoria | | |

* Structures; not necessarily houses.

Source: Leonard, J.E. and McArthur, N.A. (1999)⁷⁰

Prior to this research it was assumed that, when bushfires approached residential areas, they move so fast and are so intense that buildings in the path would ignite explosively and burn rapidly. Yet, after a bushfire, there are often houses that escape damage while neighbouring houses are destroyed. Research has shown that over 90 per cent of buildings are lost without any direct flame contact or intense radiant heat from the fire front itself. These houses are ignited either by direct ember attack or from flames and radiant heat from other items on or around the structure in the hours following flame front arrival.⁷¹ As CSIRO explains,

⁶³ Luke, R.H. and McArthur, A.G. (1977) *Bushfires in Australia*, Australian Government Publishing Service, Canberra.

⁶⁴ McArthur, A.G. (1968) 'The Tasmanian bushfires of 7th February 1967, and associated fire behaviour characteristics', Forest and Timber Bureau, 2nd Australian National Conference on Fire, 6–8 August, University of Sydney, Sydney.

⁶⁵ Cole, R.E. (1983) *House Exposed to Bushfires. Technical Record 390 (L)*, Commonwealth Experimental Building Station, Sydney.

⁶⁶ McArthur, A.G. (1982) 'The Fires of 12 February 1977 in the Western District of Victoria'. CSIRO: Melbourne.

⁶⁷ Wilson, A.A.G. (1984) *Assessing the Bushfire Hazard of Houses: A Quantitative Approach*, Technical Paper No. 6, National Centre for Rural Fire Research, Chisholm Institute of Technology, Melbourne.

⁶⁸ Ramsay, G.C., McArthur, N.A. and Dowling, V.P. (1986) 'Building survival in bushfires', 4th Australian National Biennial Conference, The Institution of Fire Engineers, Perth, 21–24 October; Ramsay, G.C., McArthur, N.A. and Dowling, V.P. (1987) 'Preliminary results from an examination of house survival in the 16 February 1983 bushfires in Australia', *Fire & Materials*, vol 11, pp49–51.

⁶⁹ Ramsay, G.C. and McArthur, N.A. (1995) 'Building in the urban interface: lessons from the January 1994 Sydney bushfires', Bushfires 95 Conference, Hobart, Tasmania.

⁷⁰ Luke, R.H. and McArthur, A.G. (1977), Foster, E. (1976), McArthur, A.G. (1982), Country Fire Authority (1983) and CSIRO on-ground surveys cited in Leonard, J.E. and McArthur, N.A. (1999) 'A History of Research into Building Performance in Australian Bushfires', Conference Proceedings, Australian Bushfire Conference, Albury, July 1999, www.csu.edu.au/special/bushfire99/papers/leonard/, accessed 2 November 2008.

⁷¹ Bush Fire Info.com (undated) 'Bushfire Basics: How do homes burn down?', www.bushfireinfo.com/bitweaver/pages/How%20do%20homes%20burn%20down, accessed 4 November 2008; Leonard, J. (undated) 'Protecting Your Home from Bushfire', CSIRO audio transcript, www.csiro.au/csiro/content/file/pfju...html, accessed 2 November 2008; Leonard, J.E. and McArthur, N.A. (1999) 'A History of Research into Building Performance in Australian Bushfires', Conference

The majority of houses destroyed in bush fires actually survive the passage of the fire front, only to burn down during the next few hours due to the fire spreading from ignitions caused by windborne burning debris. Whilst direct flame contact and radiant heat also play a part in the ignition and destruction of buildings, these mechanisms are generally only significant during the few minutes it takes for the fire front to pass. Showers of burning debris, on the other hand, may attack a building for some time before the fire front arrives, during the passage of the fire front and for several hours after the fire front has passed. This long duration of attack, to a large extent, explains why burning debris is a major cause of ignition of buildings.⁷²

Such research has led to the establishment of a number of strategies to minimise bushfire damage to houses and other buildings, as discussed next.

Reducing the Risks and Vulnerabilities of the Built Environment to Bushfires

As the world's climate progressively changes this century, many regions not traditionally at high bushfire risk may become increasingly so, especially if bushfire prevention strategies are not implemented in the planning and development of cities, towns, estates and individual properties.

Reducing Bushfire Risks to, and Vulnerabilities of, Cities, Towns and Estates

There are two key strategies to prevent bushfire damage to houses and other buildings:

- Prevent the fire from entering residential areas, primarily by ensuring a safe distance between vegetation and buildings. Various models have predicted this distance to be between 30m and 100m, more commonly near the lower bound.⁷³ As discussed in the key learning points, 100m required to reduce ember attack to a statistically acceptable level. Between 30m and 100m is enough to reduce the effects of direct flame contact and radiant heat.⁷⁴ This is the current established consensus based on a significant body of research before the 2009 Victorian bushfires. Given the unknown behaviours (both physical and social) that led to the unprecedented loss of life in the recent 2009 Victorian bushfires, the recommended distance between vegetation/forests and the built environment may change. Findings from these recent Victorian fires will be used to further inform the recommendations for setback and fuel reduced zones.
- Reduce the potential for embers to ignite buildings or material close to buildings. This is achieved by managing the vegetation, forests and grasslands near developments, including periodically reducing the ground fuel. Reducing the fuel load helps to reduce the potential for embers

Proceedings, Australian Bushfire Conference, Albury, July 1999, www.csu.edu.au/special/bushfire99/papers/leonard/, accessed 2 November 2008; Ramsay and McArthur (1995) cited in Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, p4.

⁷² Bush Fire Info.com (undated) 'Bushfire Basics: How do homes burn down?', www.bushfireinfo.com/bitweaver/pages/How%20do%20homes%20burn%20down, accessed 4 November 2008

⁷³ Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, pp17,19.

⁷⁴ Ellis, P. (2000) *Review of Current Methodology of Assessment of Bushfire Hazard and the Proscription of Appropriate Separation Distances and Building Standards. The Development of a Robust Model to Achieve this for Different Vegetation Types*, A report for the NSW Rural Fire Service, Client Report 901, CSIRO, pp17,19.

catching fire in residential areas as fuel load, landscape and features of surrounding buildings influence the magnitude of a building's exposure to flame contact and radiant heat.⁷⁵

Once bushfires enter residential areas, a range of measures to reduce the risk of buildings being damaged or destroyed exists.

Reducing Bushfire Risks to, and Vulnerabilities of, Individual Properties

The risks to, and vulnerabilities of, individual properties and houses can be reduced by first understanding the characteristics of the surroundings and the ways in which fire can reach the house, and then applying the appropriate preventative building strategies. Builders and housing developers are required to follow this process in accordance with Australian Standard AS 3959-1999.

- *Construction of Buildings in Bushfire Prone Areas* (the Standard),⁷⁶ and its amendments Amdt 1-2000⁷⁷, Amdt 2-2001.⁷⁸ This standard applies to the construction of new buildings and certain renovations and extensions. In the standard, the bushfire risk category is determined by assessing the class and proximity of vegetation, and the slope of the land in the surroundings (see Table 1.3.3). Then the estimated risk category is used to determine the minimum level of construction (see Table 1.3.4) and building features (see below for a selection of building features) required.

The process is similar in many jurisdictions. In California, builders and housing developers are required to follow the process set out in the Wildland-Urban Interface Building Code,⁷⁹ which identifies a number of Fire Hazard Severity Zones and the minimum building features that new homes in those zones are required to have.

Table 1.3.3 Determination of category of bushfire risk for a site

| Distance from Vegetation | <15 m | | 15-40 m | | >40-100 m | | >100 m | |
|-------------------------------|-------------------------------|---------|---------|------|-----------|--------|--------|------|
| | >10° | ≤10° | >10° | ≤10° | >10° | ≤10° | >10° | ≤10° |
| Predominant vegetation class | Categories of bushfire attack | | | | | | | |
| Forest | Extreme | Extreme | High | High | Medium | Medium | Low | Low |
| Woodland | Extreme | Extreme | High | High | Medium | Low | Low | Low |
| Tall shrubs | Extreme | Extreme | High | High | Medium | Low | Low | Low |
| Low shrubs | High | Medium | Medium | Low | Low | Low | Low | Low |
| Open woodland/ open shrubland | Medium | Medium | Low | Low | Low | Low | Low | Low |
| Grassland | Medium | Low | Low | Low | Low | Low | Low | Low |

Source: Committee FP-020 Construction in Bushfire-Prone Areas⁸⁰

⁷⁵ Ellis, P. and Sullivan, A. (2004) *The Significance of Suburban Fuels*, Client Report for Fire Management Unit, Department of Urban Services, ACT Government, CSIRO.

⁷⁶ Committee FP-020 Construction in Bushfire-Prone Areas (1999) *Australian Standard: Construction of Buildings in Bushfire-Prone Areas*, AS 3959-1999, Standards Australia.

⁷⁷ Committee FP-020 Construction in Bushfire-Prone Areas (2000) *Australian Standard: Construction of Buildings in Bushfire-Prone Areas*, AS 3959-1999/Amdt 1-2000, Standards Australia.

⁷⁸ Committee FP-020 Construction in Bushfire-Prone Areas (2001) *Australian Standard: Construction of Buildings in Bushfire-Prone Areas*, AS 3959-1999/Amdt 2-2001, Standards Australia.

⁷⁹ California Building Standards Commission (2007) *Chapter 7A [SFM]: Materials and Construction Methods for Exterior Wildfire Exposure*, in '2007 California Building Code', Title 24, Part 2, International Council Code, Washington, DC, www.fire.ca.gov/fire_prevention/fire_prevention_wildland_codes.php, accessed 20 November 2008.

⁸⁰ Committee FP-020 Construction in Bushfire-Prone Areas (1999) *Australian Standard: Construction of Buildings in Bushfire-Prone Areas*, AS 3959-1999, Standards Australia, p9.

Depending on what type of vegetation and category of potential bushfire attack, building codes require different levels of fire protection to be applied to buildings. (See table 1.3.4)

Table 1.3.4 Construction requirements based on the category of bushfire attack

| Category of bushfire attack | Level of construction |
|-----------------------------|-----------------------|
| Low | None |
| Medium | Level 1 |
| High | Level 2 |
| Extreme | Level 3 |

Source: Committee FP-020 Construction in Bushfire-Prone Areas (1999)⁸¹

As we have shown above, as climate changes the fire season will become longer, the number of extreme bushfire risk days will increase and the intensity of bushfires is likely to become on average worse. In March 2009, the Australian Building Codes Board responded to these increased risks by publishing a final draft proposal for a revision of Australian Standard AS 3959 which governs construction in bushfire prone areas. In March, the ABCD published a “*Final Regulatory Impact Statement*” which analyses the likely impact of a proposal to revise existing building code requirements for construction in bushfire prone areas through the adoption of a revised version of Australian Standard AS 3959.⁸² The Victorian government announced in early March 2009, that it would adopt these new recommendations immediately to guide all rebuilding efforts from the Victorian bushfires.⁸³

The proposed new standard makes a number of changes to both the way bushfire risk to buildings is assessed and how new buildings should be designed and built to reduce the risks of damage from bushfires. The level of required changes to building design is based on the outcome of the site risk assessment. Thus it is important to first understand the proposed changes to site risk assessment methodology under the new proposed revised standard. The new proposed risk assessment methodology provides two methods for determining the bushfire attack level (BAL)⁸⁴:

- “A simplified procedure that is comparable to the existing process, and involves five procedural steps to determine the relevant BAL, which is based on a set of defined factors; or
- A detailed procedure that utilises calculations to determine the category of bushfire attack where a more specific result is sought or where the site condition is outside the scope of the simplified procedure.

The simplified procedure involves the following five steps:

1. Determine the relevant Fire Danger Index (FDI);
2. Determine the relevant vegetation type;
3. Determine the distance of the site from the vegetation;
4. Determine the effective slope of the site under the vegetation; and

⁸¹ Committee FP-020 Construction in Bushfire-Prone Areas (1999) *Australian Standard: Construction of Buildings in Bushfire-Prone Areas*, AS 3959-1999, Standards Australia, p11.

⁸² Australian Building Codes Board (2009) Final Regulatory Impact Statement – Construction in Bushfire Prone Areas. ABCB. <http://www.abcb.gov.au/index.cfm?objectid=D52E9452-C106-4619-2A4EB522B8FE31D1> accessed 10 March 2009

⁸³ Australian Building Codes Board (2009) Final Regulatory Impact Statement – Construction in Bushfire Prone Areas. ABCB. <http://www.abcb.gov.au/index.cfm?objectid=D52E9452-C106-4619-2A4EB522B8FE31D1> accessed 10 March 2009

⁸⁴ Ibid

5. Determine the BAL based on steps 1 to 4.⁸⁵

The key changes from the current methodology are the inclusion of the relative Fire Danger Index (FDI) which enables variations in bushfire risks across different geographical locations to be factored into the assessment of Bushfire Attack Level. In addition, “the revised methodology is based on effective slope of the land under the vegetation, rather than the slope of the land between the vegetation and the site, which is a more important determinant of the rate of fire spread, the severity of the fire, and the ultimate level of radiant heat flux.”⁸⁶ Finally, the proposed revised Standard also incorporates additional categories for the assessment of slope and distance to support a more detailed and effective risk assessment.⁸⁷ Table 1.3.5 below provides a summary of the changes to the site assessment framework.

Table 1.3.5: Summary of changes to site assessment framework.

| Site assessment factors | Current Standard | Proposed Standard |
|--------------------------------------|---|---|
| Geographical factors | Not considered as part of the assessment. | The relative Fire Danger Index (FDI) for a region or jurisdiction is included as part of the assessment |
| Slope | Assessment includes the slope of the land between the vegetation and the site | Assessment includes the slope of the land under the vegetation |
| Vegetation | Standards define 6 classes of vegetation and 28 different types | Standards define 8 classes of vegetation and 28 different types |
| Distance from vegetation | Standards define 4 distance bands as a factor in the site assessment | Multiple distance bands included as a factor in the site assessment |
| Assessed category of bushfire attack | Site assessment defines 4 different categories of bushfire attack | Site assessment defines 6 different categories of bushfire |

(Source: ABCB, 2009⁸⁸)

Assessing these factors determines whether a building is in a low to extreme “Bushfire Attack Level.” Instead of the current four categories under the proposed new standard there will be six “Bushfire Attack Level” (BAL) categories. Based on an assessment of the above variables, the BAL of a given site is determined as one of the following six categories. Instead of the current four categories under the proposed new standard there will be six “Bushfire Attach Level” (BAL) categories: BAL-LOW; BAL-12.5; BAL-19; BAL-29; BAL-40; and BAL-FZ.⁸⁹ Table 1.3.6 shows, through a worked example, how the Bushfire Attack Level is determined.

⁸⁵ Ibid

⁸⁶ Ibid

⁸⁷ Ibid

⁸⁸ Ibid

⁸⁹ Australian Building Codes Board (2009) Final Regulatory Impact Statement – Construction in Bushfire Prone Areas. ABCB. <http://www.abcb.gov.au/index.cfm?objectid=D52E9452-C106-4619-2A4EB522B8FE31D1> accessed 10 March 2009

Table 1.3.6: Worked Example – Identification of Corresponding Site Assessment Outcome.

| Fire Danger Index | Predominant vegetation | Slope | Distance (m) | Bushfire attack category |
|-------------------|------------------------|--------------|--------------|--------------------------|
| FDI 100 | Forest | >5-10 | <23 | BAL-FZ |
| FDI 100 | Forest | >0-5 | <18 | BAL-FZ |
| FDI 100 | Forest | upslope/flat | <14 | BAL-FZ |
| FDI 100 | Forest | upslope/flat | 14-<19 | BAL-FZ |
| FDI 80 | Forest | >5-10 | <19 | BAL-FZ |
| FDI 80 | Forest | >0-5 | <5 | BAL-FZ |
| FDI 80 | Forest | upslope/flat | <12 | BAL-FZ |
| FDI 80 | Forest | upslope/flat | 12-<16 | BAL-40 |
| FDI 50 | Forest | >5-10 | <13 | BAL-FZ |
| FDI 50 | Forest | >5-10 | 13-<17 | BAL-40 |
| FDI 50 | Forest | >0-5 | <10 | BAL-FZ |
| FDI 50 | Forest | >0-5 | 10-<14 | BAL-40 |
| FDI 50 | Forest | >0-5 | 14-<20 | BAL-29 |
| FDI 50 | Forest | upslope/flat | <8 | BAL-FZ |
| FDI 50 | Forest | upslope/flat | 8-<11 | BAL-40 |
| FDI 50 | Forest | upslope/flat | 11-<17 | BAL-29 |
| FDI 40 | Forest | >5-10 | <11 | BAL-FZ |
| FDI 40 | Forest | >5-10 | 11-<14 | BAL-40 |
| FDI 40 | Forest | >5-10 | 14-<21 | BAL-29 |
| FDI 40 | Forest | >0-5 | <9 | BAL-FZ |
| FDI 40 | Forest | >0-5 | 9-<12 | BAL-40 |
| FDI 40 | Forest | >0-5 | 12-<17 | BAL-29 |
| FDI 40 | Forest | upslope/flat | <7 | BAL-FZ |
| FDI 40 | Forest | upslope/flat | 7-<10 | BAL-40 |
| FDI 40 | Forest | upslope/flat | 10-<14 | BAL-29 |
| FDI 40 | Forest | upslope/flat | 14-<21 | BAL-19 |

(Source: ABCB, 2009⁹⁰)

As mentioned above, the new ABCA “*Final Regulatory Impact Statement*” report also recommends a revised building code for construction in bushfire prone areas through the adoption of a revised

⁹⁰ Australian Building Codes Board (2009) Final Regulatory Impact Statement – Construction in Bushfire Prone Areas. ABCB. <http://www.abcb.gov.au/index.cfm?objectid=D52E9452-C106-4619-2A4EB522B8FE31D1> accessed 10 March 2009

version of Australian Standard AS 3959.⁹¹ Under the new proposed building codes, “homes at highest risk will be required to be built on concrete slabs and the roof, exterior walls and decking must be made of non-combustible materials. Metal shutters and down pipes will replace plastic fittings and door frames must be made from fire-resistant timber or metal. These revisions will apply to all new homes, rebuilds and additions.”⁹² The Australian Building Codes Board has calculated that incorporating these changes into the design of buildings will result in an additional cost of approximately \$20,000 per home.⁹³ As mentioned above, the Victorian government recently adopted this new revised version Australian Standard AS 3959⁹⁴ to guide all rebuilding efforts from the 2009 Victorian bushfires.⁹⁵

Based on our own research, independent of this review by the Australian Building Codes Board, we have come to similar conclusions regarding the changes needed to building design to reduce the risks of damage to buildings from bushfires. Specifically the strategies to reduce the risks of damage from bushfires include the following:⁹⁶

- *Ember-proofing*: Houses constructed of fireproof materials such as brick, concrete and steel can prevent embers catching on external surfaces. However, many buildings are destroyed as a result of embers entering the building and igniting internal components. Embers can be prevented from entering a building by: ensuring a tight fitting roof; the roof and walls fit tightly and are all sealed; and applying metal flywire through to chimneys, and gaps in the roof or windows.
- *Inner roof*: The risk of embers breaching the outer shell of the building and igniting internal components is serious. Most roofs are not air-tight, so embers can enter the roof and ignite inner roof components such as the timber frame, insulation and especially the dry, combustible waste materials that can accumulate, such as wrappings from insulation, off cuts from roof construction, stored boxes, wind blown leaf litter and old papers and books. Since fires in roofs are relatively hidden, they may go undetected by residents and fire fighters until the inner roof bursts into flames and spreads. Ignition of inner roof components can be minimised by:
 - Removing flammable materials periodically.
 - Having a ladder to the roof manhole and several buckets of water that can be used to put out fire spots, checking at least every 15 mins – but only if it is safe to remain in the home during the fire. Having said this, ensure there are two people to enable one person to hold the ladder. Most injuries that occur during a bushfire in built-up areas result from people falling off roofs and ladders.
 - Applying a fire retardant to all combustible components in order to reduce the chance of ignition. Fire retardants have the advantage of being applied to areas that are difficult access. It is important to note that, while many roof insulation products claim to be fire retardant, most lose this property over time and accumulate fine combustible dust.

⁹¹ Ibid

⁹² Ibid

⁹³ Ibid

⁹⁴ Ibid

⁹⁵ Ibid

⁹⁶ ACT Planning and Land Authority (2005) *FIREWise: Home Design and Construction*, ACT Government; Bush Fire Info.com (undated) 'Outside Your Home', www.bushfireinfo.com/bitweaver/pages/Outside%20your%20home, accessed 4 November 2008; Bush Fire Info.com (undated) 'Protecting the Inside of Your Home', www.bushfireinfo.com/bitweaver/pages/Inside%20your%20home, accessed 4 November 2008; Committee FP-020 Construction in Bushfire-Prone Areas (1999) *Australian Standard: Construction of Buildings in Bushfire-Prone Areas*, AS 3959-1999, Standards Australia, pp11-24; Ellis, P. and Sullivan, A. (2004) *The Significance of Suburban Fuels*, Client Report for Fire Management Unit, Department of Urban Services, ACT Government, CSIRO, pp1-4, 7-9.

Glass windows and doors: One of the most common ways for fires to start in a house is through glass windows, doors and fittings which usually have wooden frames. Windows, both the frames and the glazing, are one of the most vulnerable building components. In houses, window frames and doors are usually timber and can ignite and burn out, creating gaps through which embers can enter the house. Door frames made from steel are available as an alternative to wooden doors. Glass can crack and break from exposure to radiant heat, strong winds and airborne debris, providing access for embers to enter the house. Glass also typically allows 70 per cent of radiant heat to pass. Glass breakages and radiant heat transmission through glass can be minimised⁹⁷ by:

- Fitting bushfire-rated permanent protective screens or shutters in order to protect glass from breaking, and reduce radiant heat and ember transmission into the house.
 - Using toughened glass that can withstand higher levels of heat before breaking. It is important to note that this does not reduce the amount of radiant heat transmitted through the window.
 - Applying metal flywire prevents sparks and embers from entering the house (bronze or aluminium mesh also reduces heat stress by between 27 and 70 per cent and delays glass cracking and breaking from exposure to radiant heat).
 - Applying non-combustible shutters, which also prevent flames from entering the house and provide a buffer between the heat and the window.
- *Gutters:* Leaves and other organic matter can catch and accumulate in roof gutters and downpipes and are likely to ignite, enabling the fire to spread to the roof frame and enter the house. Ignition of gutter waste can be minimised by:
- Removing the organic matter from the gutters periodically.
 - Installing and maintaining metal (not plastic) gutter shields to prevent waste accumulation.
 - When a bushfire is pending, adding water to the gutters and inserting downpipe plugs until they are half full regardless of whether gutter shields are installed.
- *Interior furnishings:* Interior furnishings (curtains, carpets, furniture), especially those near glass windows, doors and fittings, are at risk of ignition and this risk can be minimised by:
- Removing curtains and combustible furnishings from near glass windows, doors and fittings.
- *Metal flywire, fire retardant coatings and cavities:* Metal flywire prevents embers from entering the house while allowing ventilation throughout the year. Fire retardant sprays and paints reduce the chance of ignition or delay the onset of ignition. Flywire can be applied to house features such as wall vents, eave vents, skylights, chimneys, breaks in roof lines and air-conditioning units. Many of these features also have cavities with horizontal surfaces on which dry, combustible materials can accumulate. Removing this material periodically will minimise the chance of fire entering the house.
- *Timber decks, pergolas, and timber steps:* These timber components are also highly vulnerable building components due to their large horizontal timber surface area, which allow embers to

⁹⁷ Bowditch, P.A., Sargeant, A.J., Leonard, J.E. and Macindoe, L. (2006) *Window and Glazing Exposure to Laboratory-Simulated Bushfires*, Report to the Bushfire CRC Confidential CMIT Doc., A Bushfire CRC initiative 205, www.bushfirecrc.com/research/downloads/_%2066D_Window%20and%20glazing%202006-205.pdf, accessed 7 December 2008.

settle and catch. Timber components are also very vulnerable when in contact with flame.⁹⁸ These components not only fuel the fire but also direct the fire towards adjacent doors and windows, which enables the fire to enter the house. In light of the increased bushfire risks from climate change this century, it is recommended that new homes do not build such structures or if they do they use non-combustible materials. For existing homes and buildings, which already have such structures, ignition of timber decks, pergolas, and timber steps can be minimised by:

- Using fire retardant timber.⁹⁹ Applying fire retardant sprays and intumescent paints.
 - Conditioning timber to ensure appropriate moisture content levels.¹⁰⁰
 - When a bushfire is pending, applying fire retardant tarpaulins.
 - Using non-combustible frame under deck boards.
 - Using non-combustible deck board materials adjacent to structure. CSIRO has undertaken a series of tests and experiments to better understand these issues so as to better inform future designs. They have developed recommendations of how best to design decking for bushfire areas.¹⁰¹
- *Timber fences:* Timber fences are usually close to the house and, in addition to being fuel, can prolong the time the fire burns near the house, which increases the chances of embers, flames and radiant heat igniting the house. In some cases burning fences can collapse and fall against the structure. Ignition of the fence and surrounding elements can be minimised by:
- Using durable hardwood instead of pine as it burns more gradually and is harder to ignite.
 - Removal of the fence, particularly if it is made of pine or brushwood.
 - Avoidance of garden beds and vegetation adjacent to the fence which will multiply the intensity of the fire.
 - Applying fire retardant sprays and intumescent paints, noting that these products have a very limited lifespan when exposed to weather.
 - Ensuring that timber fences are located as far away from the house as possible by locating the house in the middle of the property.

⁹⁸ Macindoe, L. and Bowditch, P.A. (2006) *Cone Calorimeter Tests for Fire Retarded Timber Assessment of Australian Decking Timbers*, Report to Bushfire CRC, CSIRO - Manufacturing and Infrastructure Technology Fire Science and Technology Laboratory, www.bushfirecrc.com/research/downloads/CMIT-2006-143%20Cone%20Calorimeter%20Tests%20for%20Fire%20Retarded%20Timber%20Assessment%20of%20Australian%20Decking%20Timbers.pdf, accessed 8 December 2008

⁹⁹ Macindoe, L., Sargeant P. and Bowditch, P.A. (2007) '*Under-Flame' Fire Tests on Timber Decks*, Report to Bushfire CRC, CSIRO Manufacturing and Materials Technology Fire Science and Technology Laboratory.

¹⁰⁰ Macindoe, L., Leonard, J. and Bowditch, P.A. (2007) *Measurements of Moisture Content in Decking Timbers Exposed to Bushfire*, Weather Conditions Report to Bushfire CRC, CSIRO - Manufacturing and Materials Technology Fire Science and Technology Laboratory and CSIRO – Sustainable Ecosystems Urban Systems, www.bushfirecrc.com/research/downloads/8730_CMMT-2007-141-Measurements-of-Moisture-Content-in-Decking-Timbers-Exposed-to-Bushfire-Weather-Conditions.pdf, accessed 8 December 2008.

¹⁰¹ Macindoe, L. and Bowditch, P.A. (2006) *Cone Calorimeter Tests for Fire Retarded Timber Assessment of Australian Decking Timbers*, Report to Bushfire CRC, CSIRO - Manufacturing and Infrastructure Technology Fire Science and Technology Laboratory, www.bushfirecrc.com/research/downloads/CMIT-2006-143%20Cone%20Calorimeter%20Tests%20for%20Fire%20Retarded%20Timber%20Assessment%20of%20Australian%20Decking%20Timbers.pdf, accessed 8 December 2008

Macindoe, L., Sargeant P. and Bowditch, P.A. (2007) '*Under-Flame' Fire Tests on Timber Decks*, Report to Bushfire CRC, CSIRO Manufacturing and Materials Technology Fire Science and Technology Laboratory.

Macindoe, L., Leonard, J. and Bowditch, P.A. (2007) *Measurements of Moisture Content in Decking Timbers Exposed to Bushfire*, Weather Conditions Report to Bushfire CRC, CSIRO - Manufacturing and Materials Technology Fire Science and Technology Laboratory and CSIRO – Sustainable Ecosystems Urban Systems, www.bushfirecrc.com/research/downloads/8730_CMMT-2007-141-Measurements-of-Moisture-Content-in-Decking-Timbers-Exposed-to-Bushfire-Weather-Conditions.pdf accessed 8 December 2008.

- *Combustible scraps:* Combustible scraps, such as wood and rubbish stacks behave similarly to timber fences but are often located at closer proximity to the house and pose a greater threat. Ignition of combustible scraps can be minimised by removing them periodically. Storage of combustible scraps against or under houses and decks is highly undesirable.
- *Gardens:* Organic waste in gardens, such as dead wood and leaves, contribute to fuel loads in the garden. Trees can also grow to create a continuous canopy between bushland and branches that overhang roofs or touch walls. Ignition of the garden can be minimised by:
 - Removing organic matter periodically.
 - Trimming tree branches periodically.
 - Only planting low shrubs close to the house.
 - Not putting garden beds next to buildings or near egress paths in the yard. During drought, use of garden mulch increases yet garden mulch can be a source of fuel to bushfires..... The results of investigations in the 2003 Canberra fire found that mulch was a major risk for residents trying to control fires in their yards.

CSIRO's studies of the 2003 Canberra bushfire showed that ground fuel loads around homes was the major factor in whether houses were damaged and whether the fire spread.¹⁰²

- *Extinguishing Spot Fires:* Assuming it is safe to do so, spot fires can be extinguished manually by the resident using fire extinguishers, a water hose and buckets of water. However, it is important to note that both flame and embers must be fully doused and extinguished. It should also be noted that citizens should be better educated in the 'Stay or Go (Early)' policy for their respective states and the implications of choosing either to stay or go early. The Bushfire CRC has done considerable work with AFAC to provide a basis for stay or go policies. In most instances, police cannot force people to evacuate, especially if they are prepared. But citizens should be mindful of recent research conducted on the stay and defend policy, which shows that most people who have already gone through a fire once, question whether they would actually do it again. This is because the experience has had such a psychological impact on them as well as being so physically demanding. In light of the recent Victorian fires the 'Stay or Go Early' policy will be reviewed.
- *Use of Fixed Water Supply – Onsite Water Tanks:* Rainwater tanks can play an important role in defending the home against a bushfire attack. Having water tanks on site can help ensure there is adequate water during a bushfire to either enable an external bushfire water sprinkler to run or provide additional water for fire-fighters. Recent studies show that steel or concrete rather than plastic¹⁰³ water tanks are preferable.¹⁰⁴
- *External bushfire water sprinkler system:*¹⁰⁵ These systems are usually custom designed and installed to cover the house (roof, walls, windows, openings, etc.) and its surroundings

¹⁰² Ellis, P. and Sullivan, A. (2003) *Assessment of ACT Suburban House Loss from the 18 January 2003 Bushfires*, Client Report No. 1326, CSIRO.

¹⁰³ See Bushfire CRC Update (2007) Tanks on trial for home defence. A Bushfire CRC project has assessed the performance of rainwater tanks in bushfire conditions, www.bushfirecrc.com/publications/downloads/Update%208.pdf, accessed 29 November 2008.

¹⁰⁴ Bianchi, R., Leonard, J.E., White, N., Sargeant, A., Bicknell, A. and Andersson, S. (2008) *Research into the Performance of Water Tanks in Bushfire*, A collaborative project between BlueScope Steel Limited and the Bushfire CRC, CSIRO– Sustainable Ecosystems (CSE) Urban Systems Program, www.bushfirecrc.com/research/downloads/Water-Tank-Behavior-in-Bushfires.pdf, accessed 1 December 2008.

¹⁰⁵ Bush Fire Info.com (undated) 'Whole-House Protection: Bushfire Sprinkler Systems', www.bushfireinfo.com/bitweaver/pages/Bushfire%20Sprinkler%20Systems, accessed 4 November 2008; Fire Protection Association

(verandas, patios, gardens, ground, etc.) in water so embers are more likely to extinguish on contact rather than catch. It is important to note that the use of these sprinkler systems for bushfire protection of houses is untested. Dr Andrew Sullivan states that *'The results we have seen for sprinkler systems on fire vehicles is that strong winds will blow away large water droplets before it is effective. Direct contact of water on surfaces is preferred.'*¹⁰⁶

Examples of Bushfire-Resistant Building Design.

Some houses already exist which have been designed to resistant extremely intense bushfires. For instance, architect Dr Ian Weir has adopted and adapted many these recommended strategies (see above) in the design of several new Western Australian homes. These houses, built in Bremer Bay, Western Australia include a roof designed to resist ember attacks, fire resistant glazing on the windows, remote controlled roller shutters to protect the windows and a sprinkler system. These features do add to the cost of the house but there are co-benefits. Houses that are designed to resist fires are also well insulated and air-tight thus requiring significantly less heating and cooling.

Another example of a house which has implemented many of the recommended strategies is Mr Williams' Steels Creek home, in the Yarra Valley. Mr Williams home survived the Victorian bushfires on the 7th of February, 2009. Some of the strategies implemented by Mr Williams included:

- having no external timber upon which fire could catch.
- door frames were made of steel and so was a percentage of the balcony.
- the roof was a colorbond tin roof
- having stronger windows than normal – he used double-glazed doors and windows.
- using fire proof buildings materials – he used autoclaved aerated concrete bricks (AAC) and concrete slab construction
- having secure local water storage and automated sprinkler system – he had a powerful sprinkler system with 30 sprinkler heads around the house.

His house was one of the few to survive the worst of the bushfires that day. At least 26 homes were destroyed in Steels Creek. The Victorian Royal Commission into the 2009 Victorian bushfires will investigate the lessons from houses such as Mr Williams' as part of their investigations.

Risks and Vulnerabilities of Bushfires to Infrastructure

Bushfires can damage infrastructure and the built environment in many ways, in addition to burning down homes and buildings. In the 2003 Canberra bushfire, local water reservoirs, water treatment plants, an electricity substation and a reservoir pump were damaged in the fires, as well as the city's main sewage centre at Lower Molonglo. Other types of infrastructure such as mobile phone towers are at risk. It is beyond the scope of this one lecture to consider how bushfires can damage all types of infrastructure and how best to reduce the risks. So here we consider some strategies to help secure and reduce the risks of damage to important infrastructure and essential energy and water services. These are chosen because the impacts of damage to essential services infrastructure providing energy and water are two of the most serious risks posed by bushfires.

Australia (2000) *External Water Spray Systems to Aid Building Protection from Wildfire*, Fire Protection Association Australia, www.fpaa.com.au/technical/docs/External%20Water%20Spray%20Systems%20-%20July%202000.pdf, accessed 4 November 2008.
¹⁰⁶ pers. comm.

Bushfires and Electricity Transmission Lines

The 2007 Victorian bushfire on January 16th highlighted how easily bushfires can damage key infrastructure. A bushfire led to the disabling of a third of Victoria's electricity supply for 24 hrs, and cost the Victorian economy AUD\$500 million.¹⁰⁷ Flame and smoke plumes are conductors of electricity and when they bridge the gap between power line conductors and the ground via vegetation or tower frameworks, the line is automatically disconnected by control systems at both ends to protect the system and surroundings from damage. The effect of a disconnection was shown in Victoria, Australia on January 16th, 2007. Fire conditions were extreme with high temperatures (for Melbourne, it was the second hottest day of the summer), freshening winds and erratic fire behaviour. A total fire ban had been declared for all areas of the state and all available fire fighting resources were responding to new threats and managing 166 active fires. The Tatong fire escaped a back-burning done the previous night and spread southwards under the influence of freshening gusty north winds. The transmission lines in the easement, which were swept by the fire, included two 330kV lines that comprised Victoria's main electricity link to the Snowy Mountain Scheme and NSW. At the time of the incident, the gap between the line conductors and vegetation below them was as little as three metres. Clearly the vegetation in this case was too close to the power lines and thus enabled the encroachment of fire.

The following steps¹⁰⁸ can be made by the relevant companies and authorities, who are in charge of poles and transmission lines, to reduce both the risk of infrastructure from being disabled from a bushfire and to reduce the risk of infrastructure causing a bushfire:

- Maintain clearances between vegetation and network assets and undertake vegetation clearing around fuse poles, switched poles and transformer poles.¹⁰⁹
- When wires or poles break and fall down, dry undergrowth may ignite and start bushfires. So companies should accelerate the replacement of rusted or corroded conductors in areas of high bushfire risk. Power companies should ensure the structures supporting power lines are secure.¹¹⁰
- Pole top fires can be caused by system faults which cause sparks to fall to the ground. These can ignite dry leaves and undergrowth and start bushfires. The risk of this can be reduced by applying silicone coatings on pole top insulators. When poles and/or cross-arms are replaced, steel cross-arms and polymer insulators should be used to eliminate any risk of this occurring.¹¹¹
- Conductor clashing causes sparks which have been known to cause bushfires. Strategies to mitigate clashing conductors include a Low Voltage (LV) Spreader program to ensure that the conductors remain separate, especially in hot and windy conditions, when conductors can sag and be blown into adjacent conductors causing sparks.¹¹²
- As poles get old they fall over, bringing live electrical equipment into contact with vegetation. All power companies and authorities should have sufficient inspection teams to ensure that this never happens. Depending on conditions, poles should be either reinforced or replaced. In rural

¹⁰⁷ The Nous Group (2007) *16 January 2007 electricity supply interruptions in Victoria: What happened and why and Opportunities and recommendations*, Executive summary, The Nous Group, p20, [www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/\\$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf](http://www.dpi.vic.gov.au/DPI/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/b535f0bd60e483bbca2573800018778d/$FILE/071023%20Exec%20Summary%20-%2016%20Jan%202007%20Incident.pdf), accessed 21 October 2008.

¹⁰⁸ Western Power (2007) *Bushfire Management Plan*, Western Power, www.wpcorp.com.au/documents/environment/200708bmp.pdf accessed 15 November 2008.

¹⁰⁹ Ibid.

¹¹⁰ Ibid.

¹¹¹ Ibid.

¹¹² Ibid.

areas of Australia there are still many timber poles. In the longer term, a cost-effective timber alternative pole replacement should be implemented nationally to reduce the risk of poles igniting in bushfires and falling down.¹¹³

- Consider underground transmission of power through regions of high fire risk. It is possible to track fire spread and temporarily disconnect power supply as fire passes.

Bushfires and Water Quality

Melbourne,¹¹⁴ Sydney,¹¹⁵ Canberra, Brisbane, and Perth's water catchments are largely surrounded by national parks and state forests which are vulnerable to bushfires. It is widely recognised that bushfires in such forests surrounding water catchments can negatively impact on water quality.¹¹⁶ A report¹¹⁷ by Poynter and Featherston identifies high intensity bushfires as the biggest threat to Melbourne's water supply catchment because of their impact on both water quality and water run-off. Forest regrowth uses more water than a mature forest. The massive area of regrowth that has resulted from a large 2003 fire is expected to reduce in-flows into the Murray River headwaters by 430 billion litres per annum within 20 years.¹¹⁸

Bushfires replace forest litter with ash and charcoal, cause enhanced run-off of these materials along with soil particles, clay and dissolved or absorbed nutrients and organic matter. This may negatively affect water quality in streams and reservoirs. Elevated nitrogen, phosphorus, calcium, magnesium and potassium concentrations have also been observed after bushfires.¹¹⁹ Nitrogen and phosphorus movement after fire may be associated with eroded sediments and run-off water. Nitrogen and phosphorus movement can be a problem because of its influence on the occurrence of commonly toxic algal blooms.¹²⁰

The most dramatic recent example of a bushfire adversely impacting on water quality was the Canberra 2003 bushfires. The bushfires damaged the vegetation of the Cotter River Catchment, which led to degradation of water quality in the catchment's three dams – Corin, Bendora and Cotter Dams. The silt and ash of the surrounding forests made the dam water turbid, so Canberra had to rely on Googong Dam on the Queanbeyan River. The bushfires, coupled with the drought and existing water shortages, reduced Canberra's water reserves significantly. To adapt to this, the following measures were undertaken:

- The ACT government adopted permanent water conservation measures. Citywide water consumption in the ACT and region has decreased significantly in 2007 from previous years. Consumption amounted to 44 gegalitres in 2007, where for the six years prior to 2007, annual

¹¹³ Ibid.

¹¹⁴ Melbourne Water (undated) 'Educational Resources: Bushfires and Water Catchments', http://education.melbournewater.com.au/content/education_resources/bushfires_and_water_catchments/bushfires_and_water_catchment_s.asp, accessed 15 November 2008.

¹¹⁵ Chafer, C. (2008) *Wildfire, Catchment Health and Water Quality: A Review of Knowledge Derived from Research Undertaken in Sydney's Water Supply Catchments 2002-2007*, Catchment Operations and Major Projects Division, Sydney Catchment Authority, Penrith, www.ewatercra.com.au/newbushfire/downloads/1000012.pdf, accessed 7 December 2008.

¹¹⁶ Wallbrink, P. et al (2004) *Impacts on water quality by sediments and nutrients released during extreme bushfires: Report 1: A review of the literature pertaining to the effect of fire on erosion and erosion rates, with emphasis on the Nattai catchment, NSW, following the 2001 Bushfires*, Sydney Catchment Authority, CSIRO Land & Water Collaborative Research Project, www.clw.csiro.au/publications/consultancy/2004/nattai_catchment_fire_erosion.pdf, accessed 7 December 2008.

¹¹⁷ Poynter, M. and Featherston, G. (2008) *Review of Timber Production in Melbourne's Water Catchments*, A report prepared for the Victorian Association of Forest Industries, www.vafi.org.au/documents/WaterCatchmentReview08.pdf, accessed 15 November 2008.

¹¹⁸ Poynter, M. and Featherston, G. (2008) *Review of Timber Production in Melbourne's Water Catchments*, A report prepared for the Victorian Association of Forest Industries, www.vafi.org.au/documents/WaterCatchmentReview08.pdf, accessed 15 November 2008.

¹¹⁹ Ice, G.G., Neary, D.G. and Adams, P.W. (2004) 'Effects of Wildfire on Soils and Watershed Processes', *Journal of Forestry*, vol 102, pp16-20.

¹²⁰ Kuhn, G. (1993) 'Nutrient loss and algal blooms in the Murray-Darling River System', *Australian Journal of Soil and Water Conservation*, vol 6, no. 3, pp20-24; Verhoeven, J. (1993) 'Implementing the New South Wales algal management strategy', *Australian Journal of Soil and Water Conservation*, vol 6, no. 3, pp30-34.

usage ranged from 52 gigalitres to 69 gigalitres - already a significant reduction compared with pre-drought years (climate adjusted). The savings averaged 15 gigalitres, or approximately 7,500 Olympic-sized swimming pools.

- ACTEW AGL, Canberra's water and energy utility, upgraded The Stromlo Water Treatment Plant to provide additional water filtration services.¹²¹

The example of the Canberra 2003 bushfires highlights how vulnerable many of Australia's capital cities are to bushfires in their water catchments and illustrates the importance of investing in water efficiency and demand management for residential and commercial buildings. (See Modules B and C.)

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