Firefighters and climate change:

The human resources dimension of adapting to climate change

Final and consolidated report

A report for the
United Firefighters Union of Australia

Prepared by the
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Australia faces challenging times as it seeks to remodel emergency services to provide a more unified, comprehensive approach while at the same time dealing with a rise in more extreme events resulting from climate change. Successful outcomes will have an important human resources element that to this point has received scant attention in the media, by government and political leaders. People will be at the heart of a successful emergency services model for Australia. While tales of heroism and human sacrifice in the spirit of community service deserve recognition and are an important part of Australian folklore, they are not a substitute for good policy. That will be brought about by having the right people in the right places with the right skills and equipment, managed and supported through appropriate and enlightened organisational structures and led by highly skilled and competent leaders.

This report was commissioned by the United Firefighters Union of Australia (UFU) to contribute to the deliberations of the Senate Standing Committee on Environment and Communications' *Inquiry into recent trends and preparedness for extreme weather events*. The report finds that the number of firefighters employed in Australia will need to grow by about 20 per cent or about 2,300 firefighters by 2020 just to keep pace with population and asset growth. Fire related extreme weather is estimated to add a further 1200 to this increase. Other elements of extreme weather such as floods, cyclone activity and heatwave conditions have not been considered in terms of their numerical impact due to lack of data but they will add to the need for fire fighting personnel.

Using ABS Census data, NIEIR has estimated the following growth in the number of firefighters over the next 20 years based on two climate change scenarios.

Table 1 Forecast firefighter demand for Australia based on two climate change scenarios[1]

	Base	H2 Scenario		H3 Scenario	
	2012	2020	2030	2020	2030
NSW	3826	4741	5728	5175	6759
VIC	2648	3405	4296	3564	4697
QLD	2525	3529	4951	3529	4892
SA	906	1098	1354	1196	1611
WA	1225	1693	2334	1751	2494
TAS	321	337	367	337	395
NT	255	369	522	383	560
ACT	334	435	586	455	656
AUST	**12041**	**15607**	**20136**	**16391**	**22065**

Source: ABS Census data/NIEIR forecast.

[1] In this study NIEIR has adopted High Case scenarios developed through the CSIRO climate change simulation CCAM (Mark 2) and CCAM (Mark 3). They are identified as H2 and H3. These scenarios are adopted directly from Lucas et al (2007). High Case scenarios have been adopted for reasons described in Chapter 2. The scenarios are fully described in Hennessy et al (2005) and summarised by Lucas et al (2007). The summary description is attached in Appendix 4.

The growth rates proposed are arguably modest. We have not attempted to adjust for weaknesses in the current provision of emergency services. Between 24 and 26 of the 67 SoR regions still remain below 50 firefighters per 100,000 resident population in 2020 and 2030 (it varies slightly with scenario). The ratio of firefighters to population and assets moves up slightly for both scenarios by 2030 to accommodate extreme weather events. In contrast, if recruitment patterns of the past five years are maintained, these ratios move in the opposite direction as shown in Table 2.

Table 2 Outcomes existing spending pattern, high and low climate change scenario

	2013	2030		
	Base	Current growth	H2 scenario	H3 scenario
Population ratio	53	46	70	76
Asset ratio	1.8	1.65	2.5	2.7

In other words, current recruitment patterns will diminish fire-fighting resources during a period when governments are expecting them to do more and climate change is likely to place increased demands on fire fighting resources.

The distribution of firefighters in the community shows significant variation in the level of protection given to people and property in different parts of Australia. This is reflected in response times and performance. Some of the longest response times and lowest levels of resource provision are in the areas that have seen the largest by changes in high Forest Fire Danger Index (FFDI) days. These are the same areas where the number of extreme fire danger days is expected to grow as a result of climate change. They are often also areas that are prone to flooding from extreme rainfall events predicted to be associated with climate change. NIEIR has estimated that areas with negligible firefighters[2] represents a population and asset base comparable to Brisbane and the areas that appear to be under-serviced by firefighters represents almost half of the Australian population and $2.5 trillion in assets.

The number and spread of firefighters has implications for the protection of life and property. The difference between the Base Case forecasts (maintaining the existing numerical relationship between firefighters and population) and the H2 and H3 Scenarios is between five and eight million people and $1.5 and $2 trillion in assets having a benchmark level of protection (<50 firefighters per 100,000 population). The gap between current recruitment patterns and climate change adjusted projections is even larger. While there is scope to undertake more research in this area to better understand these relationships and thereby improve forecasting, the number of people at risk and the value of assets at risk would suggest that this additional research is a small price to pay for improved risk management. This research would allow appropriate benchmarks to be confirmed and recruitment targets developed in order to protect the community and allow for sound workforce planning.

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[2] Here the reference to firefighters is to people who identified their occupation as being a firefighter. The number of actual frontline fire fighters is likely to be between 65 and 85 per cent of this number as discussed in the report.

E.1 Changing expectations of firefighters

The nature of emergencies faced by Australian firefighters is broadening and the number of extreme events firefighters can expect to face as a result of changing climate is expected to grow. Weather in the south of the continent is becoming drier and hotter with increased bushfire risk as well as health risks associated with extreme heat. Bushfire risk is not only increasing in most parts of Australia but bushfire seasons are becoming longer with fewer respite years. More intensive rainfall periods increase the likelihood of major floods. Northern Australia is becoming wetter and while the number of tropical cyclones may decrease, the proportion of intense cyclones will increase. All coastal communities face risks associated with sea level rise and storm surges. Heatwaves will create more medical emergencies requiring first responders and drought will impact many rural communities and volunteer firefighters.

In a climate affected world the pressure to increase the proportion of paid firefighters in relation to volunteers will become stronger (the proportion is creeping up slowly). The core group of predominately self-employed volunteers are unlikely to be able to invest more hours in the face of longer seasons and longer more intense campaigns. Economic pressure will be unrelenting on businesses making it harder for employers to maintain their commitment to volunteer fire fighting. The age profile of volunteers will take its toll. Off-putting factors such as training requirements and attention to process will not diminish. Urban sprawl into new housing areas will mean there are more assets to be protected close to vegetated areas. Yet the occupants of these new homes are generally young families that require two bread-winners to meet mortgage commitments not able to commit the time required for volunteer firefighting. The predominately Anglo Celtic individualist culture of many brigades will find it hard to attract people from diverse cultural backgrounds. The growth of part-time residents in traditional farming areas will diminish the pool of potential volunteers unless significant change is made to working arrangements.

All this is set against a backdrop of rapidly changing expectations of emergency services workers in general and firefighters in particular. The 'all-hazards-all risks' approach means they will be involved in a whole range of disasters; their 'first responder' role asks them to provide emergency medical assistance; a community resilience approach means they will take on new roles supporting community risk management strategies and community disaster committees (with which many will no doubt take a lead); they will need to be more mobile providing surge capability nationally and internationally, and; they will need to be able to operate in different jurisdictions with different organisations using different protocols and different equipment. To do this they will need the support of government and the insurance industry who must be willing to provide the numbers of people, the training, the equipment and the leadership for firefighters to do the job expected of them and be able to return, like any other worker, safely to their homes and families at the end of their shift.

While NIEIR has used its best endeavours to provide forecasts about which there is a reasonable level of confidence, we should note that the data available was limited and these forecasts would benefit from access to more comprehensive data on the relationship between extreme events and firefighters and how the lengthening of fire seasons interacts with human resources issues for agencies. We would also recommend the development of agreed performance benchmarks for firefighting services against which the adequacy of service provision can be judged. We note that the Productivity Commission has been moving toward this goal but the data available is still short of what would be required to establish a common operational standard for Australia.

Preface

The National Institute of Economic and Industry Research (NIEIR) has been commissioned by the United Firefighters Union of Australia (UFU) to prepare a report on the implications of climate change for firefighters and emergency services. The report is intended to support a UFU submission to the Senate Environment and Communications Reference Committee on *Recent trends in preparedness for extreme weather events*. This is the final report in a series of three provided to the UFU. The first Interim Report canvassed the relevant issues and updated a project undertaken in 2009 by the Workplace Research Centre (WRC) at the University of Sydney (Wright, 2009) that examined the implications for Victorian firefighters of a changing climate. The second Interim Report sought to establish a baseline from which the requirement for additional firefighters to 2030 can be projected.

The overall goal of this project is to provide insights into the changing requirements for firefighters based on climate change scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The project builds on NIEIR's extensive database of regional Australia, developed for the State of the Regions (SoR) report (NIEIR, 2012), and comprehensive regional modelling and forecasting capability. Part of the report uses the regional structure developed for the SoR that divides Australia into 67 regions representing combinations of local government areas (see Appendix 2).

Establishing a baseline for firefighters has been somewhat problematic because of different estimates of firefighter numbers in Australia. This report uses as its primary source data from the 2011 ABS Census (ABS Special Order) for people categorised in the occupation of Fire Fighter (ANZSCO 441212) (ABS 1220.0). It uses place of work for the distribution of those firefighters. Comparisons are provided to data assembled by the Productivity Commission (SCRGSP, 2012) and provided by the UFU for various states. For estimations of the impact of changing weather conditions on demand for firefighters, we rely on work led by the Bureau of Meteorology and the CSIRO represented by Lucas et al (2007) and Clarke et al (2012) on changes in the Forest Fire Danger Index (FFDI). This work represents the latest and most comprehensive scientific studies available for Australia. While the cause of changes in the FFDI has not been conclusively established, human induced climate change is one explanation for these changes.

Projections used in this report have been developed using the NIEIR Regional IMP Model that is based on a local government area (LGA) level input-output model (NIEIR, 2012). Key variables used for understanding future demand are population and asset values as well as projected change in FFDI and volunteerism. This final report also attempts to understand the implications of not providing adequate resources for fires and other emergencies attended by firefighters. The work was undertaken during January and February 2013.

Abbreviations

ABS	Australian Bureau of Statistics
ANZSCO	Australia and New Zealand Standard Classification of Occupations
BOM	Bureau of Meteorology
BRCIM	Bushfire Royal Commission Implementation Monitor
CFA	Country Fire Authority (Victoria)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ERP	Estimated Resident Population
FFDI	Forest Fire Danger Index
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
MFB	Metropolitan Fire Brigade (Victoria)
NIEIR	National Institute for Economic and Industry Research
NSDR	National Strategy for Disaster Resilience
RFS	NSW Rural Fire Service
RVA	Replacement Value of Assets
SoR	State of the Regions report
TFB	Total Fire Ban
UFU	United Firefighters Union
VBRC	Victorian Bushfire Royal Commission
VicDoH	Victorian Department of Health
WRC	Workforce Research Centre (University of Sydney)

1. Changing context of fire fighting in Australia

Australian firefighters face a mosaic of changes that are affecting the way they do their job and the context of their job. This is both adding to the demand for people to do the job as well as the skills and capability required of the job. This chapter will briefly review these issues and their implications for forecasting demand for firefighters in Australia.

1.1 All-hazards, all-agencies approach

In March 2012 the Victorian Deputy Premier announced that all the State's emergency services agencies would henceforth participate in responding to major disasters under new laws passed by the Parliament (Ryan P. , 2012). He said the *Emergency Services Legislation Amendment Bill 2011* paved the way for an 'all-hazards, all-agencies' approach to disaster management. In fact, as the Victorian Bushfires Royal Commission, noted (VBRC, 2009), the *Emergency Management Act 1986* enacted following the Ash Wednesday bushfires was intended to provide the legislative foundation for an all-hazards all agencies approach to emergency management. The philosophical underpinning of the all-hazards approach is that all emergencies and disasters, regardless of their cause, create similar problems and that many of the measures required to deal with these problems are generic. Citing the inquiry into the 2012 Victorian floods, the Bushfire Royal Commission Implementation Monitor (BRCIM) noted:

> *Emergency management agencies are no longer restricted to responding to one type of hazard. This was apparent during the Victorian floods of 2010-11 and 2012 where the CFA provided substantial expertise and assistance to VICSES*. (BRCIM, 2012)

However the BCRIM noted that an 'all hazards, all agencies' philosophy had not been fully operationalised because of barriers to culture, communication, coordination, interoperability, information collation and sharing. Despite this, he said it was clearly the direction for the future (p. 231).

While other states refer to the all-hazards approach in different terms this is clearly a central theme of emergency management in Australia. For example Queensland refers to as a 'whole of government approach' to coordination of 'all-hazards'. (Ryan K., 2005)

The implication for this report is that consideration needs to be given to all hazards and potential disasters that could emerge from a changing climate not just the potential for increased fire risk. This will engage firefighters in a broad range of emergency response activities such as floods and cyclones. As noted elsewhere, it is expected that more extreme weather associated with climate change will result in more floods and fewer but more extreme cyclones.

1.2 First responder role

As well as the broadening nature of disasters to which firefighters are expected to respond, there is also a broader range of services that they are expected to provide when they do respond. The concept of a 'first responder' is now fairly well established internationally and indeed is actively promoted by agencies such as the US Department of Homeland Security. Paramedics Australia provides the following definition:

> *A first responder (FR) is an individual who has completed accredited training in advanced first aid and emergency scene management and responds to emergency situations to provide initial clinical management in the out-of-hospital environment*. (Paramedics Australia, 2013)

The role of firefighters as first responders is becoming standard practice as the Victorian Department of Health outlines on its web site:

> *When a person experiences a cardiac arrest within Metropolitan Melbourne, Ambulance Victoria paramedics and Metropolitan Fire Brigade (MFB) firefighters are dispatched simultaneously to the patient.*
>
> *MFB firefighters are trained in the initial management of life threatening medical emergencies. If they are the first to arrive at the scene of the emergency, they will provide emergency medical care until the ambulance paramedics arrive and take over.* (Vic DoH)

Having received enthusiastic support of the National Heart Foundation of Australia, the Australasian College for Emergency Medicine, the Australian Resuscitation Council and the Australasian College of Physicians the program is now being trialled in country areas with the Country Fire Authority (CFA).

The first responder role of firefighters will further broaden their involvement in emergency management. The emergence of this role for firefighters will broaden their role in climate related emergencies such as those associated with extreme heat for, example; cardiac arrest and motor vehicle accidents. (The Climate Institute, 2013) (Climate Commission, 2013)

1.3 Community resilience

The National Strategy for Disaster Resilience (NSDR) (COAG, 2011) shifts emphasis from emergency management to community resilience; from reactive response to prevention, mitigation, preparedness and recovery and strongly advocates adoption of shared responsibility by government, community leaders, businesses, NGOs, households and individuals (Goode, 2011). Former Victorian Police Commissioner Neil Comrie has argued that encouraging communities to be more resilient and share responsibility will ensure there is greater understanding of the risks associated with bushfires and other emergency events and reduce community complacency. But he says this will be a major challenge for government and emergency management agencies, requiring them to relinquish long established practices of absolute control of many aspects of emergency management and in devolving some of this control to local communities. (BRCIM, 2012)

Good et al (Goode, 2011) in their review of recent disaster inquires note that Australia is a long way off having the systems and resources to build disaster resilient communities while there is a lack of consensus about the concept and little evidence at this point to support it as a solution. They note that most emergency services still operate in silos with each agency focused on their own responsibilities. In fact they say the current arrangements support an environment in which agencies compete for funding and power. These 'silos of knowledge' make it unclear as to who is responsible for assessing and communicating risks. The emergency services sector is not currently well equipped to communicate risk and is not adequately engaged with its communities. Australia does not have locally developed toolkits to support community empowerment. While they note that the CFA *Fireguard* provides a toolkit it does not reflect an all-hazards community-based approach.

Implementation of a community resilience approach will require all emergency services workers to acquire new skills in communication and community engagement as well as achieving higher levels of interoperability. Good et al (Goode, 2011) note that the problems in this regard start at the top of the emergency services organizations highlighting consistent criticism of leadership and the need to improve leadership training. So an implication of a resilience approach is the need to provide better integration, better skills and more emergency service workers who are better equipped for both their response duties and their broader community engagement and education role.

1.4 Interoperability

The Victorian Bushfire Royal Commission Implementation Monitor listed as a key tenant of emergency services reform the need 'to further develop agency interoperability'. (BRCIM, 2012) While Neil Comrie was concerned about interoperability between agencies that generally deal with different hazards it is clear that in terms of fire services there are significant interoperability challenges within states and between different state services.

The question of interoperability goes to management systems, communications, technology and basic fire fighting equipment. Good et al (Goode, 2011) point out that when responsibility is distributed between agencies the horizontal coordination becomes highly fraught. The UFU has pointed out that even within a state such as Victoria there are interoperability issues between equipment used by the MFB and CFA. Western Australia has recently moved to align radio and communication equipment but communication technology still appears to be an issue for many services. The UFU has pointed out issues with the recent despatch of firefighters from Victoria to assist in Tasmania where their ability to assist was restricted because of equipment differences between the two states.

The silo effect on interoperability also has an impact with an all-hazards approach. Both the Victorian Flood Inquiry and the Queensland Flood Inquiry discussed the need to equip specialised fire agencies to deal with floods. For example water-proof radio equipment and vehicles capable of traversing flood waters (Goode, 2011). Victoria's Fire Services Commissioner says the Fire Services Act 2010 is explicit about pursuing interoperability between the State's fire services (Lapsley, 2011). But the issue appears to be broader than just fire services within one state and needs to take in other emergency services and other states. While the Commissioner agrees that interoperability "is more complicated than just turning the toggle on a radio" and goes to creating an 'attitude of cooperation' the UFU says the State has effectively abandoned a trial of embedding MFB staff in the CFA and CFA staff in the MFB. The Victorian White Paper on Emergency Management recognises interoperability as a key challenge for 'future' emergency management. (VicGov, 2012)

Interoperability will be increasingly important in a changing climate because of the range of extreme events (fire, flood, cyclone, storm surges), an anticipated increase in intensity of events and the need for strong surge capability. The all-hazards approach will increasingly be called upon. Firefighters will be engaged in a broader range of disasters while the likelihood of catastrophic events in different parts of Australia (and the broader region) will require that personnel are able to operate in different jurisdictions as effectively as their home base. In other words, in order to deal with major catastrophes firefighters from one state need to be able to move to other states (and internationally) in order to meet peak resource demand efficiently and effectively.

1.5 National standards and mutual agreements

In order to give effect to the principle of interoperability, national standards and mutual agreements between the states will be required. Good et al (Goode, 2011) notes that emergency management is primarily a state responsibility and that state arrangements are sometimes inadequate.

> *Every State/Territory has had to learn and develop their system of emergency management individually. The resources that are available within the State/Territory has determined the quality of emergency management*. (p. 16)

Recommendations to improve interoperability have followed virtually every bushfire inquiry since the Stretton Royal Commission recommended a single fire fighting organization for country Victoria after the 1939 bushfires. That recommendation was acted upon following the 1943-44 bushfires (BRCIM, 2012). This trend will need to continue at a national level to deal with the sort of emergencies and disasters that can happen as a result of more extreme weather expected to accompany a warming climate. However, given the range of interests and jurisdictions involved it is most likely to happen as a result of mutual agreements between states – that recognize the need for interoperability between states and between agencies – and common standards for protocols, communication and equipment used by emergency services. All of these may take some time to evolve but they will both help in responding to disasters and protect the safety of people involved in the provision of emergency services.

2. Climate change

Interceding over the top of changes facing firefighters outlined in Chapter 1 are the implications of Climate Change. The Intergovernmental Panel on Climate Change (IPCC) has produced a range of scenarios for how greenhouse gas emissions might develop over the course of this century and the impact of global warming on the earth's climate (Pachauri, 2007). Sadly, evidence would suggest that the planet is tracking at the more pessimistic end of these scenarios. This was highlighted in a report prepared by the Potsdam Institute for Climate Impact Research and Climate Analytics for the World Bank (PICIA, 2012). The Report predicts that a 4°C warmer world could be a reality by the 2060s if current commitments and pledges are not met and even if they are there is a 20 per cent chance of 4°C warmer planet by 2100. In his introduction to the report, the President of the World Bank, Dr Jim Yong Kim says:

> *The 4°C scenarios are devastating: the inundation of coastal cities; increasing risks for food production potentially leading to higher malnutrition rates; many dry regions becoming drier, wet regions becoming wetter; unprecedented heat waves in many regions, especially in the tropics; substantially exacerbated water scarcity in many regions; increased frequency of high intensity tropical cyclones; the irreversible loss of biodiversity, including coral reef systems*. (p. v)

In her recent report on climate change the Victorian Commissioner for Environmental Sustainability takes up the view that the planet is heading toward the more pessimistic climate change projections (Auty, 2012).

> *Importantly it needs to be noted that our global emissions are currently tracking at close to [the IPCC] A1F1 [scenario], the first and most resource intense scenario. This business-as-usual path represents a worst-case scenario for climate change outcomes.*

What are the expectations of climate change for Australia; leading climate change scientist Penny Whetton summarised the outlook in the following terms:

> *The best estimate of annual average warming by 2030 (above 1990 temperatures) is around 1.0 ºC across Australia, with warming of 0.7–0.9 ºC in coastal areas and 1–1.2 ºC inland.*
>
> *Drying is likely in southern areas of Australia, especially in winter, and in southern and eastern areas in spring, due to a contraction in the rainfall belt towards the higher latitudes of the southern hemisphere. Changes in summer tropical rainfall in northern Australia remain highly uncertain.*
>
> *Intense rainfall events in most locations will become more extreme, driven by a warmer, wetter atmosphere. The combination of drying and increased evaporation means soil moisture is likely to decline over much of southern Australia. An increase in fire-weather risk is likely with warmer and drier conditions*. (Whetton, 2011)

In last year's State of Climate report, the CSIRO and the Bureau of Meteorology said that modelling shows:

- Australian average temperatures are projected to rise by 1.0 to 5.0°C by 2070 when compared to climate in recent decades – this means an increase in the number of hot days and warm nights and a decline in cool days and cool nights;
- an increase in the number of droughts is expected in southern Australia but it is also likely that there will be an increase in intense rainfall events in many areas; and
- it is likely there will be fewer tropical cyclones in the Australian region, on average, but the proportion of intense cyclones is expected to increase (CSIRO/BOM, 2012)

Discussing the implications of these scenarios for South-Eastern Australian, the Victorian Commissioner for Environmental Sustainability says:

> *Although there are likely to be decreases in average rainfall we are also expected to experience an increase in the intensity of the highest 1% of rainfall events. In other words, there will be more dry days but the days when it does rain will be wetter. These changes will be most pronounced in summer and autumn. This means we will continue to have the kind of extreme rains we saw in [the Victorian floods of] February and March of 2011 and 2012 and that events of this nature may become more severe. This possibility must be a key factor in future planning*. (p. 19)

These changes will have implications for floods, bushfires, cyclones and human health impacts of heatwaves and severe rainfall. In addition, sea level rises will affect many coastal communities making them more prone to storm surges.

Discussing the implications of climate change for bushfires, the Commissioner says:

> *When the [Forest Fire Danger Index] data are analysed in more recent periods, it becomes clear that not-significant seasons are becoming rarer. Almost every season can be categorised as having produced fire events which can be described at least as "important"*. (Auty, 2012)
>
> *More concerning, the analysis of the data prompts the conclusion that "serious" and "major" fire seasons are becoming more common.*
>
> *This analysis of the data suggests that even though the number of fires may not have changed, their impacts are presently (and, upon extrapolation, in the future) expected to worsen.*
>
> *It is anticipated that an increase in 'serious' – 'major' seasons may be more likely. Further – and of concern to planners, environmentalists, land managers, health professionals, governments and the general public – seasons with no significant impact may become a thing of the past*. (p. 107)

Reviewing the recent (January 2013) heatwave experienced in Australia, the Australian Climate Commission issued a report (Karoly, 2013) saying:

- *The length, extent and severity of the current heatwave are unprecedented in the measurement record.*
- *Although Australia has always had heatwaves, hot days and bushfires, climate change is increasing the risk of more frequent and longer heatwaves and more extreme hot days, as well as exacerbating bushfire conditions.*
- *Climate change has contributed to making the current extreme heat conditions and bushfires worse.*

The report goes on to say:

> *While many factors influence the potential for bushfires, so called 'fire weather' is highly sensitive to changes in climatic conditions (Clarke et al., 2012). Changes such as hotter temperatures, longer duration of heat events, high winds due to strong temperature gradients and drier soils and fuel can dramatically exacerbate fire conditions. Thus when fire occurs in more extreme weather conditions, there is the potential for the fire to be far more intense and difficult to control*.

Meteorologist Chris Lucas (Lucas, 2007) has analysed how fire weather is changing by examining indicators for the Forest Fire Danger Index (FFDI) from observations at a range of weather stations. As well as dangerous fire weather becoming more frequent, he and his colleagues report that fire seasons are becoming longer.

> *Fire weather is clearly changing across Australia with a tendency towards more dangerous conditions being observed across the country. Significant trends in median and 90th percentile FFDI are observed in all seasons, but overall, it is the summer months – the peak of the southern fire season-- that shows the least amount of change. The largest changes are occurring in the spring and autumn, broadly consistent with the model projections. The fire season is lengthening, with an earlier start and a later end. The number of 'extreme' fire weather days is increasing in spring, summer and autumn. In a regional sense, the Murray Darling Basin region is seeing the biggest change in fire weather danger, with significant positive trends observed in all four seasons. In general, the eastern portion of Australia is seeing larger trends in more seasons, but almost every region shows some degree of change*.

While Lucas et al highlight the greater intensity and lengthening in the above comment, their work also draws attention to the point made earlier by the Commissioner for Environmental Sustainability that relatively mild seasons will become rarer. Elsewhere, Lucas et al make the point that the lengthening of the fire season means there will be less opportunity to take preventative action such as fuel reduction burns which require conditions that are dry enough for burning but wet and mild enough to prevent a burn getting out of control (Lucas, 2007).

As well as increased fire weather associated with hot and dry weather, the Australian Climate Commission (Karoly, 2013) and the Commissioner for Environmental Sustainability (Auty, 2012) have noted the impacts of heatwaves on human health with increased mortality (particularly for the elderly) and higher risk of accidents due to impaired judgment and behaviour on the roads, at home or in the workplace. Drought will impose its own hardships on rural communities with implications for volunteer firefighters whose importance will be discussed in the next chapter.

In summary, while the nature of emergencies faced by Australian firefighters is broadening (Chapter 1) the number of emergencies firefighters can expect to face as a result of changing climate is also growing. Weather in the south of the continent is becoming drier and hotter with increased bushfire risk as well as health risk associated with extreme heat. Bushfire risk is not only increasing in most parts of Australia but bushfire seasons are becoming longer with fewer respite years. More intensive rainfall periods increase the likelihood of major floods. Northern Australia is becoming wetter and while the number of tropical cyclones may decrease, the proportion of intense cyclones will increase. All coastal communities face risks associated with sea level rise and storm surges. Heatwaves will create more medical emergencies requiring first responders and drought will impact many rural communities and volunteer firefighters.

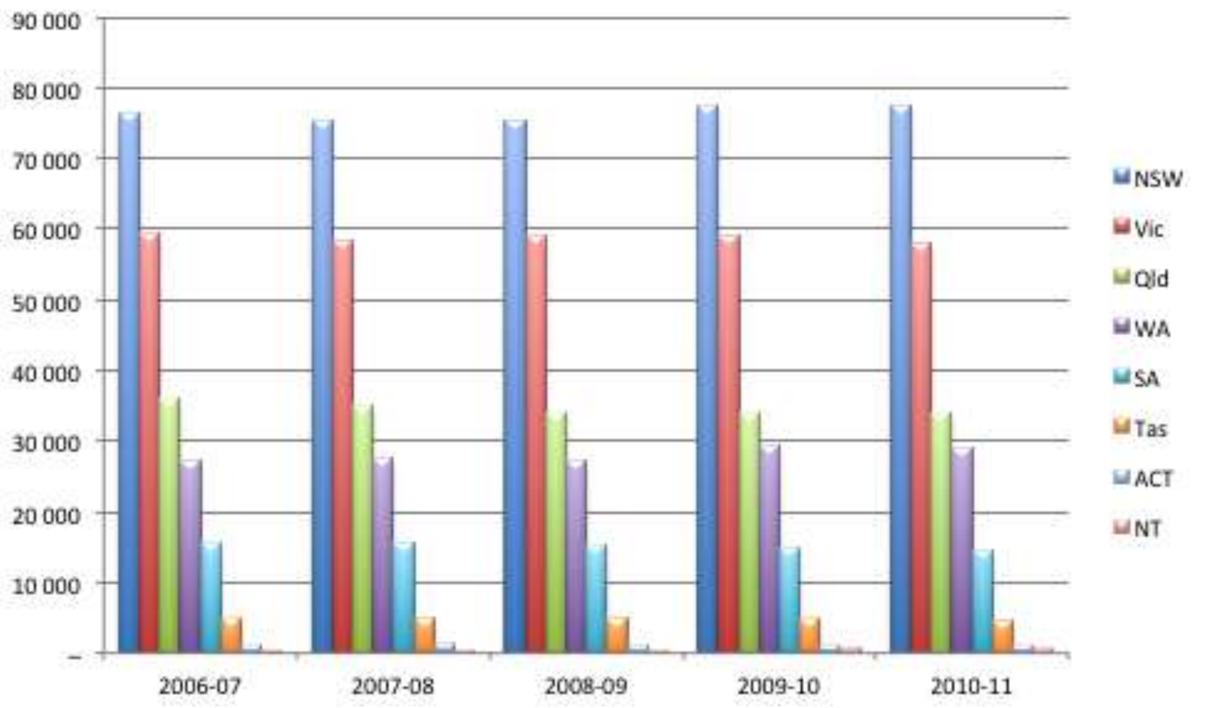
3. Volunteerism

Volunteerism in Australian fire fighting services (and indeed many emergency services) faces a number of challenges. Between 1995 and 2003 there were declines in the number of volunteers although at least some of this can be explained by book keeping losses of long-time inactive members. (McLennan, 2008) These declines appear to have stabilised since the mid-2000s although major operational issues facing volunteer-based brigades persist including:

- shrinking membership in many small remote (and ageing) communities in parts of South Eastern Australia likely to be exacerbated by climate change and declining agricultural production;
- static brigade membership in new population growth centres; and
- lack of volunteers able to turn out to emergencies during business hours especially in growing urban/rural fringe communities (McLennan, 2008).

In relation to the last point, it is noted that lack of volunteers was not found to be an issue in the 2009 Black Saturday Victorian fires (Jones, 2011) however this was a Saturday afternoon. It is not known what the consequences may have been if the fires had broken out on a working day.

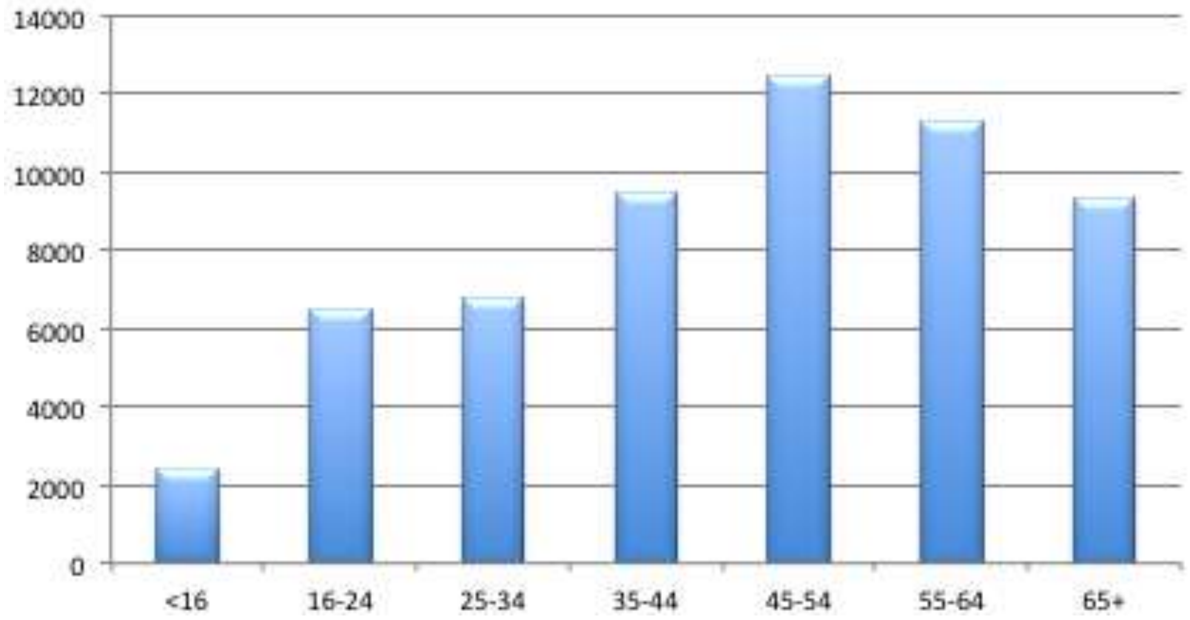
Figure 1: Volunteer firefighters by state



Source: SCRGSP, 2012.

Although volunteer numbers are often cited because of their importance to largely volunteer services, particularly in rural areas, the relatively stable numbers in Figure 1 do not reveal the available workforce. The Jones Inquiry (Jones, 2011), commissioned by the Victorian Government in response to concerns that the CFA was not doing enough to support volunteers, found that of the CFA's reported 59,000 volunteers in 2010 37 per cent were 'non-operational' and of the operational volunteers only 63 per cent turned out 'at least' once in 2008 and 73 per cent turned out at least once in 2009 (the year of the Black Saturday fires). More than a third of volunteers (35 per cent) were over 54 and 37 per cent are within the 35 to 55 year age bracket.

Figure 2: Age profile of CFA volunteers (May 2011)



Source: Jones, 2011.

McLennan has stressed to NIEIR that it is not the number of volunteers listed that is important but the number of volunteer hours available to the respective fire service or emergency service that is important (private communication). In an earlier paper, he had written that volunteerism was in crisis and this crisis was created by economic and demographic factors (McLennan & Birch, 2005).

> *Globalisation and deregulation of the economy, and technological innovation, have resulted in structural changes in the nature of work: privatisation, casualisation, self-employment, and demands for increased productivity. These factors make it more difficult for members of communities to volunteer, regardless of their motivation to do so. Further, like many other OECD countries, Australia's birth rate has fallen over the last three decades, resulting in a decline in the proportion of the population aged between 25 and 45 years a trend that is unlikely to be reversed in the foreseeable future. These economic and demographic changes make it difficult for Australian volunteer rural fire agencies to meet their community protection responsibilities.*

In a summary of research undertaken by the LaTrobe University volunteerism research team with the Bushfire CRC, Adrian Birch highlights that fire fighting is a particular type of volunteering subject to demands that are ever present and at times more intense than volunteers in most fields (Birch, 2011). "*Clearly, volunteer firefighting presents special challenges: the sometimes critical nature of the work; the need for unscheduled, rapid response around the clock; the physical and emotional demands; and the various risks*." (p. 2) These particular challenges also attract a particular type of volunteer. Birch reports that a higher proportion of volunteers are in the workforce compared to the general population and therefore subject to work/volunteering conflict. More specifically, disproportionately higher numbers are self-employed. These self-employed volunteers are generally the ones called on during business hours, which in turn can become a detriment to their business.

A survey of the NSW Rural Fire Service in 2007 (Unpublished, 2007) found that most volunteers were male (86 per cent), with a median age of 44, 91 per cent were born in Australia and of those born overseas they were born predominately in the United Kingdom, New Zealand or North America. The estimated time volunteers spent on RFS activities was 34 hours a month (mean, 24 hours a month median) which compared to an ABS estimated average time for volunteering of 11 hours a month (mean, 5 hours a month median) although the author suggests there may be some overestimation. Most volunteering is associated with school or recreational activities (people generally 35 to 50) but parents of young children are often not in a position to commit the hours required for fire fighting (Birch, 2011).

The Jones Inquiry found a similar profile to the NSW survey among Victorian fire fighting volunteers. Its survey was more specific in terms of employment of volunteers finding that 48 per cent had their own business, 44 per cent employed in either agriculture, forestry or fishing and only 13 per cent not in employment (compared to a community average of 39 per cent) (Jones, 2011).

The older male, self-employed, Anglo bias of volunteers creates some management issues with many volunteers reporting frustration with RFS bureaucracy, processes and brigade politics (Unpublished, 2007). These issues are second only to work/volunteering clashes as reasons for leaving. However, individualism can also manifest as dysfunctional behaviour with some volunteers 'cherry picking' 'enjoyable' tasks and neglecting necessary but less enjoyable tasks. Birch notes there appears to be a degree of 'rejection of diversity in membership' among volunteers which may limit the ability to attract and retain recruits from culturally and linguistically diverse backgrounds (Birch, 2011).

There is no easy answer to the challenge of maintaining volunteer based fire fighting services. Despite the Jones Inquiry's 41 recommendations to the Victorian Government, the recently released White Paper on emergency services management recognised the problem of managing volunteers but was short of a solution other than the need to improve management through recognition, minimise barriers, provide training and consultation. (VicGov, 2012) However the incentive for governments to try to maintain volunteer-based services is strong as the value of CFA volunteers to the community has been estimated at $840 million a year (Jones, 2011). Birch estimates that to staff each of the 6,417 brigades in

Australia with one round-the-clock crew of four would require 128,340 firefighters or a force larger than the Australian Defence Force (Birch, 2011).

In a climate affected world the pressure to increase the proportion of paid firefighters will become stronger (the proportion is creeping up slowly). The core group of predominately self-employed volunteers are unlikely to be able to invest more hours in the face of longer seasons and longer more intense campaigns. Economic pressure will be unrelenting on businesses making it harder for employers to maintain their commitment to volunteer fire fighting. The age profile of volunteers will take its toll. Training requirements and attention to process will grow. Urban sprawl into new housing areas will mean there are more assets to be protected close to vegetated areas. Yet the occupants of these new homes are generally young families that require two bread winners to meet mortgage commitments. The predominately Anglo Celtic individualist culture of many brigades will find it hard to attract people from diverse cultural backgrounds who are a large part of these new suburbs. In addition, the growth of part-time residents in traditional farming areas will diminish the pool of potential volunteers unless significant change is made to working arrangements.

4. Establishing a baseline

4.1 Baseline firefighters

Establishing a baseline from which to project future firefighter requirements provides its own case study of the fractured nature of Australia's emergency services. The Productivity Commission (SCRGSP, 2012) has attempted to assemble a data set for the past five years based on advice from State and Territory Governments. This data set is problematic. The ABS Census categorises a group of people as Fire Fighters based on its ANZSCO (ABS 1220.0) classification of occupations. ANZSCO occupation 441212 is Fire Fighter described as an occupation that "responds to fire alarms and emergency calls, controls and extinguishes fires and protects life and property." This data will be a core piece of information for this report.

The Productivity Commission data set has Australia with 13,229 firefighters in 2011 distributed between the states, as per Table 3 below.

Table 3 Permanent and part time FTE[(a)]

	2006-07	2007-08	2008-09	2009-10	2010-11
NSW[(b)]	3887	3926	3982	4013	4023
VIC[(c)]	4119	4185	4687	4045	3911
QLD[(d)]	2239	2358	2353	2373	2422
WA[(e)]	932	973	996	1028	1076
SA[(f)]	905	938	976	1020	1005
TAS	287	296	267	280	274
ACT	291	329	296	294	305
NT[(g)]	182	186	194	207	213
AUST	**12842**	**13191**	**13752**	**13260**	**13229**

Notes: (a) FTE = full time equivalent.
(b) NSW: Numbers for fire service organisations' human resources include retained firefighters and community fire unit members.
(c) VIC: Includes data for Victoria's land management agency, the Department of Sustainability and Environment (DSE). Due to data issues with the DSE 2007-08 component, DSE figures for 2007-08 have been derived from 2006-07 DSE figures. Victorian Permanent Firefighter numbers are over reported between 2007-08 and 2008-09 due to inclusion of some non-fire fighting personnel from within Victoria's land management agencies.
(d) QLD: Firefighting personnel include senior fire officers, Assistant Commissioners, the Deputy Commissioner and the Commissioner.
(e) WA: Support staff data include all non-fire specific staff, including those that support SES and volunteer marine rescue. Data for the Department of Environment and Conservation are not included.
(f) SA: The SA Fire and Emergency Services Commission employs most support personnel. Fire agency support staff include Metropolitan Fire Service training, building inspection and fire cause investigatory staff.
(g) NT: Numbers reflect NT Fire and Rescue Service and Bushfires NT.
– Nil or rounded to zero.

Source: SCRGSP, 2012.

Underlying the growth for Australia is an erratic set of changes for a number of states demonstrating an array of policy approaches to managing fire services. The picture is further confused when the Productivity Commission data for 2010-2011 is compared with Census data (ABS, 2013). The disparity is greatest in Victoria where data supplied by the State Government is higher by more than half. This illustrates one of the problems in creating a baseline for projections because of the difference between who governments regard as firefighters and people who regard themselves as firefighters (and, as discussed presently, who is actually available as a frontline firefighter). Examining both the Productivity Commission data and Census data suggests the rate of growth of firefighters nationally over the five years was less than 2.4 per cent.

Figure 3: Comparison of firefighter data: Census versus Productivity Commission

Source: ABS, 2013 and SCRGSP, 2012.

A further complicating factor comes from assessing how many of the firefighters identified above are actually available for frontline fire fighting duties. The following table attempts to analyse the proportion of firefighters available for frontline fire fighting duties in three states where data was available. Census and Productivity Commission data have been modified to take account of known variance with the data by removing seasonal firefighters, staff who perform some fire fighting duty and supervisors in order to compare like with like. Table 4 shows that after these adjustments between 65 and 85 per cent of people who the Census identifies as firefighters may be actual frontline firefighters.

Table 4 Comparison frontline firefighters to Census and Productivity Commission

State	Census	Productivity Commission	Frontline (estimate)	% Census (adjusted)
VIC	1080 [a]	1021 [b]	925[c]	85.6
QLD	1551 [d]	1496 [e]	1300[f]	83.8
TAS	308	274	202[f]	65.6

Notes: (a) DSE staff excluded.
(b) DSE and seasonal firefighters excluded.
(c) Source: MFB reports, CFA Chief Officer Staffing Chart April 2012.
(d) (e) Less station officer sand SFOs.
(f) UFU estimates.

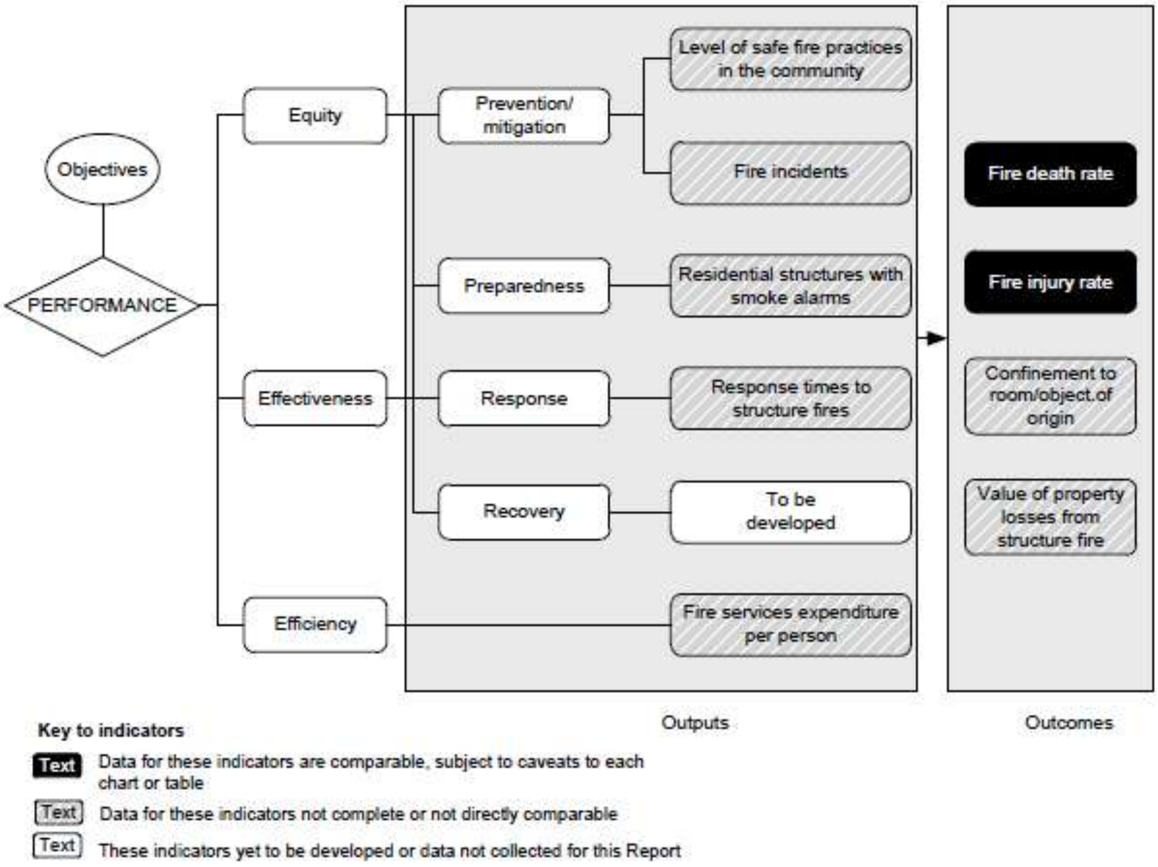
Sources: ABS, 2013, SCRGSP, 2012, NIEIR, UFU, MFB and CFA reports as identified above.

4.2 Spatial distribution of firefighters

The most important outcomes firefighters are expected to achieve are the protection of people and property. This is reflected in the Productivity Commission evaluation framework set out in the Figure below. Spatial distribution of firefighters influences both the effectiveness and equity of fire fighting services. Response times are influenced by land area as well as population, infrastructure, traffic and crewing configuration (SCRGSP, 2012). There is a difference in response times between the States and between types of area. For example, response times in major cities will often be in the range of 10 to 12 minutes while in outer regional and remote areas response times can be in excess of 20 minutes.

This report will use Estimated Resident Population (ERP) and replacement value of asset values (RVA) to compare the number of firefighters in a local government area (LGA) or region. That is, the report assumes that as these two measures change, the need for firefighters will change. In saying this, it is recognised that population and assets are not a complete set of drivers of the need for firefighters. Other considerations will include the changing use of equipment, local conditions (e.g. vegetation) and the use of volunteers. Use of equipment is beyond the scope of this report, limited assessment has been made of local vegetation conditions and challenges with the continuing reliance on volunteers were discussed earlier.

Figure 4: Fire events performance indicator framework



Source: SCRGSP, 2012.

It should be noted that the use of Census data includes all people who described their occupation as a firefighter. This means people whose fire fighting activities are essentially specialist (but nonetheless important) rather than of a general community nature. For example, airport firefighters, private industry firefighters (asset protection staff), military firefighters etc. It will also include firefighters employed by the Department of Sustainability and Environment in Victoria for the specific purpose of fighting fires on public forest land. These specialist firefighters are reflected in the spatial distribution.

The maps below show the spatial distribution of firefighters in relation to asset values and population. The most obvious observation is the amount of Australia that has none or negligible numbers of firefighters. As noted above, there are areas that have a high number of firefighters because of natural assets (for example, areas of East Gippsland with low populations and asset values but the presence of firefighters because of large areas of state forest), private assets (mining, private forests), airports and aggregations due to, for example state and regional command centres. State maps are appended at Appendix 1.

Figure 5: Distribution of firefighters per $billion replacement asset values

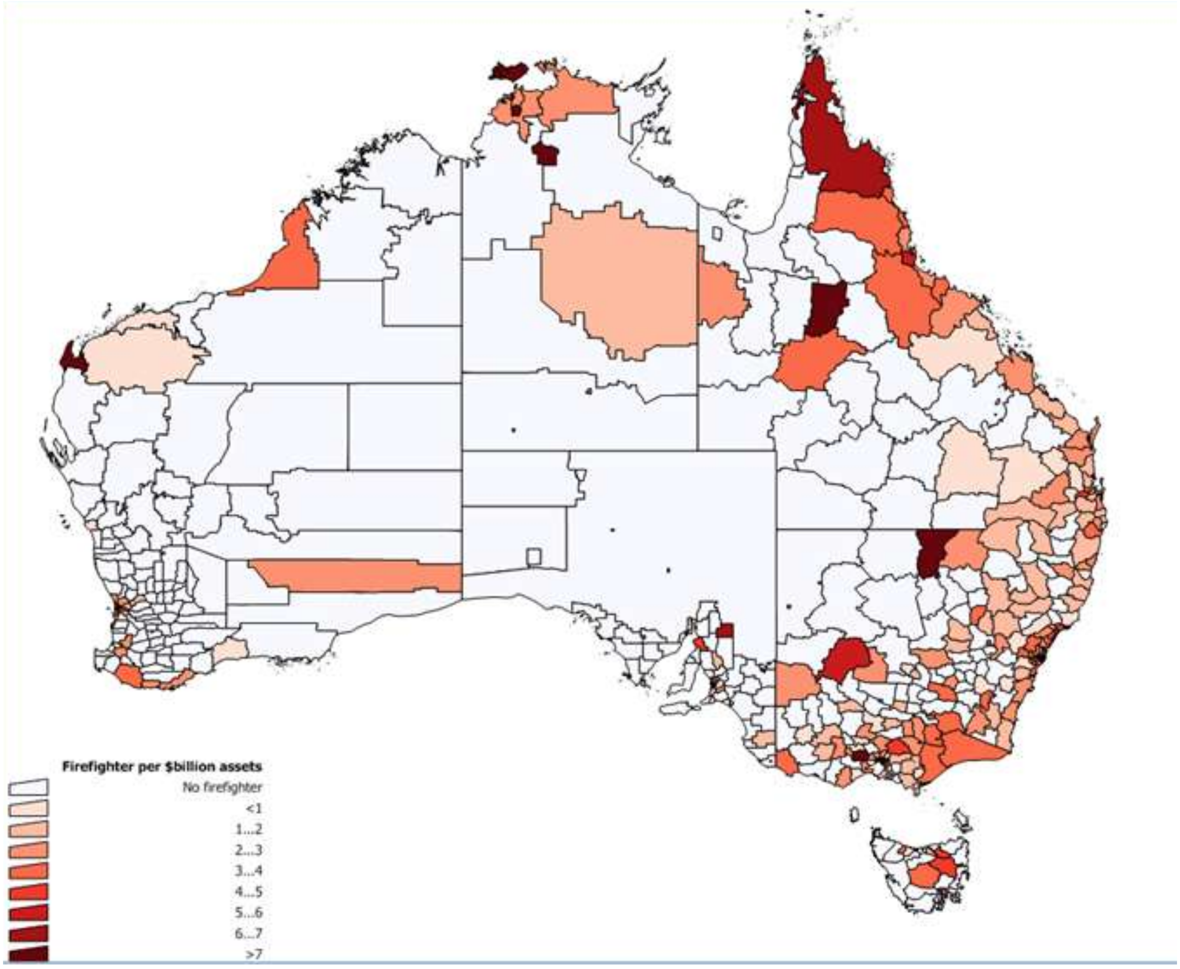
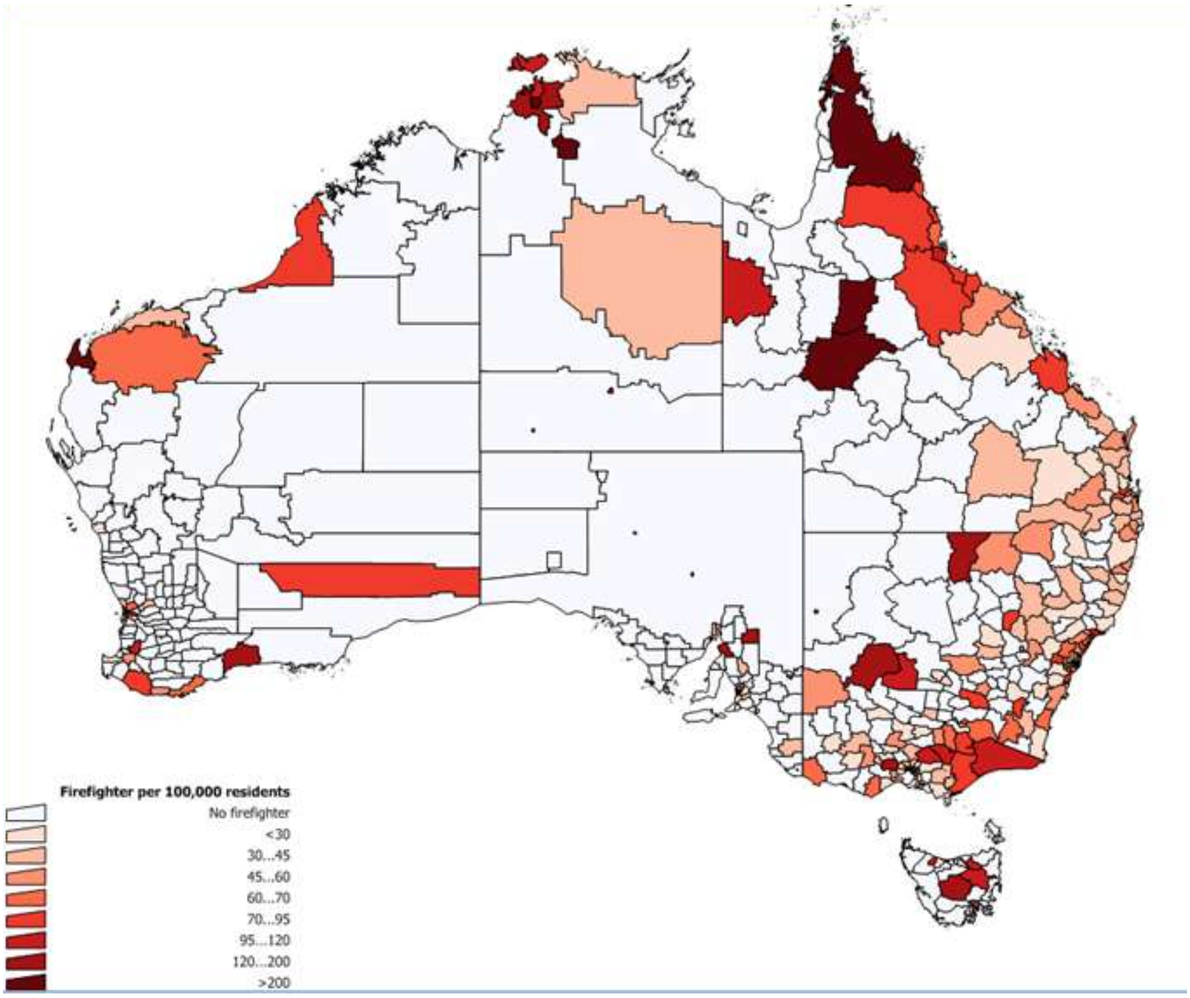
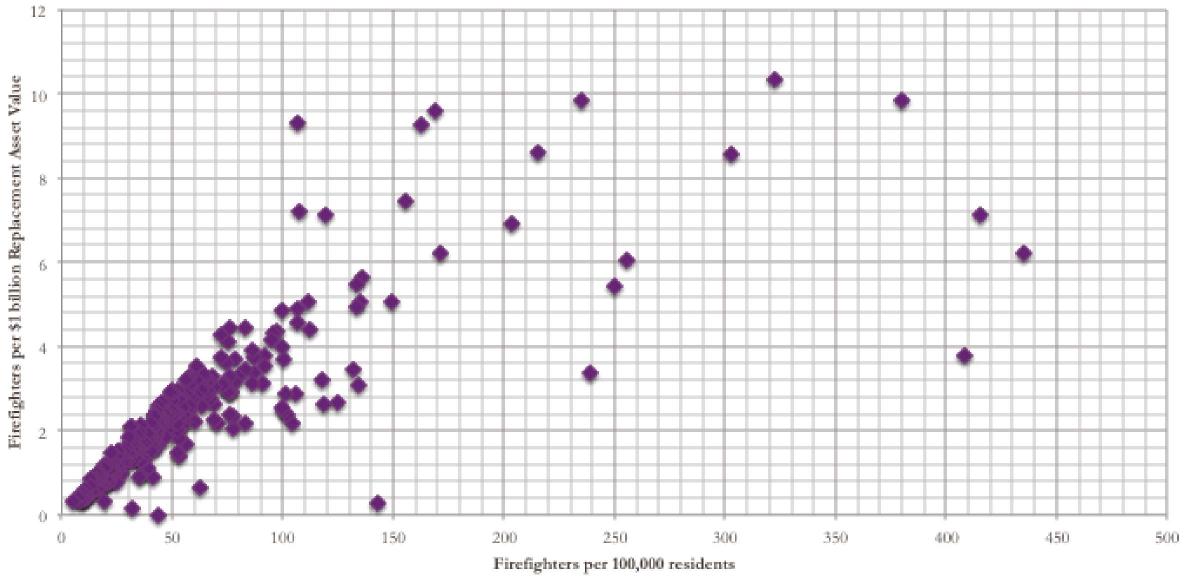


Figure 6: Distribution of firefighters based on population



Placing the unserviced areas to one side for the moment, the scatter plot below shows the spread of firefighters matched to asset values and population (two outliers have been removed for the purpose of illustration). It is important to note that the calculations used above and the scatter plot below are based on the Census data that includes all people who describe their occupation as firefighter. As already noted this will include specialists firefighters who may not be available for community protection as well as supervisors. The previous section noted that even after making adjustments for known variance, actual frontline firefighters may be only 65 to 85 per cent of the Census figures used here.

Figure 7: Spread of firefighters (LGA)



Source: ABS 2013/NIEIR.

The scatter plot shows that for most LGAs that have firefighters, there are less than three for every billion dollars of replacement asset value and less than 60 for every 100,000 resident population. To understand what this means, NIEIR needed to identify some level of good performance. Data on comparative performance at a local level was not available for this study (although some data is published by the Productivity Commission at a state level in their Review of Government Services (SCRGSP, 2012)).

To establish an indicator for good performance, NIEIR consulted a senior fire officer, through the client, and asked him to suggest locations where services would be regarded as good practice. Craigieburn and Mildura in Victoria were both suggested. The Jones Inquiry (Jones, 2011) had also highlighted Craigieburn. As a result, Hume and Mildura LGAs in Victoria were adopted as a benchmark for good practice. Mildura in an agricultural area with a mixed professional/volunteer service had 56 firefighters for every 100,000 of resident population while Hume (minus Melbourne Airport) in an urban fringe area had 43. Neither represents a high water mark in terms of firefighters per resident population or asset values. Utilising a mid-point between the two of 50 firefighters per 100,000 ERP NIEIR identified that 151 LGAs (excluding LGAs where there are no fire fighters) were below this benchmark and 131 LGAs above. The value of assets in LGAs below the benchmark is almost $2.5 trillion and the population is almost 12 million.

Returning to the LGAs without any firefighters, some 284 Australian LGAs do not have a firefighter (or the presence is negligible in statistical terms keeping in mind some may perform fire fighting duties but this is not their primary occupation). The total value of assets in these LGAs is just under $500 billion and the population is just under 2 million. This means assets and people roughly equivalent to Brisbane are without firefighters and totally dependent on volunteers.

5. Firefighters and climate change

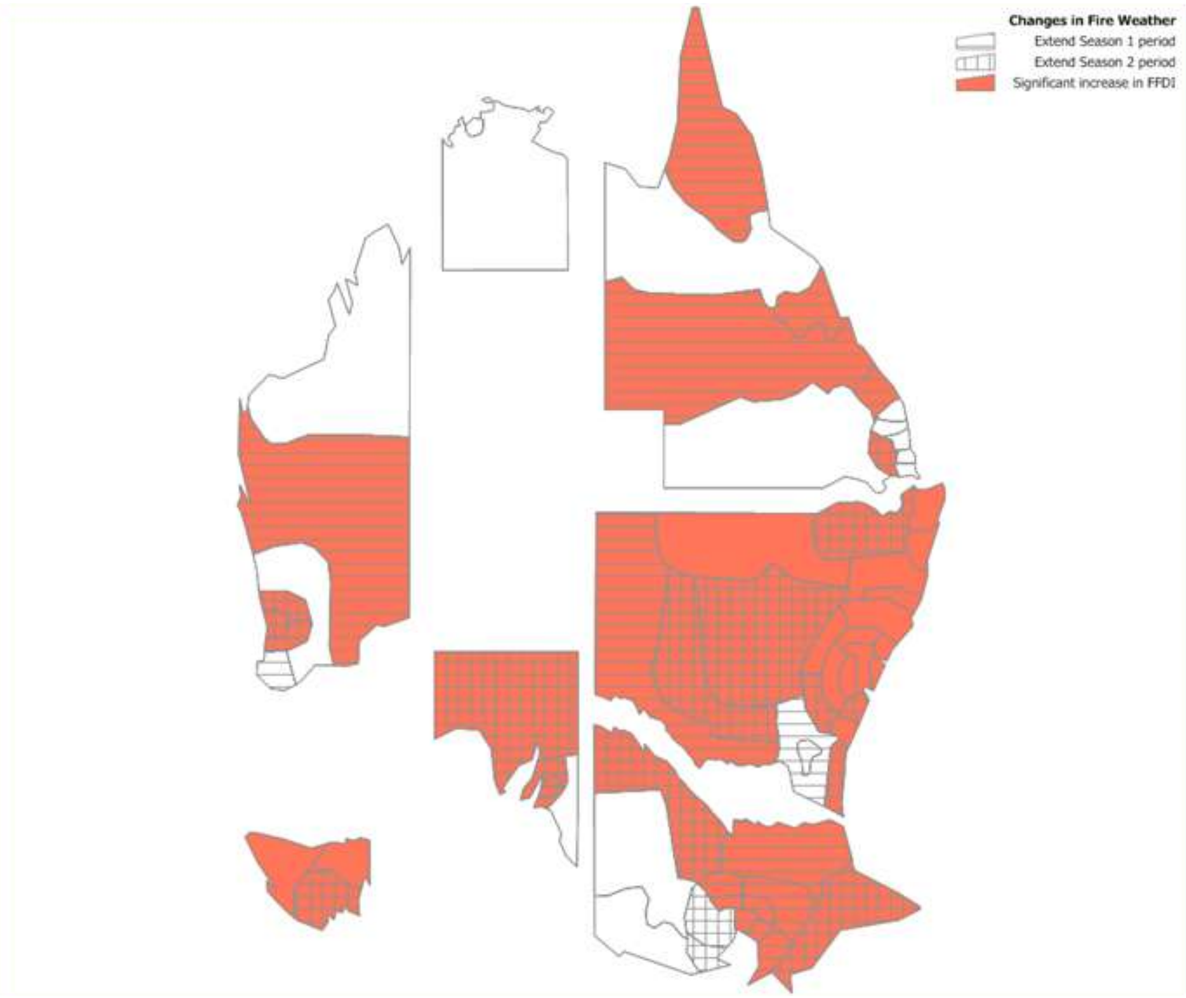
The broad perspective on climate change and its impact for fire fighting in Australia has been discussed earlier. In this Chapter we develop a quantitative assessment using the baselines discussed in the previous chapter. This work builds toward a model for forecasting future demand for firefighters. This Chapter draws heavily on the database assembled by Chris Lucas at the Bureau of Meteorology and described in (Lucas, 2007) and (Clarke, 2012)[3]. The work of Clarke et al analyses historical data (1973 – 2010) from observations at 38 stations nationally. It found significant increase in the annual 90th percentile Forest Fire Danger Index (FFDI) at 24 stations with none showing a significant decrease. There was a bias in the number of significant increases toward the southeast of the continent while the largest trends occurred in the interior with the smallest near the coast. Trends observed suggested increased fire weather conditions at many locations across Australia due to both increased magnitude of FFDI and a lengthened fire season (Clarke, 2012).

For this project, observations from the stations listed in Clarke et al were adapted and interpreted to coincide with NIEIR's 67 SoR regions. The Figure below shows areas where significant change was found in the Forest Fire Danger Index (FFDI) between 1973 and 2010. This shows that 54 of NIEIR's 67 SOR regions show some significant change in fire conditions. FFDI is widely used as the basis for issuing weather warnings by fire agencies. It uses standard weather observations of temperature, relative humidity, averaged wind speed and rainfall to estimate fire weather conditions (Clarke, 2012). There are a number of approaches to how FFDI is used. The following Figure uses the annual 90th percentile FFDI to show increased intensity and the seasonal median FFDI that provides information on the timing of fire weather. Season extension periods represent three-month seasonal blocks and are based on comparison with historical estimates in Luke and McArthur (Luke, 1978).

In order to integrate the patterns of firefighter distribution established in the previous chapter at an LGA level, that data has been aggregated to NIEIR SoR regions (Appendix 2 has a list of LGAs and their relationship to SOR regions). The first figure below shows the change in fire weather regarded by Lucas as significant while the next two show firefighters in relation to resident population and replacement asset values for the 67 SoR regions.

3 While these projects represent the latest available thinking on this subject new research is underway on fire weather. The current data set is expected to be reviewed this year with a revised dataset available in 2014.

Figure 8: Changes in fire weather 1973 to 2010 adapted from Clarke, 2012



Of particular interest to this study is the relationship between areas being impacted by changing fire weather and the distribution of firefighters in Australia. To do this, NIEIR simplified the Clarke et al analysis and awarded a score of one for a significant change in the total FFDI and one for each block of three months where there was significant change outside of the historical fire season (Luke, 1978). That means a score of three would be the result of a region exhibiting growth in FFDI and two blocks of additional fire season, two would mean any two of these and one would mean just one of these factors. Regions that did not exhibit any significant change in fire weather conditions were eliminated (14 regions). Remaining regions were evaluated as to whether they were above or below the benchmark (50:100,000) established in the previous section. This reduced the list to 30 regions. The Table below lists SOR regions where firefighter ratios are currently below the benchmark described earlier and where significant change has been seen in the FFDI between 1973 and 2010 (excluding 5 inner urban SORs). In other words, relatively high risk and low protection. The estimated value of assets and population in these regions is shown in the Table. Almost nine million people live in these regions with assets of about $1,899 billion. The choice of cut-off for whether a region is well serviced or underserviced will always be subject to challenge. It is accepted that may be the case with the following list. It is based on the best available data at this point in time.

Figure 9: Firefighters per 100,000 population for SoR regions

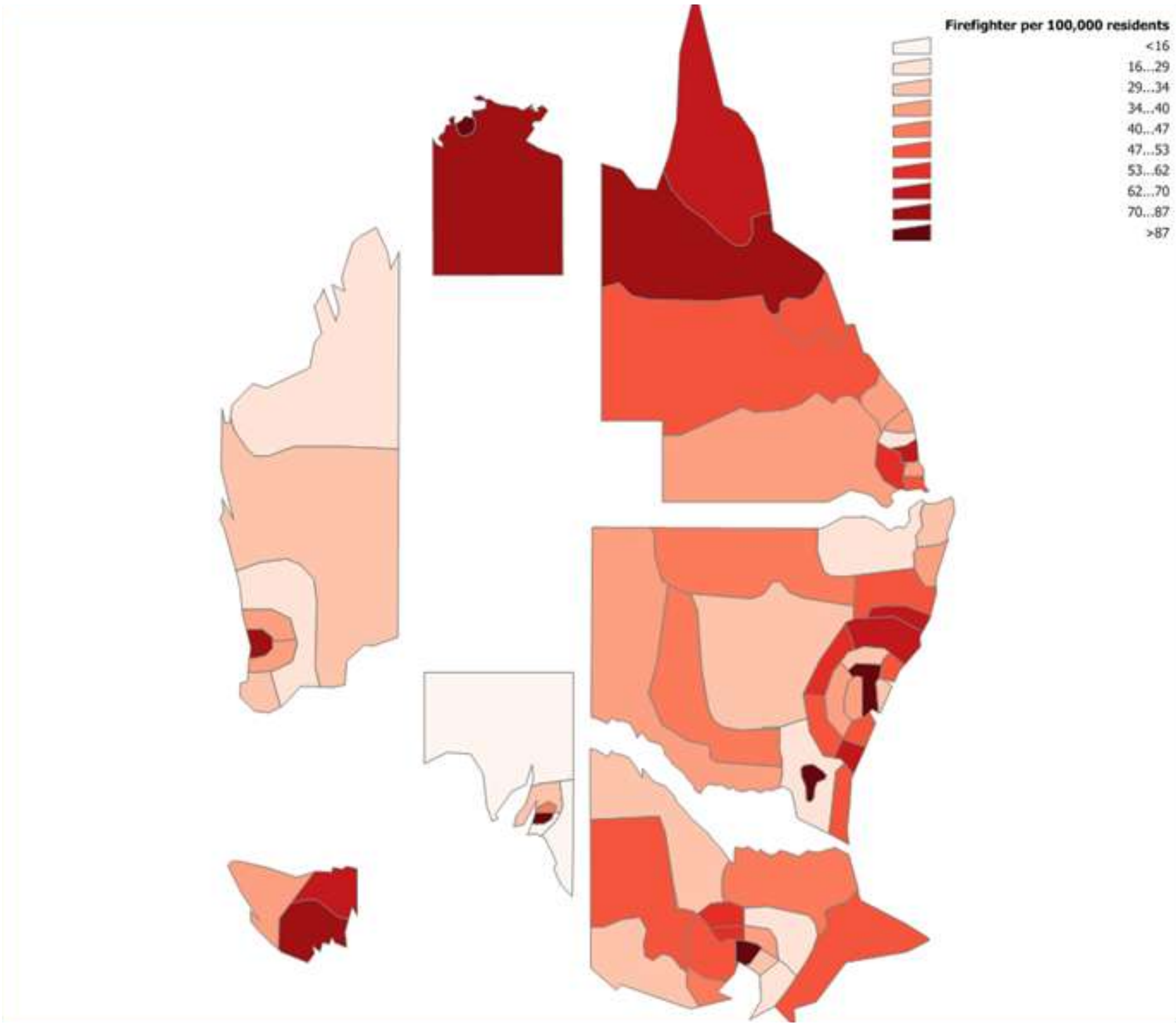


Figure 10: Firefighters by replacement asset prices by SoR regions

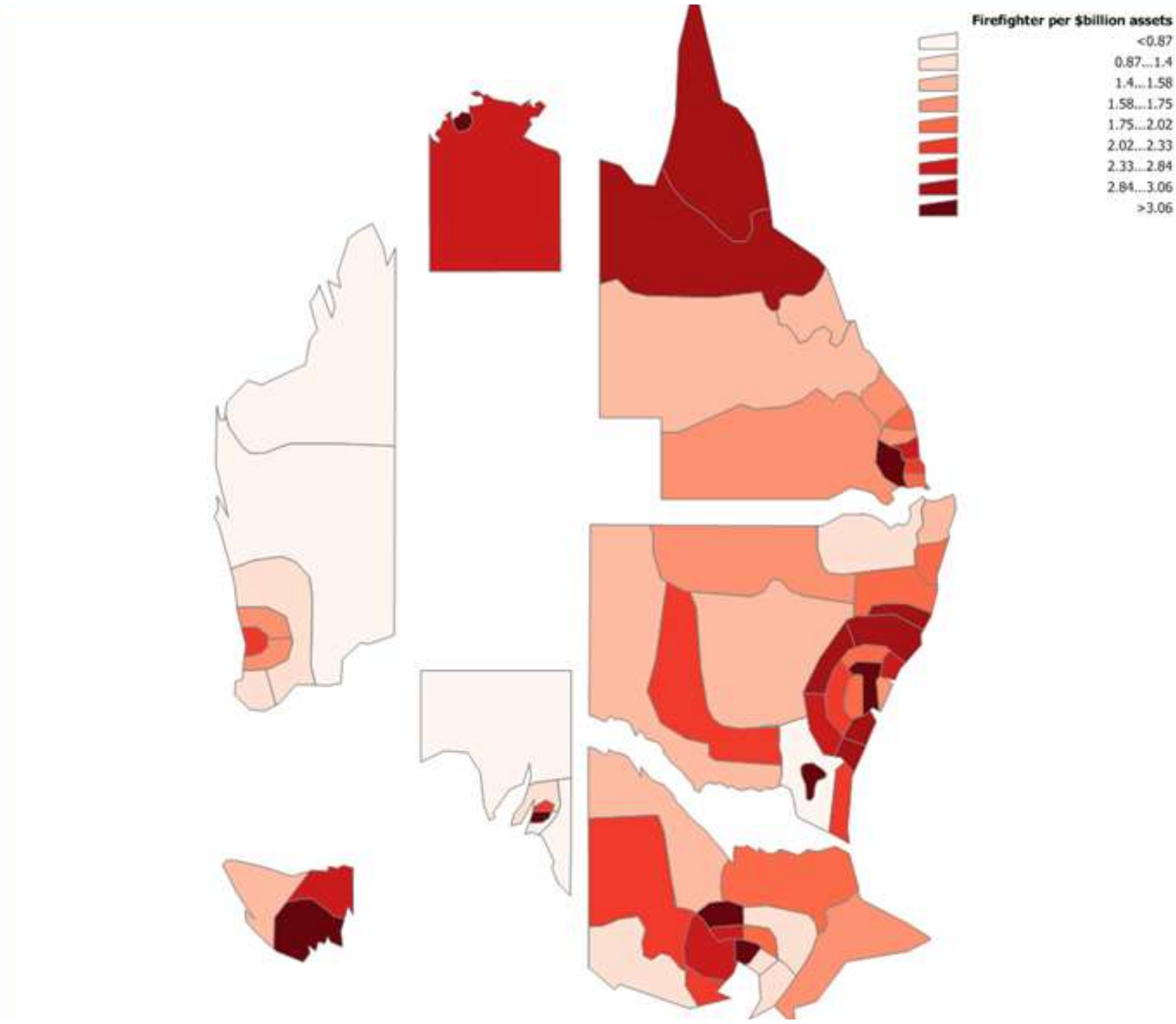
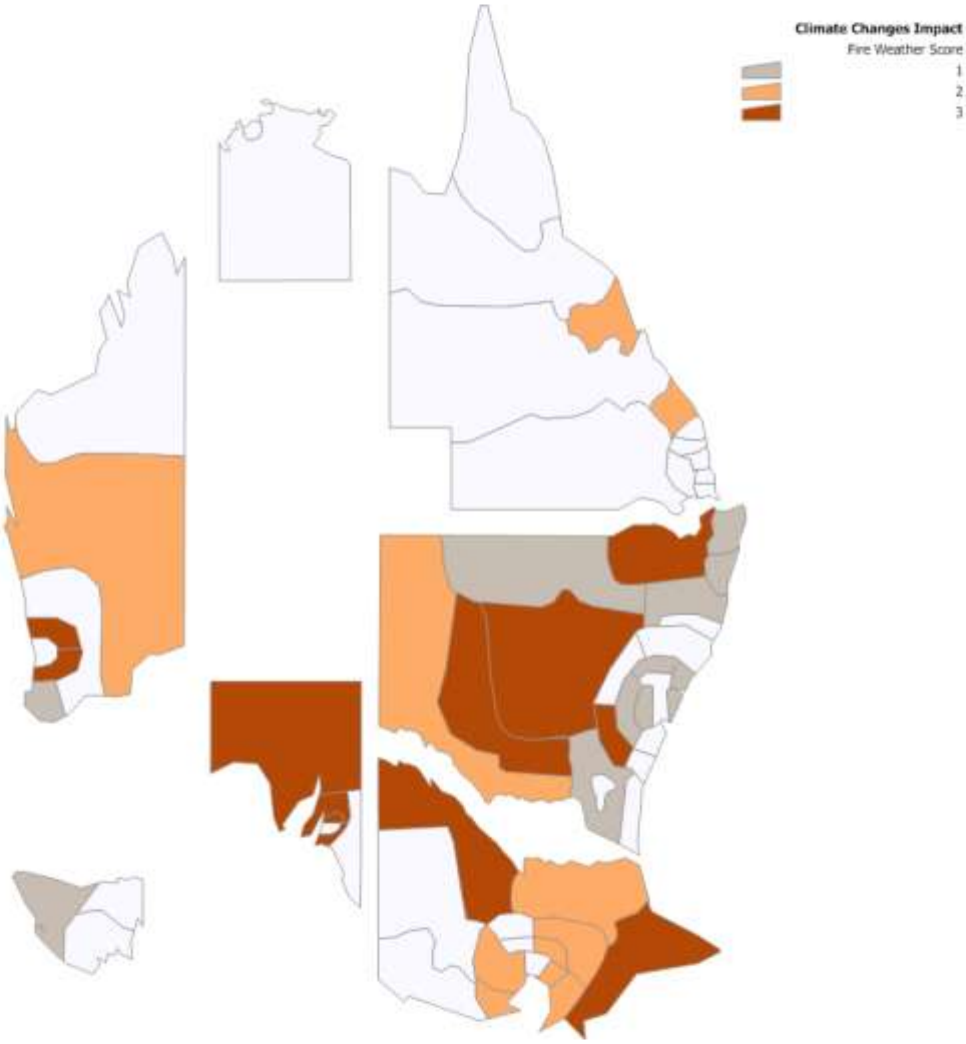


Table 5 SoR regions at risk from changing fire danger and below benchmark firefighter numbers

SoR name	Fire weather score	Firefighters	Population	Asset value ($m)	FF per 100,000 residents	FF per $b assets
Adelaide North	3	266	603036	123480	44	2.16
Melbourne Eastern Outer	2	130	526666	98009	25	1.33
Melbourne Southern Outer	2	98	607715	112725	16	0.87
Melbourne Western	2	347	730448	131392	48	2.64
NSW Central West	3	59	178691	38318	33	1.53
NSW Mid North Coast	1	100	254367	52073	39	1.93
NSW Murray Far West	2	46	133843	31773	34	1.44
NSW Northern Inland	3	46	182752	40098	25	1.14
NSW Northern Rivers	1	85	287493	60093	30	1.42
NSW Orana	1	52	120811	29893	43	1.75
NSW Outer Hunter	1	84	169412	44629	50	1.89
NSW Riverina	3	62	139458	29974	44	2.06
NSW Southern Inland	1	43	208744	53543	20	0.80
Perth Outer North	3	199	546496	115361	36	1.72
Perth Outer South	3	210	560273	130885	38	1.61
QLD Mackay	2	83	170140	55741	49	1.48
QLD Wide Bay Burnett	2	101	278972	58488	36	1.73
SA Far North and West	3	11	87378	28533	13	0.40
SA Fleurieu	3	17	116770	24264	14	0.68
SA North	3	43	140027	32850	31	1.32
Sydney Northern Beaches	1	132	277657	53018	48	2.49
Sydney Outer North	1	150	452467	81851	33	1.83
Sydney Outer South West	3	207	437889	74483	47	2.78
TAS North West	1	41	113779	27463	36	1.49
VIC Geelong	2	101	216968	47231	47	2.14
VIC Gippsland	3	129	258565	78818	50	1.64
VIC Hume	2	111	265827	59001	42	1.88
VIC Loddon Mallee	3	90	308745	62446	29	1.44
WA Gascoyne Goldfields	2	41	123840	54783	34	0.76
WA Peel South West	1	80	266766	67942	30	1.18
Totals		**3164**	**8765995**	**1899158**	**36**	**1.67**

Figure 11: Regions currently below population/firefighter benchmark and climate change impact score



6. Forecasting the future

Forecasting future demand and the potential shortfall of resources to deal with the impacts of climate change and extreme weather first requires understanding the current trajectory of firefighter employment. Using ABS Census data introduced in Chapter 4 NIEIR has developed a business as usual projection based on maintaining current relationships with asset values and population after allowing for some productivity gain.

Table 6 Baseline projections based on growth in population and assets after allowing for productivity

	2010	2015	2020	2025	2030
NSW	3604	3999	4424	4706	4991
VIC	2423	2776	3131	3372	3713
QLD	2248	2695	3202	3559	4047
SA	819	929	998	1061	1139
WA	989	1305	1559	1749	2022
TAS	301	327	337	350	367
NT	235	285	342	412	457
ACT	310	353	396	433	472
AUST	**10930**	**12670**	**14389**	**15641**	**17207**

Source: NIEIR based on ABS 2013 firefighters and NIEIR forecast growth in population and replacement asset value.

In the base case (above), firefighters need to grow at an annual rate of between two and three percent in line with the economic cycle. This means that the number of employed firefighters (all firefighters) needs to grow approximately 50 per cent over the 20 year period between 2010 and 2030 to maintain parity with population and asset growth. In this scenario, growth is in line with expectations for state growth with WA growing at roughly twice the national average over the period and Tasmania at half the national rate.

Including climate change impact requires some additional work. Lucas et al (Lucas, 2007) has provided the only work that attempts to forecast changes in fire weather based on IPCC/CSIRO climate change scenarios. Forecasts are made for a range of variables however for this study forecast days where the FFDI is in excess of 50 have been chosen for reasons that will become apparent shortly. The Lucas et al project was confined to the South East of Australia. For this study, South East Australian sites have been matched with regions in the west and the north based on rainfall, temperature and humidity. This is somewhat arbitrary but the main relevance is for including South West Australia in order to interpret how this would impact the workload of firefighters nationally.

To establish the relationship between changes in the FFDI and firefighter workload, a time series of Total Fire Ban (TFB) days for Victoria was developed from data sourced from the CFA web site. TFB days are generally declared when the FFDI is predicted to be in excess of 50. This time series was then correlated with a series of data obtained from the Productivity Commission (SCRGSP, 2012) on the incidence of fires and other activities that require the attention of firefighters. This shows a strong relationship between TFB days and fire activity, particularly landscape fire. These relationships were then applied to the data from Lucas et al to understand how changes in predicted extreme weather would impact the need for fire services. The relationship between increase fire activity and demand for firefighters has been estimated at this stage. The ratio was applied at a regional level in order to accommodate regional variation and further adjusted to reflect areas where landscape fires would be less common (inner urban areas) or treated differently i.e. arid zones. Climate Change scenarios used were the two higher scenarios used by Lucas et al (2007) given comments in Chapter 1 that anticipate the planet is heading toward the higher end of expectations. The outcomes are summarised below. A complete table of outcomes for the two scenarios in each SOR region is attached as Appendix 3.

Table 7 Forecast demand for firefighters based on climate change scenarios

	Base	H2 Scenario		H3 Scenario	
	2012	2020	2030	2020	2030
NSW	3826	4741	5728	5175	6759
VIC	2648	3405	4296	3564	4697
QLD	2525	3529	4951	3529	4892
SA	906	1098	1354	1196	1611
WA	1225	1693	2334	1751	2494
TAS	321	337	367	337	395
NT	255	369	522	383	560
ACT	334	435	586	455	656
AUST	**12041**	**15607**	**20136**	**16391**	**22065**

Neither this project nor Lucas, 2007 were able to deal adequately with the relationship between vegetation and fire activity. For that reason, little attention should be paid to the impacts in Australia's arid regions where approaches to managing fires are quite different to the grassy plains and more forested areas. Although as noted above, the results for arid areas and inner urban areas were adjusted so as not to overstate outcomes. The overall outcome of this calculation is that Australia would require 15,000 to 16,000 firefighters by 2020 and 16 to 22,000 firefighters by 2030 to meet demand from climate change and growth.

It should be borne in mind however that the above calculation deals with increases in fire weather and not the issue of longer fire seasons and the potential impact of longer seasons on both paid and volunteer firefighters. As identified in the previous Chapter, quite a large number of regions face the prospect of longer fire seasons.

NIEIR is not aware of any work that would allow this study to adequately consider the impact of cyclones on firefighters in tropical areas. This will require further work nevertheless it should be noted as a consideration.

The growth rates proposed in this study are not excessive and indeed it could be argued are quite modest. While the modelled baseline growth was driven by asset values and population from the existing base it did not adjust for any of the flaws in the baseline. In other words we did not attempt to adjust for weaknesses in the current provision of emergency services. Between 24 and 26 of the 67 SoR regions still remain below the benchmark of 50 firefighters per 100,000 resident population in 2020 and 2030 (it varies slightly with scenario). The ratio of firefighters to population and assets moves up slightly for both scenarios by 2030 to accommodate extreme weather events. In contrast, if annual recruitment patterns exhibited for the past five years (SCRGSP, 2012) are maintained, these ratios move in the opposite direction as shown in Table 8 below.

Table 8 Outcomes existing spending pattern, high and low climate change scenario

	2013	2030		
	Base	Current growth	H2 scenario	H3 scenario
Population ratio	53	46	70	76
Asset ratio	1.8	1.65	2.5	2.7

Current recruitment patterns will diminish fire fighting resources during a period when governments are expecting them to do more, when extreme weather is placing additional demands on services and when those same demands are making it difficult to maintain engaged volunteers.

From a risk management perspective, at a time when the risk of loss of life, or injury or loss of property is increasing the ability to address that risk will be diminishing. One way to illustrate this is to say that the difference between the Base Case forecasts in this report (which are already higher than the current growth in recruitment) and the H2 Scenario would be that an additional 5.5 million Australians and $1.5 trillion in assets would receive adequate (>50 firefighters per 100,000) protection in 2030. The difference between the Base Case and the H3 Scenario would be than an additional 8 million Australians and $2 trillion in assets would receive adequate protection in 2030. Failure to achieve these benchmarks of course means the reverse, that these people and assets are not adequately protected. While there is scope to undertake more research in this area to better understand these relationships and thereby improve forecasting, the number of people at risk and the value of assets at risk would suggest that this additional research is a small price to pay for improved risk management. This research would allow appropriate benchmarks to be set and recruitment targets developed in order to protect the community and allow for sound workforce planning.

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Appendix 1

Figure A.1: New South Wales – Firefighters per 100,000 residents

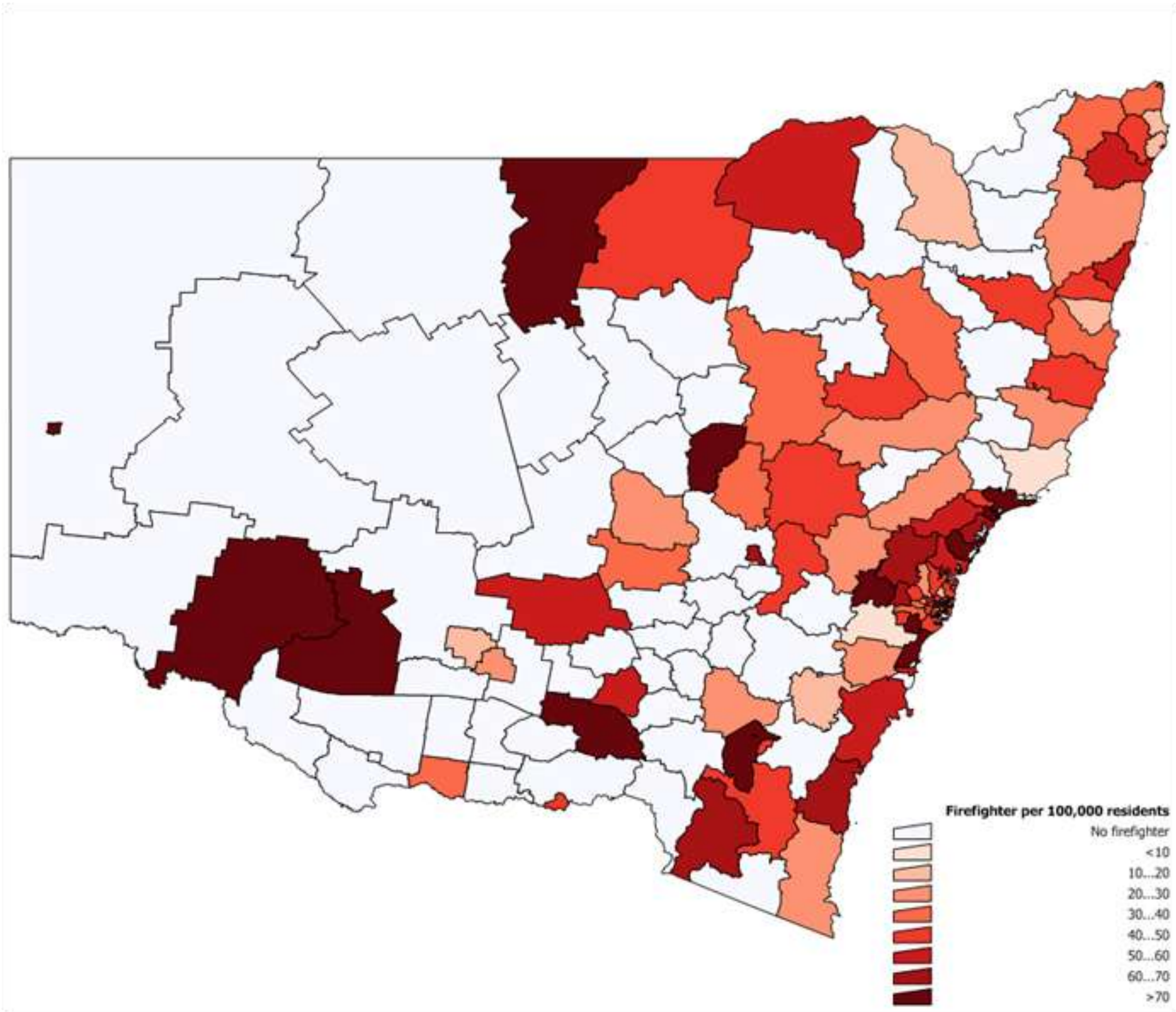


Figure A.2: New South Wales – Firefighters per $ billion assets

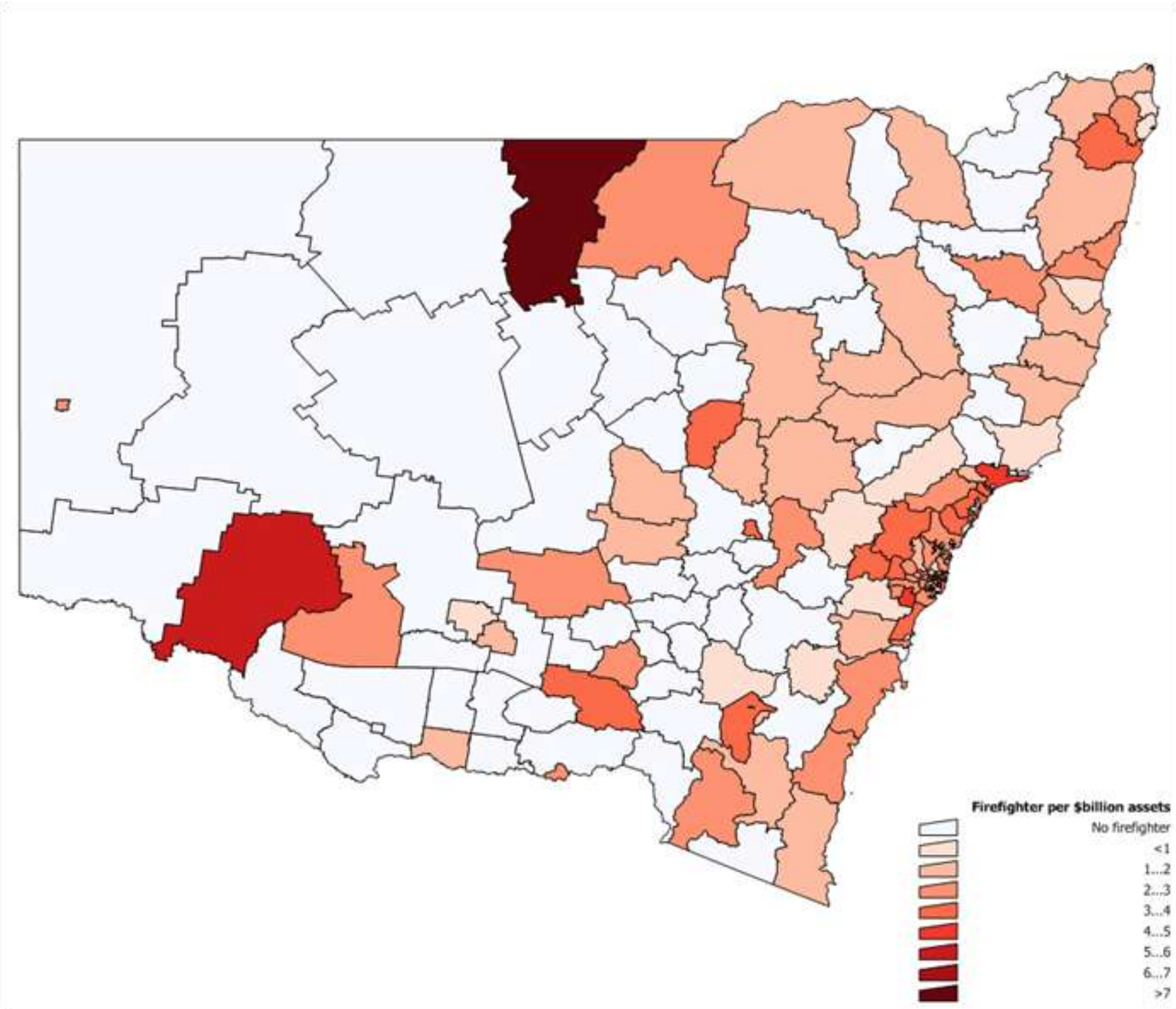


Figure A.3: Victoria – Firefighters per 100,000 residents

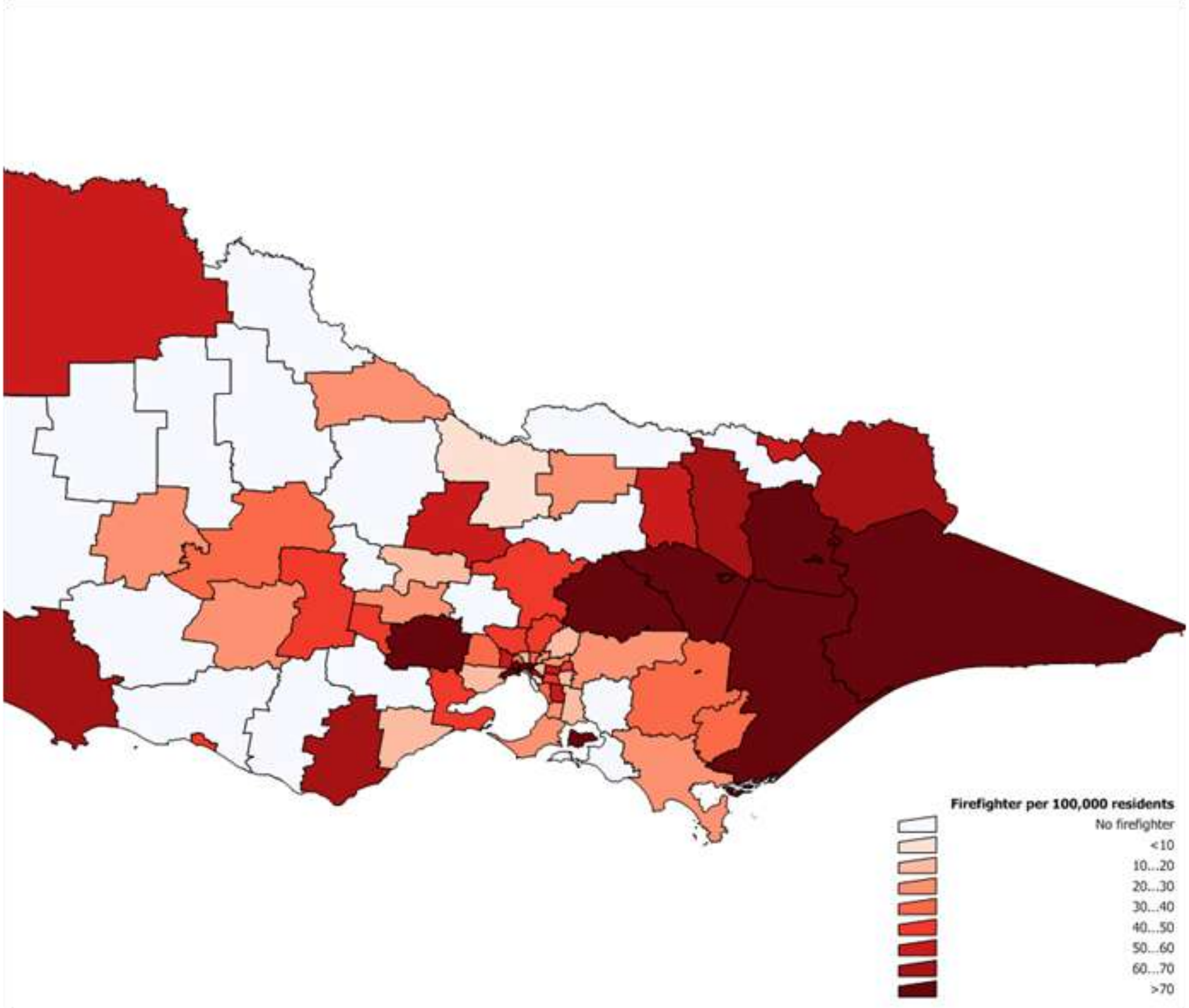


Figure A.4: Victoria – Firefighters per $ billion assets

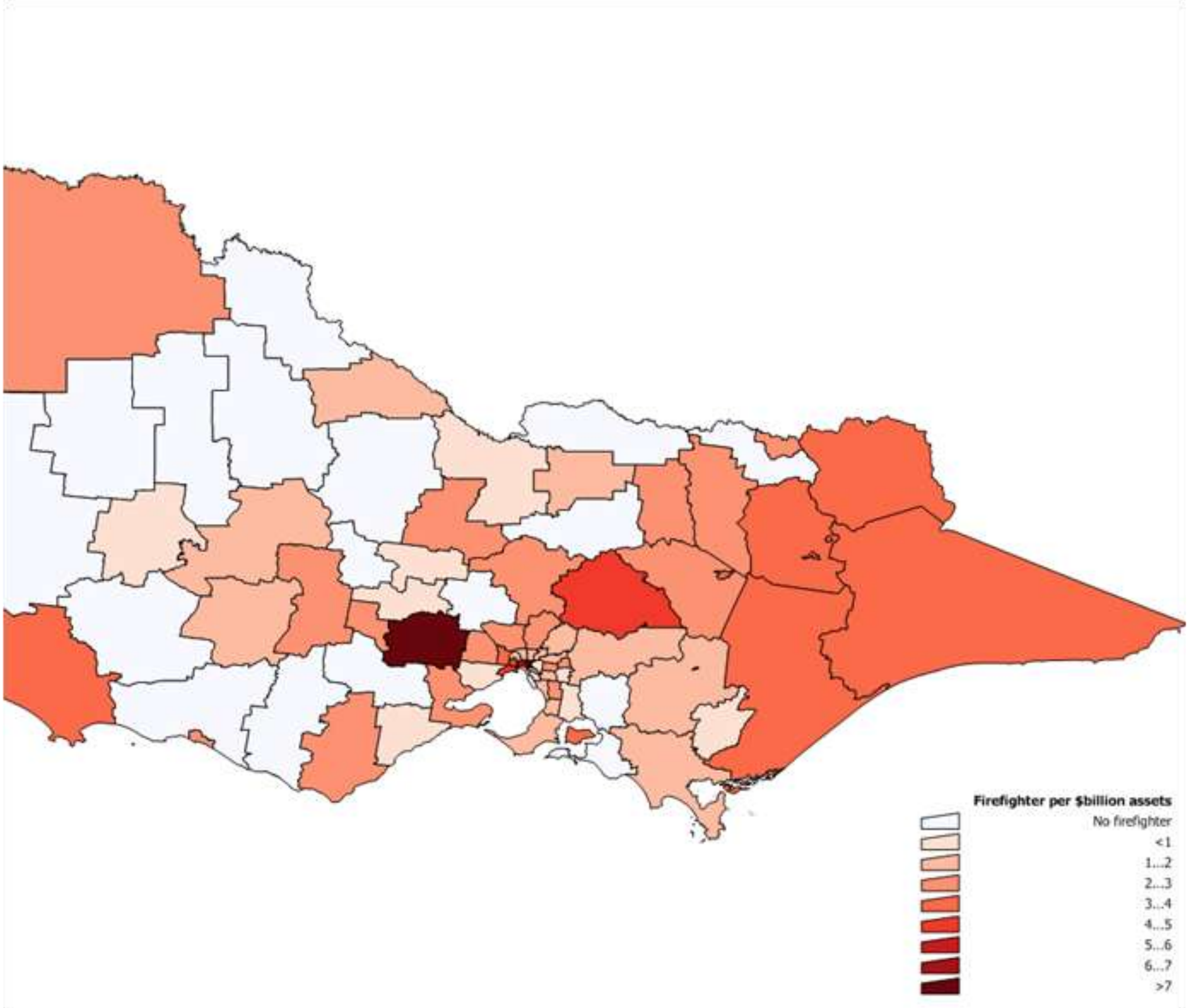


Figure A.5: Queensland – Firefighters per 100,000 residents

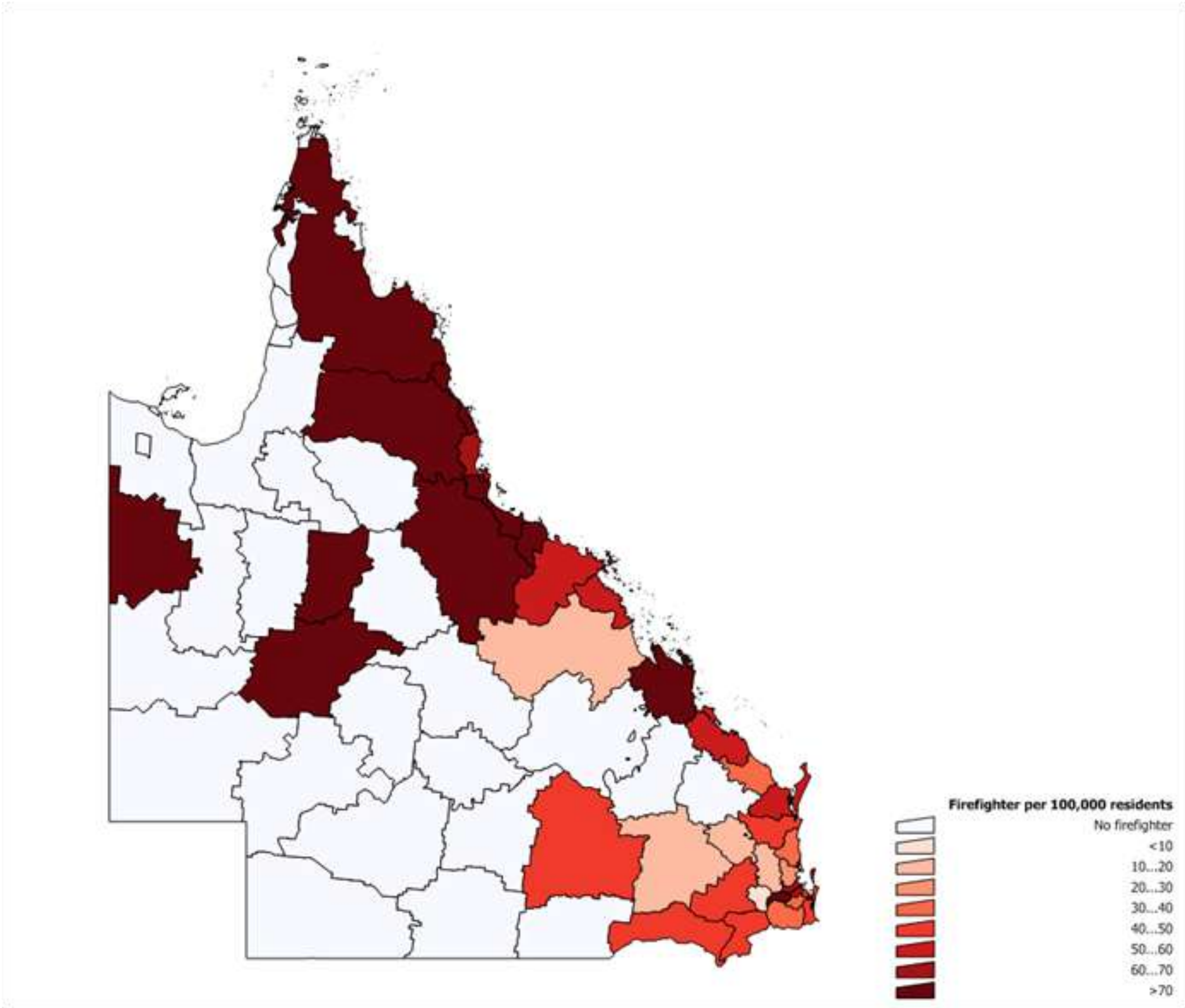


Figure A.6: Queensland – Firefighters per $ billion assets

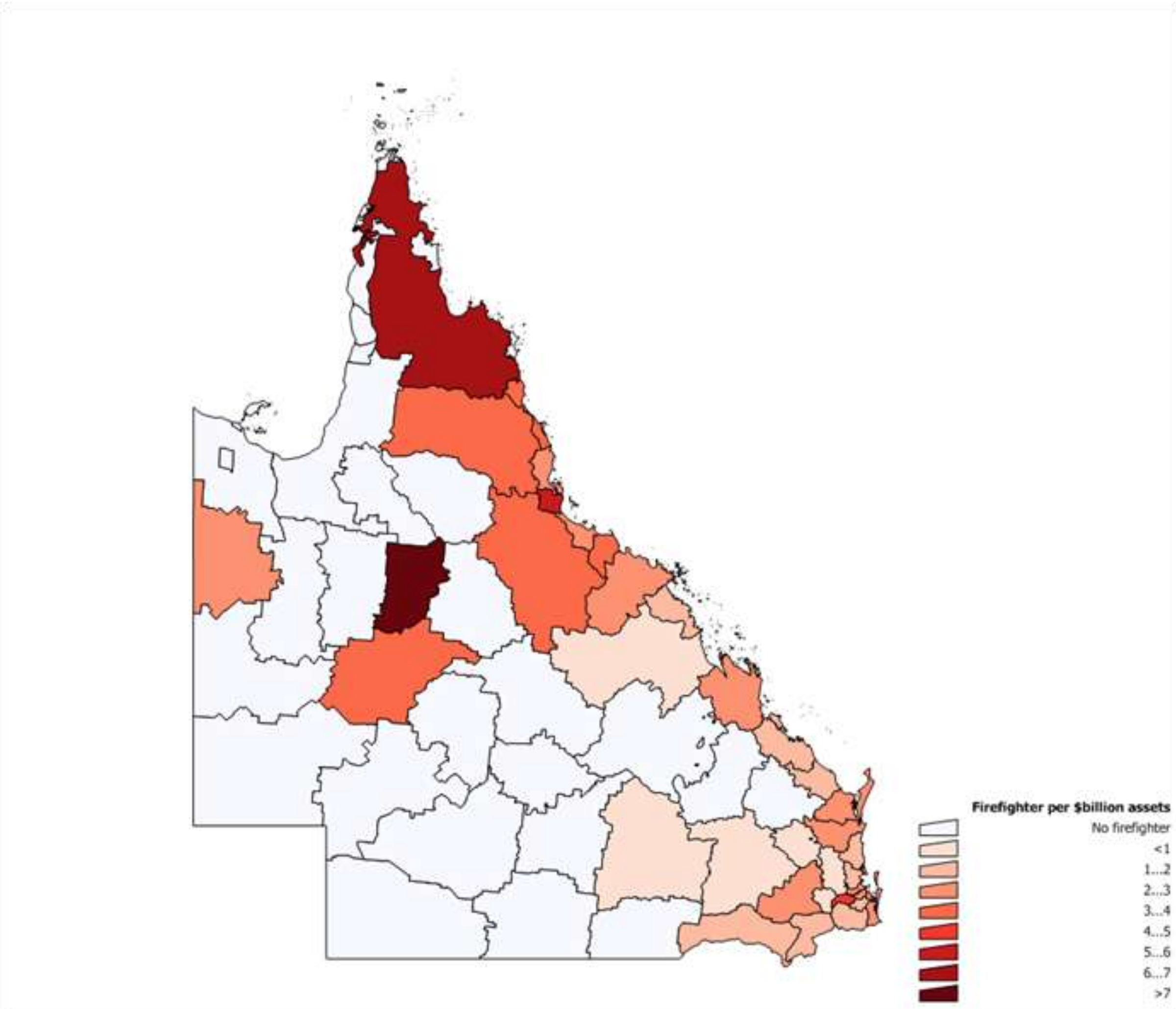


Figure A.7: South Australia – Firefighters per 100,000 residents

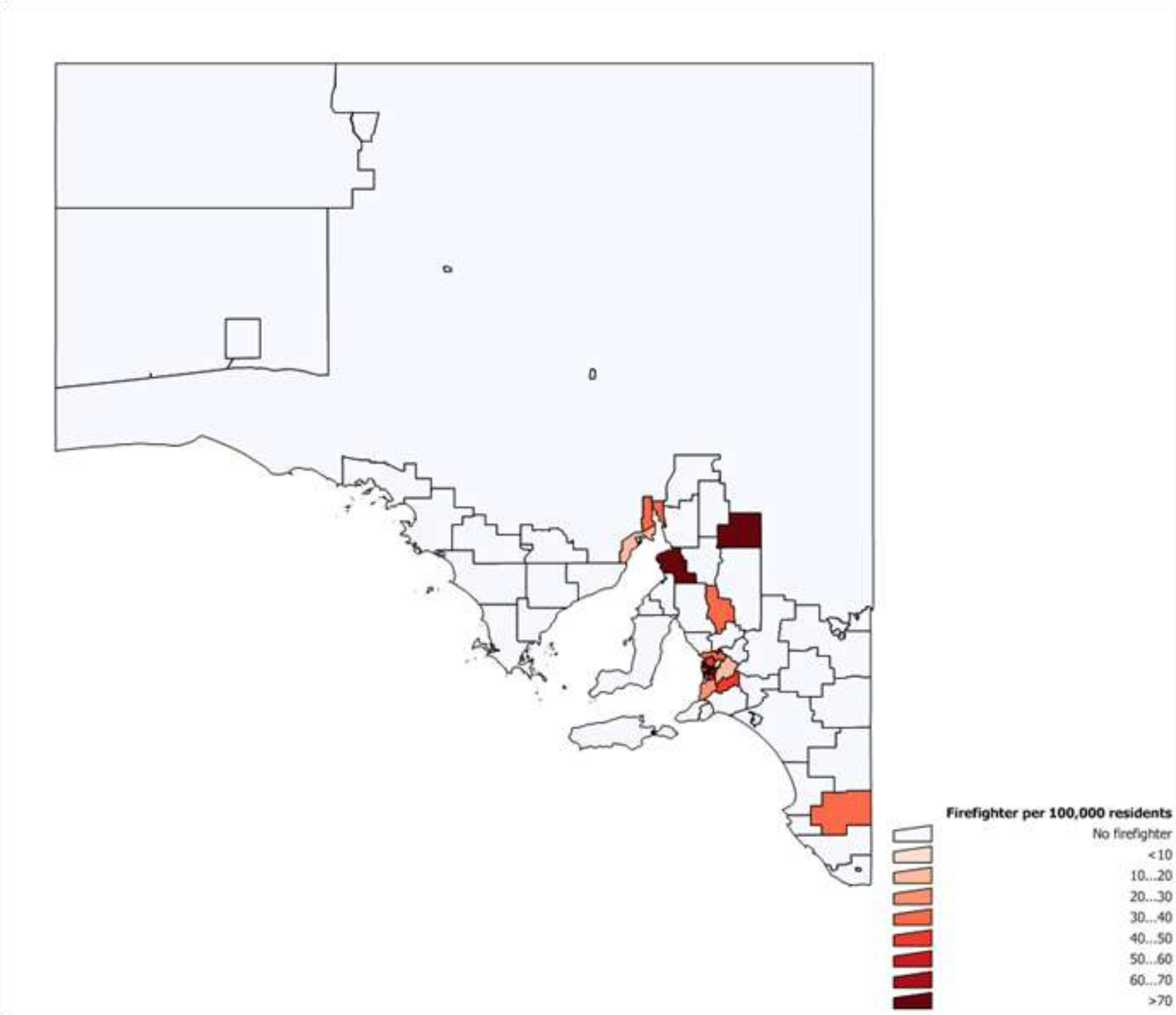


Figure A.8: South Australia – Firefighters per $ billion assets

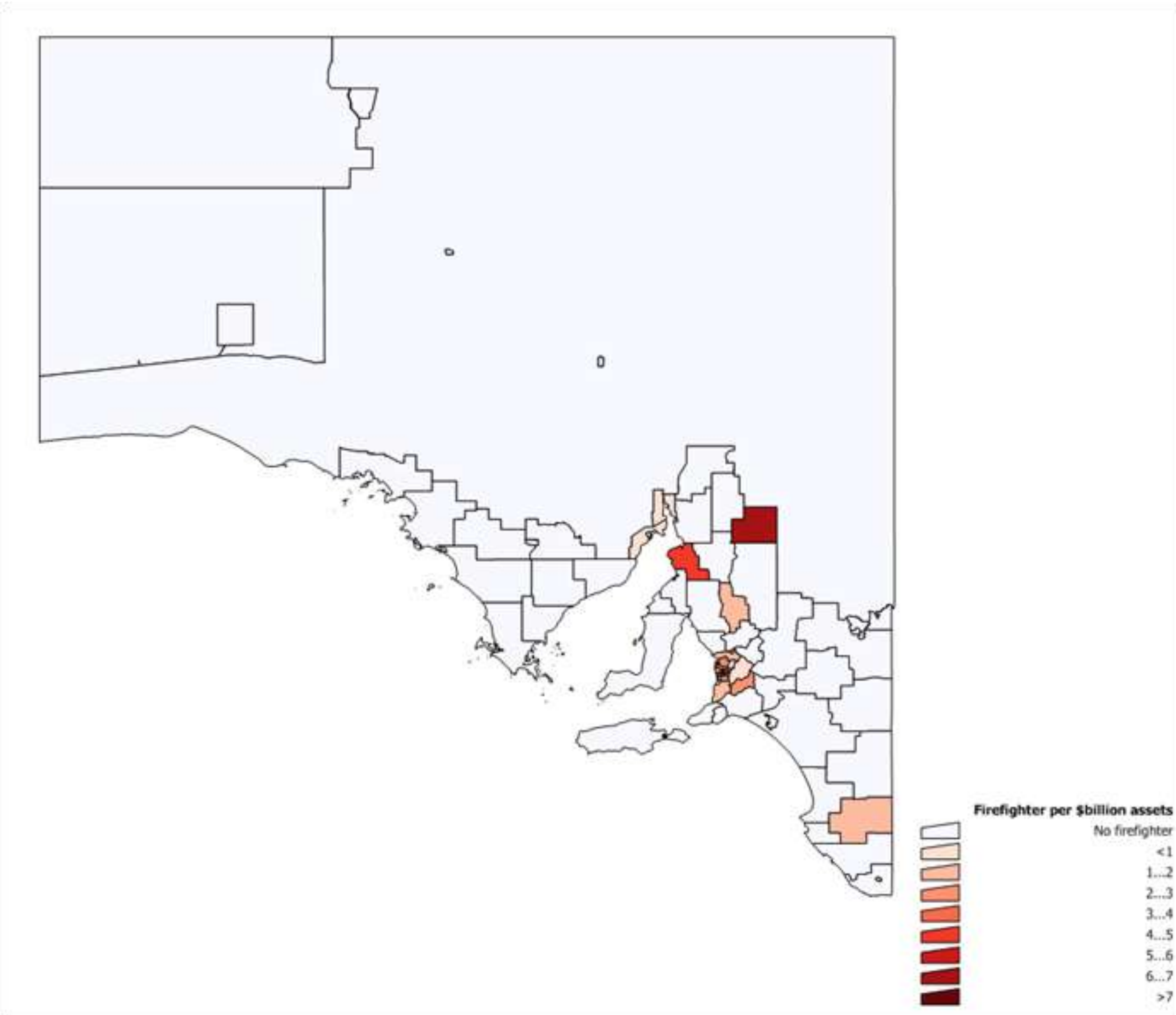


Figure A.9: Western Australia – Firefighters per 100,000 residents

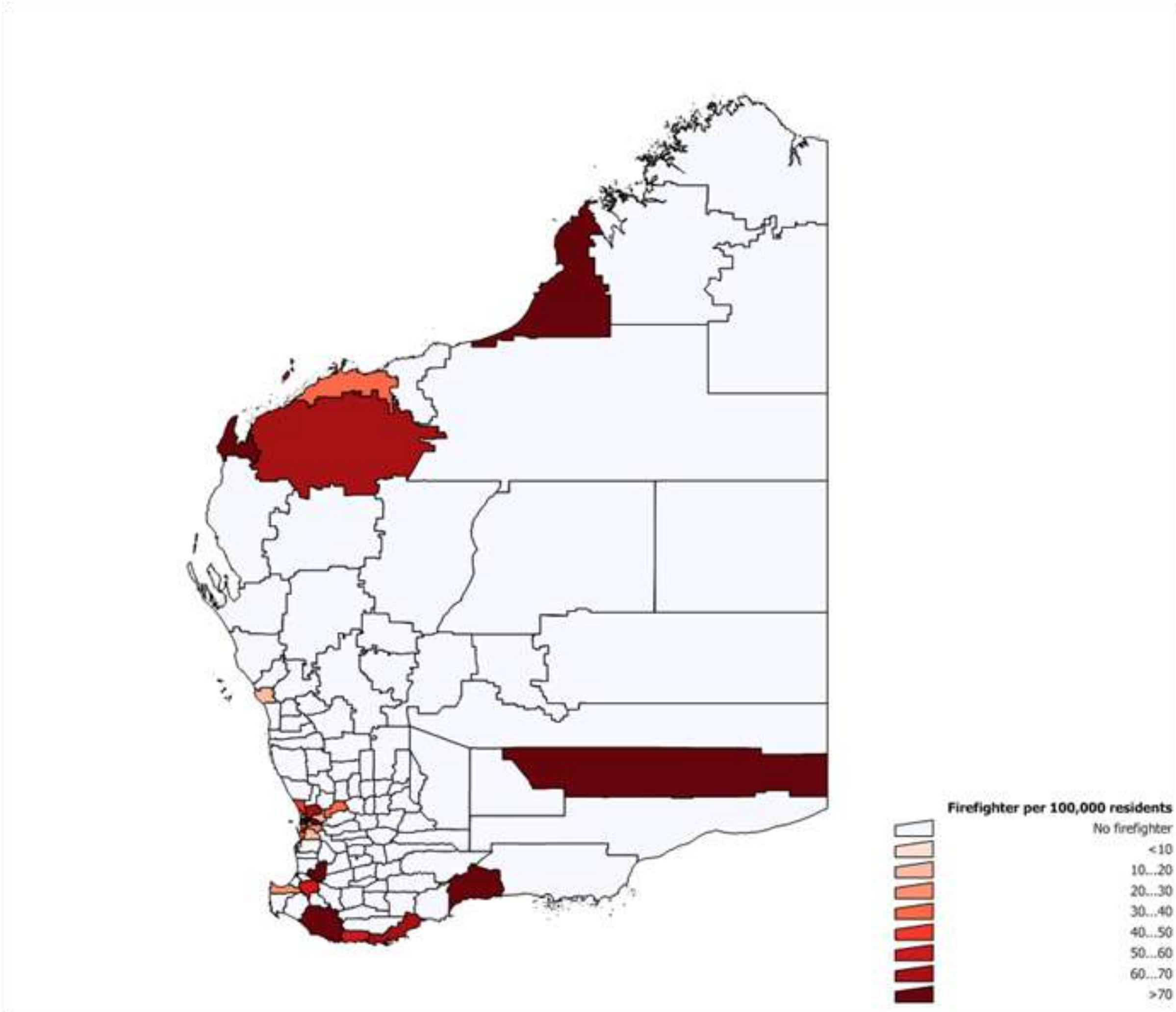


Figure A.10: Western Australia – Firefighters per $ billion assets

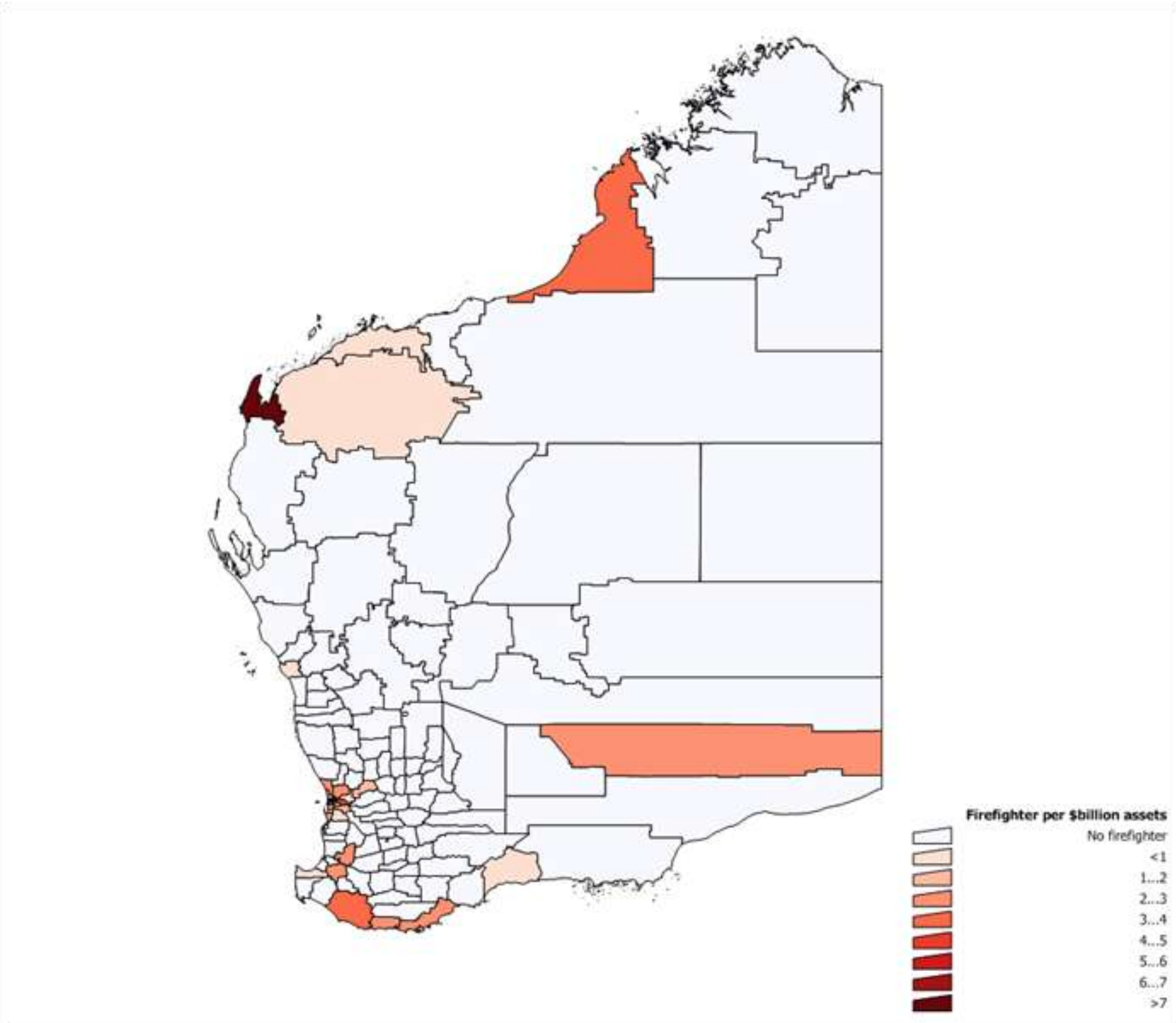


Figure A.11: Tasmania – Firefighters per 100,000 residents

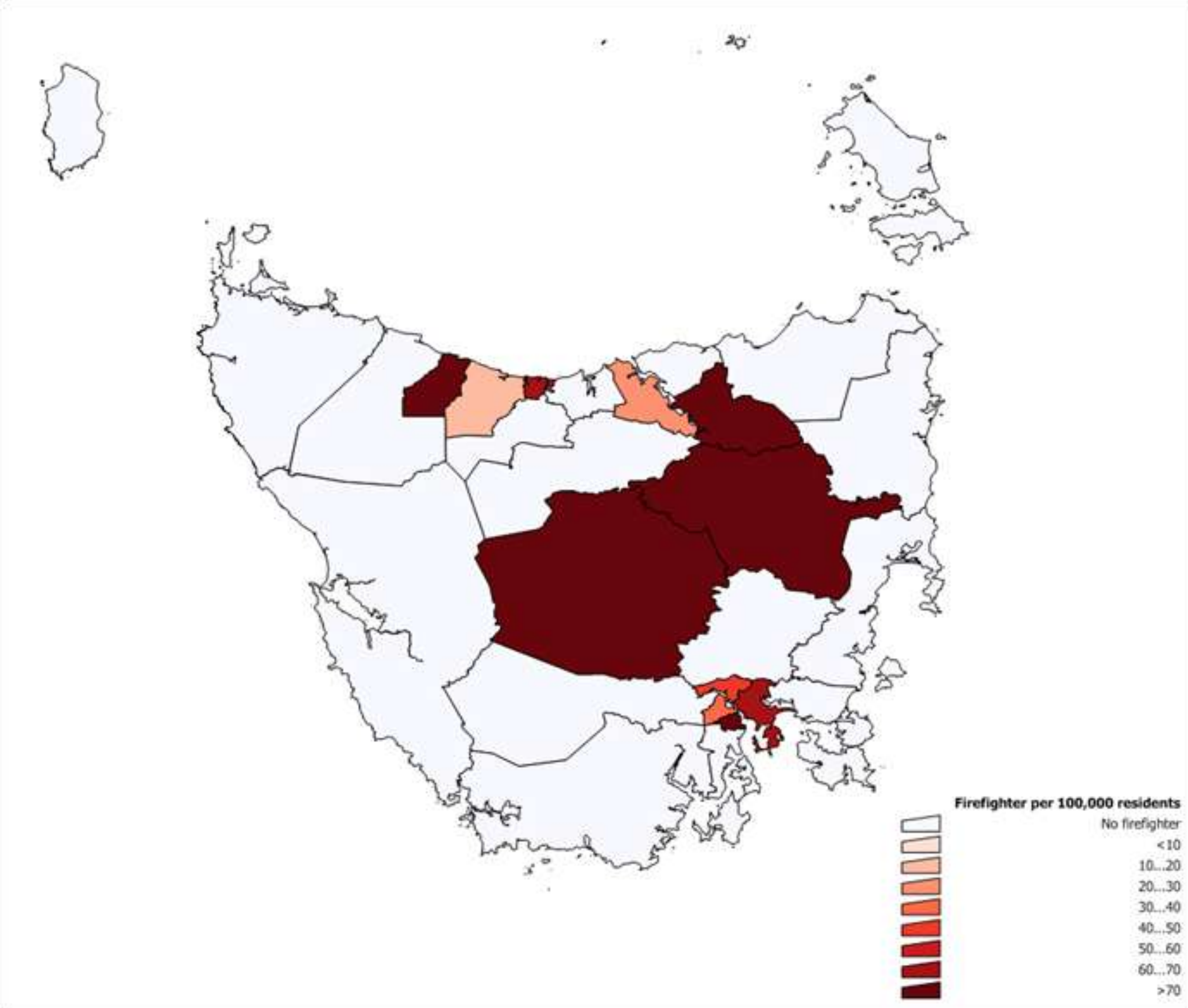
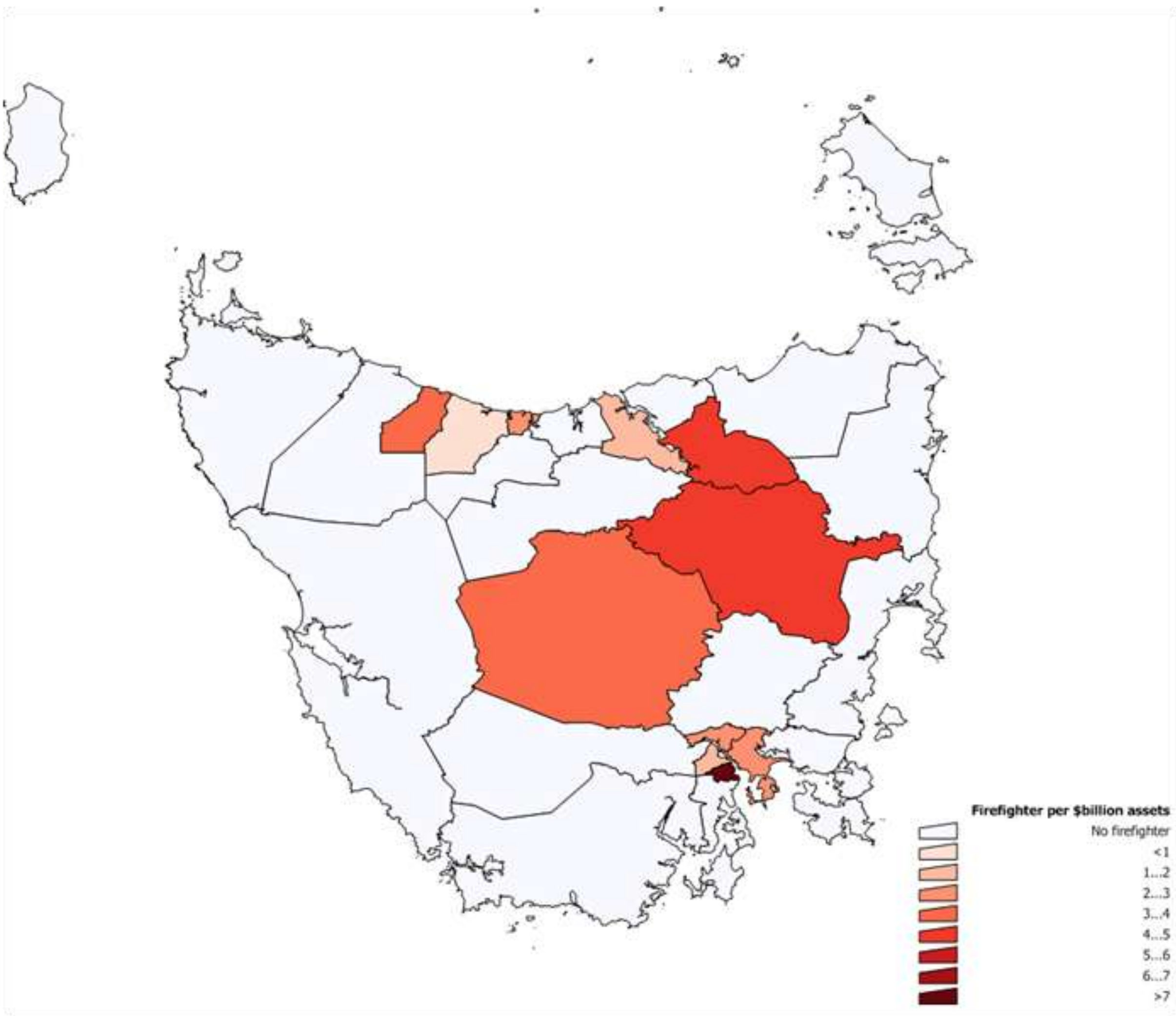


Figure A.12: Tasmania – Firefighters per $ billion assets



Appendix 2

Local Government Area	SoR Region
Albury (C)	NSW Murray Far West
Armidale Dumaresq (A)	NSW Northern Inland
Ashfield (A)	Sydney Old West
Auburn (C)	Sydney Parramatta Bankstown
Ballina (A)	NSW Northern Rivers
Balranald (A)	NSW Murray Far West
Bankstown (C)	Sydney Parramatta Bankstown
Bathurst Regional (A)	NSW Central West
The Hills Shire (A)	Sydney Outer North
Bega Valley (A)	NSW South Coast
Bellingen (A)	NSW Mid North Coast
Berrigan (A)	NSW Murray Far West
Blacktown (C)	Sydney Outer West
Bland (A)	NSW Central West
Blayney (A)	NSW Central West
Blue Mountains (C)	Sydney Outer West
Bogan (A)	NSW Orana
Bombala (A)	NSW Southern Inland
Boorowa (A)	NSW Southern Inland
Botany Bay (C)	Sydney Central
Bourke (A)	NSW Orana
Brewarrina (A)	NSW Orana
Broken Hill (C)	NSW Murray Far West
Burwood (A)	Sydney Old West
Byron (A)	NSW Northern Rivers
Cabonne (A)	NSW Central West
Camden (A)	Sydney Outer South West
Campbelltown (C)	Sydney Outer South West
Canada Bay (A)	Sydney Central
Canterbury (C)	Sydney Old West
Carrathool (A)	NSW Riverina
Central Darling (A)	NSW Murray Far West
Cessnock (C)	NSW Newcastle
Clarence Valley (A)	NSW Northern Rivers
Cobar (A)	NSW Orana
Coffs Harbour (C)	NSW Mid North Coast
Conargo (A)	NSW Murray Far West
Coolamon (A)	NSW Riverina
Cooma-Monaro (A)	NSW Southern Inland
Coonamble (A)	NSW Orana
Cootamundra (A)	NSW Riverina
Corowa Shire (A)	NSW Murray Far West

Local Government Area	SoR Region
Cowra (A)	NSW Central West
Deniliquin (A)	NSW Murray Far West
Dubbo (C)	NSW Orana
Dungog (A)	NSW Outer Hunter
Eurobodalla (A)	NSW South Coast
Fairfield (C)	Sydney Parramatta Bankstown
Forbes (A)	NSW Central West
Gilgandra (A)	NSW Orana
Glen Innes Severn (A)	NSW Northern Inland
Gloucester (A)	NSW Outer Hunter
Gosford (C)	NSW Central Coast
Goulburn Mulwaree (A)	NSW Southern Inland
Greater Taree (C)	NSW Mid North Coast
Greater Hume Shire (A)	NSW Murray Far West
Great Lakes (A)	NSW Outer Hunter
Griffith (C)	NSW Riverina
Gundagai (A)	NSW Southern Inland
Gunnedah (A)	NSW Northern Inland
Guyra (A)	NSW Northern Inland
Gwydir (A)	NSW Northern Inland
Harden (A)	NSW Southern Inland
Hawkesbury (C)	Sydney Outer West
Hay (A)	NSW Riverina
Holroyd (C)	Sydney Parramatta Bankstown
Hornsby (A)	Sydney Outer North
Hunters Hill (A)	Sydney Central
Hurstville (C)	Sydney South
Inverell (A)	NSW Northern Inland
Jerilderie (A)	NSW Murray Far West
Junee (A)	NSW Riverina
Kempsey (A)	NSW Mid North Coast
Kiama (A)	NSW Illawarra
Kogarah (C)	Sydney South
Ku-ring-gai (A)	Sydney Outer North
Kyogle (A)	NSW Northern Rivers
Lachlan (A)	NSW Central West
Lake Macquarie (C)	NSW Newcastle
Lane Cove (A)	Sydney Central
Leeton (A)	NSW Riverina
Leichhardt (A)	Sydney Central
Lismore (C)	NSW Northern Rivers
Lithgow (C)	NSW Central West
Liverpool (C)	Sydney Outer South West
Liverpool Plains (A)	NSW Northern Inland
Lockhart (A)	NSW Riverina
Maitland (C)	NSW Newcastle

Local Government Area	SoR Region
Manly (A)	Sydney Northern Beaches
Marrickville (A)	Sydney Old West
Mid-Western Regional (A)	NSW Orana
Moree Plains (A)	NSW Northern Inland
Mosman (A)	Sydney Northern Beaches
Murray (A)	NSW Murray Far West
Murrumbidgee (A)	NSW Riverina
Muswellbrook (A)	NSW Outer Hunter
Nambucca (A)	NSW Mid North Coast
Narrabri (A)	NSW Northern Inland
Narrandera (A)	NSW Riverina
Narromine (A)	NSW Orana
Newcastle (C)	NSW Newcastle
North Sydney (A)	Sydney Central
Oberon (A)	NSW Central West
Orange (C)	NSW Central West
Palerang (A)	NSW Southern Inland
Parkes (A)	NSW Central West
Parramatta (C)	Sydney Parramatta Bankstown
Penrith (C)	Sydney Outer West
Pittwater (A)	Sydney Northern Beaches
Port Macquarie-Hastings (A)	NSW Mid North Coast
Port Stephens (A)	NSW Outer Hunter
Queanbeyan (C)	NSW Southern Inland
Randwick (C)	Sydney Eastern Beaches
Richmond Valley (A)	NSW Northern Rivers
Rockdale (C)	Sydney South
Ryde (C)	Sydney Central
Shellharbour (C)	NSW Illawarra
Shoalhaven (C)	NSW South Coast
Singleton (A)	NSW Outer Hunter
Snowy River (A)	NSW Southern Inland
Strathfield (A)	Sydney Old West
Sutherland Shire (A)	Sydney South
Sydney (C)	Sydney Central
Tamworth Regional (A)	NSW Northern Inland
Temora (A)	NSW Riverina
Tenterfield (A)	NSW Northern Inland
Tumbarumba (A)	NSW Southern Inland
Tumut Shire (A)	NSW Southern Inland
Tweed (A)	NSW Northern Rivers
Upper Hunter Shire (A)	NSW Outer Hunter
Upper Lachlan Shire (A)	NSW Southern Inland
Uralla (A)	NSW Northern Inland
Urana (A)	NSW Murray Far West
Wagga Wagga (C)	NSW Riverina

Local Government Area	SoR Region
Wakool (A)	NSW Murray Far West
Walcha (A)	NSW Northern Inland
Walgett (A)	NSW Orana
Warren (A)	NSW Orana
Warringah (A)	Sydney Northern Beaches
Warrumbungle Shire (A)	NSW Orana
Waverley (A)	Sydney Eastern Beaches
Weddin (A)	NSW Central West
Wellington (A)	NSW Orana
Wentworth (A)	NSW Murray Far West
Willoughby (C)	Sydney Central
Wingecarribee (A)	NSW Southern Inland
Wollondilly (A)	Sydney Outer South West
Wollongong (C)	NSW Illawarra
Woollahra (A)	Sydney Eastern Beaches
Wyong (A)	NSW Central Coast
Yass Valley (A)	NSW Southern Inland
Young (A)	NSW Southern Inland
Unincorporated NSW	NSW Murray Far West
Alpine (S)	VIC Hume
Ararat (RC)	VIC Grampians
Ballarat (C)	VIC Grampians
Banyule (C)	Melbourne Northern Inner
Bass Coast (S)	VIC Gippsland
Baw Baw (S)	VIC Gippsland
Bayside (C)	Melbourne Southern Inner
Benalla (RC)	VIC Hume
Boroondara (C)	Melbourne Eastern Inner
Brimbank (C)	Melbourne Western
Buloke (S)	VIC Loddon Mallee
Campaspe (S)	VIC Loddon Mallee
Cardinia (S)	Melbourne Southern Outer
Casey (C)	Melbourne Southern Outer
Central Goldfields (S)	VIC Loddon Mallee
Colac-Otway (S)	VIC South West
Corangamite (S)	VIC South West
Darebin (C)	Melbourne Northern Inner
East Gippsland (S)	VIC Gippsland
Frankston (C)	Melbourne Southern Outer
Gannawarra (S)	VIC Loddon Mallee
Glen Eira (C)	Melbourne Southern Inner
Glenelg (S)	VIC South West
Golden Plains (S)	VIC Grampians
Greater Bendigo (C)	VIC Loddon Mallee
Greater Dandenong (C)	Melbourne Southern Inner
Greater Geelong (C)	VIC Geelong

Local Government Area	SoR Region
Greater Shepparton (C)	VIC Hume
Hepburn (S)	VIC Grampians
Hindmarsh (S)	VIC Grampians
Hobsons Bay (C)	Melbourne Western
Horsham (RC)	VIC Grampians
Hume (C)	Melbourne Northern Outer
Indigo (S)	VIC Hume
Kingston (C)	Melbourne Southern Inner
Knox (C)	Melbourne Eastern Outer
Latrobe (C)	VIC Gippsland
Loddon (S)	VIC Loddon Mallee
Macedon Ranges (S)	VIC Loddon Mallee
Manningham (C)	Melbourne Eastern Outer
Mansfield (S)	VIC Hume
Maribyrnong (C)	Melbourne Western
Maroondah (C)	Melbourne Eastern Outer
Melbourne (C)	Melbourne City
Melton (S)	Melbourne Western
Mildura (RC)	VIC Loddon Mallee
Mitchell (S)	VIC Hume
Moira (S)	VIC Hume
Monash (C)	Melbourne Eastern Inner
Moonee Valley (C)	Melbourne Western
Moorabool (S)	VIC Grampians
Moreland (C)	Melbourne Northern Inner
Mornington Peninsula (S)	Melbourne Southern Outer
Mount Alexander (S)	VIC Loddon Mallee
Moyne (S)	VIC South West
Murrindindi (S)	VIC Hume
Nillumbik (S)	Melbourne Northern Outer
Northern Grampians (S)	VIC Grampians
Port Phillip (C)	Melbourne Southern Inner
Pyrenees (S)	VIC Grampians
Queenscliffe (B)	VIC Geelong
South Gippsland (S)	VIC Gippsland
Southern Grampians (S)	VIC South West
Stonnington (C)	Melbourne Southern Inner
Strathbogie (S)	VIC Hume
Surf Coast (S)	VIC South West
Swan Hill (RC)	VIC Loddon Mallee
Towong (S)	VIC Hume
Wangaratta (RC)	VIC Hume
Warrnambool (C)	VIC South West
Wellington (S)	VIC Gippsland
West Wimmera (S)	VIC Grampians
Whitehorse (C)	Melbourne Eastern Inner

Local Government Area	SoR Region
Whittlesea (C)	Melbourne Northern Outer
Wodonga (RC)	VIC Hume
Wyndham (C)	Melbourne Western
Yarra (C)	Melbourne Northern Inner
Yarra Ranges (S)	Melbourne Eastern Outer
Yarriambiack (S)	VIC Grampians
Unincorporated Vic	VIC Gippsland
Aurukun (S)	QLD Far North Torres
Balonne (S)	QLD Darling Downs South West
Banana (S)	QLD Fitzroy Central West
Barcaldine (R)	QLD Fitzroy Central West
Barcoo (S)	QLD Fitzroy Central West
Blackall Tambo (R)	QLD Fitzroy Central West
Boulia (S)	QLD Townsville North West
Brisbane (C)	SEQ Brisbane City
Bulloo (S)	QLD Darling Downs South West
Bundaberg (R)	QLD Wide Bay Burnett
Burdekin (S)	QLD Townsville North West
Burke (S)	QLD Townsville North West
Cairns (R)	QLD Far North Torres
Carpentaria (S)	QLD Townsville North West
Cassowary Coast (R)	QLD Far North Torres
Central Highlands (R)	QLD Fitzroy Central West
Charters Towers (R)	QLD Townsville North West
Cherbourg (S)	QLD Wide Bay Burnett
Cloncurry (S)	QLD Townsville North West
Cook (S)	QLD Far North Torres
Croydon (S)	QLD Far North Torres
Dalby (R)	QLD Darling Downs South West
Diamantina (S)	QLD Fitzroy Central West
Doomadgee (S)	QLD Townsville North West
Etheridge (S)	QLD Far North Torres
Flinders (S)	QLD Townsville North West
Fraser Coast (R)	QLD Wide Bay Burnett
Gladstone (R)	QLD Fitzroy Central West
Gold Coast (C)	SEQ Gold Coast
Goondiwindi (R)	QLD Darling Downs South West
Gympie (R)	QLD Wide Bay Burnett
Hinchinbrook (S)	QLD Townsville North West
Hope Vale (S)	QLD Far North Torres
Ipswich (C)	SEQ West Moreton
Isaac (R)	QLD Mackay
Kowanyama (S)	QLD Far North Torres
Lockhart River (S)	QLD Far North Torres
Lockyer Valley (R)	SEQ West Moreton
Logan (C)	SEQ Logan Redland

Local Government Area	SoR Region
Longreach (R)	QLD Fitzroy Central West
Mackay (R)	QLD Mackay
McKinlay (S)	QLD Townsville North West
Mapoon (S)	QLD Far North Torres
Moreton Bay (R)	SEQ Moreton Bay
Mornington (S)	QLD Townsville North West
Mount Isa (C)	QLD Townsville North West
Murweh (S)	QLD Darling Downs South West
Napranum (S)	QLD Far North Torres
North Burnett (R)	QLD Wide Bay Burnett
Northern Peninsula Area (R)	QLD Far North Torres
Palm Island (S)	QLD Townsville North West
Paroo (S)	QLD Darling Downs South West
Pormpuraaw (S)	QLD Far North Torres
Quilpie (S)	QLD Darling Downs South West
Redland (C)	SEQ Logan Redland
Richmond (S)	QLD Townsville North West
Rockhampton (R)	QLD Fitzroy Central West
Roma (R)	QLD Darling Downs South West
Scenic Rim (R)	SEQ West Moreton
Somerset (R)	SEQ West Moreton
South Burnett (R)	QLD Wide Bay Burnett
Southern Downs (R)	QLD Darling Downs South West
Sunshine Coast (R)	SEQ Sunshine Coast
Tablelands (R)	QLD Far North Torres
Toowoomba (R)	QLD Darling Downs South West
Torres (S)	QLD Far North Torres
Torres Strait Island (R)	QLD Far North Torres
Townsville (C)	QLD Townsville North West
Weipa (T)	QLD Far North Torres
Whitsunday (R)	QLD Mackay
Winton (S)	QLD Fitzroy Central West
Woorabinda (S)	QLD Fitzroy Central West
Wujal Wujal (S)	QLD Far North Torres
Yarrabah (S)	QLD Far North Torres
Unincorporated QLD	No SOR
Adelaide (C)	Adelaide South
Adelaide Hills (DC)	SA Fleurieu
Alexandrina (DC)	SA Fleurieu
Anangu Pitjantjatjara (AC)	SA Far North and West
Barossa (DC)	SA North
Barunga West (DC)	SA North
Berri and Barmera (DC)	SA East
Burnside (C)	Adelaide South
Campbelltown (C)	Adelaide North
Ceduna (DC)	SA Far North and West

Local Government Area	SoR Region
Charles Sturt (C)	Adelaide North
Clare and Gilbert Valleys (DC)	SA North
Cleve (DC)	SA Far North and West
Coober Pedy (DC)	SA Far North and West
Copper Coast (DC)	SA North
Elliston (DC)	SA Far North and West
Flinders Ranges (DC)	SA Far North and West
Franklin Harbour (DC)	SA Far North and West
Gawler (T)	SA North
Goyder (DC)	SA North
Grant (DC)	SA East
Holdfast Bay (C)	Adelaide South
Kangaroo Island (DC)	SA Fleurieu
Karoonda East Murray (DC)	SA East
Kimba (DC)	SA Far North and West
Kingston (DC)	SA East
Wudinna (DC)	SA Far North and West
Light (RegC)	SA North
Lower Eyre Peninsula (DC)	SA Far North and West
Loxton Waikerie (DC)	SA East
Mallala (DC)	SA North
Maralinga Tjarutja (AC)	SA Far North and West
Marion (C)	Adelaide South
Mid Murray (DC)	SA East
Mitcham (C)	Adelaide South
Mount Barker (DC)	SA Fleurieu
Mount Gambier (C)	SA East
Mount Remarkable (DC)	SA North
Murray Bridge (RC)	SA East
Naracoorte and Lucindale (DC)	SA East
Northern Areas (DC)	SA North
Norwood Payneham St Peters (C)	Adelaide South
Onkaparinga (C)	Adelaide South
Orroroo-Carrieton (DC)	SA North
Peterborough (DC)	SA North
Playford (C)	Adelaide North
Port Adelaide Enfield (C)	Adelaide North
Port Augusta (C)	SA Far North and West
Port Lincoln (C)	SA Far North and West
Port Pirie City and Dists (M)	SA North
Prospect (C)	Adelaide North
Renmark Paringa (DC)	SA East
Robe (DC)	SA East
Roxby Downs (M)	SA Far North and West
Salisbury (C)	Adelaide North
Southern Mallee (DC)	SA East

Local Government Area	SoR Region
Streaky Bay (DC)	SA Far North and West
Tatiara (DC)	SA East
Tea Tree Gully (C)	Adelaide North
The Coorong (DC)	SA East
Tumby Bay (DC)	SA Far North and West
Unley (C)	Adelaide South
Victor Harbor (C)	SA Fleurieu
Wakefield (DC)	SA North
Walkerville (M)	Adelaide South
Wattle Range (DC)	SA East
West Torrens (C)	Adelaide South
Whyalla (C)	SA Far North and West
Yankalilla (DC)	SA Fleurieu
Yorke Peninsula (DC)	SA North
Unincorporated SA	SA Far North and West
Albany (C)	WA Wheatbelt Great Southern
Armadale (C)	Perth Outer South
Ashburton (S)	WA Pilbara Kimberley
Augusta-Margaret River (S)	WA Peel South West
Bassendean (T)	Perth Outer North
Bayswater (C)	Perth Outer North
Belmont (C)	Perth Central
Beverley (S)	WA Wheatbelt Great Southern
Boddington (S)	WA Peel South West
Boyup Brook (S)	WA Peel South West
Bridgetown-Greenbushes (S)	WA Peel South West
Brookton (S)	WA Wheatbelt Great Southern
Broome (S)	WA Pilbara Kimberley
Broomehill-Tambellup (S)	WA Wheatbelt Great Southern
Bruce Rock (S)	WA Wheatbelt Great Southern
Bunbury (C)	WA Peel South West
Busselton (S)	WA Peel South West
Cambridge (T)	Perth Central
Canning (C)	Perth Central
Capel (S)	WA Peel South West
Carnamah (S)	WA Gascoyne Goldfields
Carnarvon (S)	WA Gascoyne Goldfields
Chapman Valley (S)	WA Gascoyne Goldfields
Chittering (S)	WA Wheatbelt Great Southern
Claremont (T)	Perth Central
Cockburn (C)	Perth Outer South
Collie (S)	WA Peel South West
Coolgardie (S)	WA Gascoyne Goldfields
Coorow (S)	WA Gascoyne Goldfields
Corrigin (S)	WA Wheatbelt Great Southern
Cottesloe (T)	Perth Central

Local Government Area	SoR Region
Cranbrook (S)	WA Wheatbelt Great Southern
Cuballing (S)	WA Wheatbelt Great Southern
Cue (S)	WA Gascoyne Goldfields
Cunderdin (S)	WA Wheatbelt Great Southern
Dalwallinu (S)	WA Wheatbelt Great Southern
Dandaragan (S)	WA Wheatbelt Great Southern
Dardanup (S)	WA Peel South West
Denmark (S)	WA Wheatbelt Great Southern
Derby-West Kimberley (S)	WA Pilbara Kimberley
Donnybrook-Balingup (S)	WA Peel South West
Dowerin (S)	WA Wheatbelt Great Southern
Dumbleyung (S)	WA Wheatbelt Great Southern
Dundas (S)	WA Gascoyne Goldfields
East Fremantle (T)	Perth Central
East Pilbara (S)	WA Pilbara Kimberley
Esperance (S)	WA Gascoyne Goldfields
Exmouth (S)	WA Gascoyne Goldfields
Fremantle (C)	Perth Central
Geraldton-Greenough (C)	WA Gascoyne Goldfields
Gingin (S)	WA Wheatbelt Great Southern
Gnowangerup (S)	WA Wheatbelt Great Southern
Goomalling (S)	WA Wheatbelt Great Southern
Gosnells (C)	Perth Outer South
Halls Creek (S)	WA Pilbara Kimberley
Harvey (S)	WA Peel South West
Irwin (S)	WA Gascoyne Goldfields
Jerramungup (S)	WA Wheatbelt Great Southern
Joondalup (C)	Perth Outer North
Kalamunda (S)	Perth Outer South
Kalgoorlie-Boulder (C)	WA Gascoyne Goldfields
Katanning (S)	WA Wheatbelt Great Southern
Kellerberrin (S)	WA Wheatbelt Great Southern
Kent (S)	WA Wheatbelt Great Southern
Kojonup (S)	WA Wheatbelt Great Southern
Kondinin (S)	WA Wheatbelt Great Southern
Koorda (S)	WA Wheatbelt Great Southern
Kulin (S)	WA Wheatbelt Great Southern
Kwinana (T)	Perth Outer South
Lake Grace (S)	WA Wheatbelt Great Southern
Laverton (S)	WA Gascoyne Goldfields
Leonora (S)	WA Gascoyne Goldfields
Mandurah (C)	WA Peel South West
Manjimup (S)	WA Peel South West
Meekatharra (S)	WA Gascoyne Goldfields
Melville (C)	Perth Outer South
Menzies (S)	WA Gascoyne Goldfields

Local Government Area	SoR Region
Merredin (S)	WA Wheatbelt Great Southern
Mingenew (S)	WA Gascoyne Goldfields
Moora (S)	WA Wheatbelt Great Southern
Morawa (S)	WA Gascoyne Goldfields
Mosman Park (T)	Perth Central
Mount Magnet (S)	WA Gascoyne Goldfields
Mount Marshall (S)	WA Wheatbelt Great Southern
Mukinbudin (S)	WA Wheatbelt Great Southern
Mullewa (S)	WA Gascoyne Goldfields
Mundaring (S)	Perth Outer North
Murchison (S)	WA Gascoyne Goldfields
Murray (S)	WA Peel South West
Nannup (S)	WA Peel South West
Narembeen (S)	WA Wheatbelt Great Southern
Narrogin (T)	WA Wheatbelt Great Southern
Narrogin (S)	WA Wheatbelt Great Southern
Nedlands (C)	Perth Central
Ngaanyatjarraku (S)	WA Gascoyne Goldfields
Northam (S)	WA Wheatbelt Great Southern
Northampton (S)	WA Gascoyne Goldfields
Nungarin (S)	WA Wheatbelt Great Southern
Peppermint Grove (S)	Perth Central
Perenjori (S)	WA Gascoyne Goldfields
Perth (C)	Perth Central
Pingelly (S)	WA Wheatbelt Great Southern
Plantagenet (S)	WA Wheatbelt Great Southern
Port Hedland (T)	WA Pilbara Kimberley
Quairading (S)	WA Wheatbelt Great Southern
Ravensthorpe (S)	WA Gascoyne Goldfields
Rockingham (C)	Perth Outer South
Roebourne (S)	WA Pilbara Kimberley
Sandstone (S)	WA Gascoyne Goldfields
Serpentine-Jarrahdale (S)	WA Peel South West
Shark Bay (S)	WA Gascoyne Goldfields
South Perth (C)	Perth Central
Stirling (C)	Perth Central
Subiaco (C)	Perth Central
Swan (C)	Perth Outer North
Tammin (S)	WA Wheatbelt Great Southern
Three Springs (S)	WA Gascoyne Goldfields
Toodyay (S)	WA Wheatbelt Great Southern
Trayning (S)	WA Wheatbelt Great Southern
Upper Gascoyne (S)	WA Gascoyne Goldfields
Victoria Park (T)	Perth Central
Victoria Plains (S)	WA Wheatbelt Great Southern
Vincent (T)	Perth Central

Local Government Area	SoR Region
Wagin (S)	WA Wheatbelt Great Southern
Wandering (S)	WA Wheatbelt Great Southern
Wanneroo (C)	Perth Outer North
Waroona (S)	WA Peel South West
West Arthur (S)	WA Wheatbelt Great Southern
Westonia (S)	WA Wheatbelt Great Southern
Wickepin (S)	WA Wheatbelt Great Southern
Williams (S)	WA Wheatbelt Great Southern
Wiluna (S)	WA Gascoyne Goldfields
Wongan-Ballidu (S)	WA Wheatbelt Great Southern
Woodanilling (S)	WA Wheatbelt Great Southern
Unincorporated WA	No SOR
Wyalkatchem (S)	WA Wheatbelt Great Southern
Wyndham-East Kimberley (S)	WA Pilbara Kimberley
Yalgoo (S)	WA Gascoyne Goldfields
Yilgarn (S)	WA Wheatbelt Great Southern
York (S)	WA Wheatbelt Great Southern
Break O'Day (M)	TAS North
Brighton (M)	TAS Hobart South
Burnie (C)	TAS North West
Central Coast (M)	TAS North West
Central Highlands (M)	TAS Hobart South
Circular Head (M)	TAS North West
Clarence (C)	TAS Hobart South
Derwent Valley (M)	TAS Hobart South
Devonport (C)	TAS North West
Dorset (M)	TAS North
Flinders (M)	TAS North
George Town (M)	TAS North
Glamorgan-Spring Bay (M)	TAS Hobart South
Glenorchy (C)	TAS Hobart South
Hobart (C)	TAS Hobart South
Huon Valley (M)	TAS Hobart South
Kentish (M)	TAS North West
King Island (M)	TAS North West
Kingborough (M)	TAS Hobart South
Latrobe (M)	TAS North West
Launceston (C)	TAS North
Meander Valley (M)	TAS North
Northern Midlands (M)	TAS North
Sorell (M)	TAS Hobart South
Southern Midlands (M)	TAS Hobart South
Tasman (M)	TAS Hobart South
Waratah-Wynyard (M)	TAS North West
West Coast (M)	TAS North West
West Tamar (M)	TAS North

Local Government Area	SoR Region
Unincorporated Tas	No SOR
Alice Springs (T)	NT Lingiari
Barkly (S)	NT Lingiari
Belyuen (S)	NT Lingiari
Central Desert (S)	NT Lingiari
Coomalie (S)	NT Darwin
Darwin (C)	NT Darwin
East Arnhem (S)	NT Lingiari
Katherine (T)	NT Lingiari
Litchfield (M)	NT Darwin
MacDonnell (S)	NT Lingiari
Palmerston (C)	NT Darwin
Roper Gulf (S)	NT Lingiari
Tiwi Islands (S)	NT Lingiari
Victoria-Daly (S)	NT Lingiari
Wagait (S)	NT Lingiari
West Arnhem (S)	NT Lingiari
Unincorporated NT	NT Lingiari
Unincorporated ACT	ACT

Appendix 3

Table A.1 Low scenario forecast

				Firefighters		Population		Assets ($m)		FF per 100,000 residents		FF per $bn assets	
State	SOR	SOR Name	2011	2020 Low	2030 Low	2020	2030	2020	2030	2020	2030	2020	2030
1	1	Sydney Central	719	916	1056	759694	837768	243545	281098	121	126	3.76	3.76
1	2	Sydney Eastern Beaches	87	107	123	289798	313664	59387	66986	37	39	1.81	1.84
1	3	Sydney Northern Beaches	132	166	193	297608	307970	62304	72194	56	63	2.67	2.68
1	4	Sydney Old West	116	147	168	380743	417272	68606	77944	38	40	2.14	2.16
1	5	Sydney Outer North	150	193	240	498159	538161	101327	119362	39	45	1.91	2.01
1	6	Sydney Outer South West	207	269	342	564723	688785	108258	136893	48	50	2.48	2.50
1	7	Sydney Outer West	344	448	553	701877	780797	148959	176543	64	71	3.01	3.14
1	8	Sydney Parramatta Bankstown	292	379	433	820669	883969	168702	193437	46	49	2.25	2.24
1	9	Sydney South	244	296	348	495014	521685	94489	106795	60	67	3.13	3.26
1	10	NSW Central Coast	205	267	323	341821	373544	77607	89161	78	86	3.44	3.62
1	11	NSW Central West	59	94	136	186031	190004	44098	48472	51	72	2.14	2.81
1	12	NSW Illawarra	194	239	293	307995	332506	79547	89378	78	88	3.01	3.28
1	13	NSW Mid North Coast	100	117	145	272544	293995	61643	71097	43	49	1.90	2.03
1	14	NSW Murray Far West	46	59	71	134871	137297	36542	40597	44	51	1.61	1.74
1	15	NSW Newcastle	326	424	501	509215	556575	130570	149505	83	90	3.25	3.35
1	16	NSW Northern Inland	46	72	104	184724	184987	44911	48783	39	56	1.61	2.14
1	17	NSW Northern Rivers	85	102	129	304233	326363	71425	82815	33	40	1.42	1.56
1	18	NSW Orana	52	78	105	121827	121247	34331	37732	64	87	2.27	2.79
1	19	NSW Outer Hunter	84	111	134	181930	192604	53787	60473	61	69	2.07	2.21
1	20	NSW Riverina	62	87	110	140900	144415	34842	38373	62	76	2.50	2.87
1	21	NSW South Coast	87	108	137	179410	196307	45722	53097	60	70	2.37	2.57
1	22	NSW Southern Inland	43	60	82	221783	234460	66476	79352	27	35	0.90	1.04
2	23	Melbourne City	429	595	747	150766	204334	96033	118458	395	366	6.19	6.31
2	24	Melbourne Eastern Inner	179	229	281	557630	630336	119523	140545	41	45	1.91	2.00

Table A.1 Low scenario forecast (continued)

				Firefighters		Population		Assets ($m)		FF per 100,000 residents		FF per $bn assets	
State	SOR	SOR Name	2011	2020 Low	2030 Low	2020	2030	2020	2030	2020	2030	2020	2030
2	25	Melbourne Eastern Outer	130	176	222	563503	610694	118279	139787	31	36	1.49	1.59
2	26	Melbourne Northern Inner	272	354	434	572828	646398	112362	132209	62	67	3.15	3.28
2	27	Melbourne Northern Outer	237	339	433	474904	553489	94723	116149	71	78	3.57	3.73
2	28	Melbourne Southern Inner	215	277	340	808917	898445	186902	220713	34	38	1.48	1.54
2	29	Melbourne Southern Outer	98	136	171	704581	796970	139951	167050	19	22	0.97	1.03
2	30	Melbourne Western	347	520	682	892145	1037295	172035	208458	58	66	3.03	3.27
2	31	VIC Geelong	101	137	172	239815	269237	56744	67249	57	64	2.42	2.56
2	32	VIC Gippsland	129	172	225	285714	317967	98619	117600	60	71	1.74	1.91
2	33	VIC Grampians	105	137	170	244406	268610	53943	62440	56	63	2.54	2.72
2	34	VIC Hume	111	154	196	291701	327668	72330	86299	53	60	2.13	2.28
2	35	VIC Loddon Mallee	90	122	152	328880	356966	73609	85142	37	43	1.66	1.79
2	36	VIC South West	45	57	71	159312	173313	38716	45127	36	41	1.47	1.57
3	37	SEQ Brisbane City	731	1049	1381	1267527	1379525	370209	469114	83	100	2.83	2.94
3	38	SEQ Gold Coast	241	354	493	645475	793369	162262	210050	55	62	2.18	2.35
3	39	SEQ West Moreton	160	280	420	361630	512150	76129	112679	77	82	3.68	3.73
3	40	SEQ Logan Redland	161	236	315	513648	593206	110130	143719	46	53	2.14	2.19
3	41	SEQ Moreton Bay	110	161	215	478055	546506	95883	122376	34	39	1.68	1.75
3	42	SEQ Sunshine Coast	122	176	242	386879	463781	91632	118150	45	52	1.92	2.05
3	43	QLD Darling Downs South West	101	194	325	303635	343148	82395	105352	64	95	2.35	3.09
3	44	QLD Far North Torres	182	246	316	312204	345214	78004	97352	79	92	3.16	3.25
3	45	QLD Fitzroy Central West	120	248	424	276760	314440	133876	177965	90	135	1.85	2.38
3	46	QLD Mackay	83	127	187	218437	257144	83329	110275	58	73	1.52	1.70
3	47	QLD Townsville North West	201	308	415	315464	366921	100747	130923	98	113	3.05	3.17
3	48	QLD Wide Bay Burnett	101	150	218	326465	375136	77191	99115	46	58	1.94	2.20
4	49	Adelaide South	499	642	793	600391	662681	147315	166479	107	120	4.36	4.76
4	50	Adelaide North	266	354	437	612452	678370	139870	160357	58	64	2.53	2.73
4	51	SA East	10	12	14	135223	138705	33642	36021	9	10	0.37	0.40
4	52	SA Far North and West	11	14	17	89996	92975	32933	36646	16	18	0.43	0.46
4	53	SA Fleurieu	17	22	28	125455	133661	28138	31945	17	21	0.78	0.86

Table A.1 Low scenario forecast (continued)

				Firefighters		Population		Assets ($m)		FF per 100,000 residents		FF per $bn assets	
State	SOR	SOR Name	2011	2020 Low	2030 Low	2020	2030	2020	2030	2020	2030	2020	2030
4	54	SA North	43	54	65	148481	160409	38160	42942	37	40	1.43	1.51
5	55	Perth Central	441	696	933	728865	882187	300992	400017	96	106	2.31	2.33
5	56	Perth Outer North	199	333	469	694295	871435	181849	249934	48	54	1.83	1.88
5	57	Perth Outer South	210	353	491	712297	878460	206998	282087	49	56	1.70	1.74
5	58	WA Gascoyne Goldfields	41	75	113	139309	148444	72748	93072	54	76	1.03	1.21
5	59	WA Peel South West	80	138	199	357381	475686	106755	148852	39	42	1.30	1.34
5	60	WA Pilbara Kimberley	28	48	63	129028	140882	167645	224540	37	44	0.29	0.28
5	61	WA Wheatbelt Great Southern	33	50	66	143086	146749	48273	60679	35	45	1.03	1.09
6	62	TAS Hobart South	178	194	212	269751	285725	63100	68234	72	74	3.08	3.11
6	63	TAS North	89	98	107	150962	157831	36616	39484	65	68	2.69	2.71
6	64	TAS North West	41	45	48	117270	118680	30054	31909	38	40	1.49	1.49
7	65	NT Darwin	155	247	353	152458	189505	67793	96925	162	186	3.64	3.64
7	66	NT Lingiari	84	123	169	116985	141601	43142	62464	105	119	2.84	2.71
8	67	ACT	316	435	586	404688	446654	107938	129092	108	131	4.03	4.54

Table A.2		High scenario forecast											
				Firefighters		Population		Assets ($m)		FF per 100,000 residents		FF per $bn assets	
State	SOR	SOR Name	2011	2020 Low	2030 Low	2020	2030	2020	2030	2020	2030	2020	2030
1	1	Sydney Central	719	945	1172	759694	837768	243545	281098	124	140	3.88	4.17
1	2	Sydney Eastern Beaches	87	111	137	289798	313664	59387	66986	38	44	1.86	2.04
1	3	Sydney Northern Beaches	132	172	215	297608	307970	62304	72194	58	70	2.75	2.97
1	4	Sydney Old West	116	151	186	380743	417272	68606	77944	40	45	2.20	2.39
1	5	Sydney Outer North	150	203	272	498159	538161	101327	119362	41	51	2.00	2.28
1	6	Sydney Outer South West	207	307	449	564723	688785	108258	136893	54	65	2.83	3.28
1	7	Sydney Outer West	344	470	627	701877	780797	148959	176543	67	80	3.16	3.55
1	8	Sydney Parramatta Bankstown	292	392	481	820669	883969	168702	193437	48	54	2.32	2.49
1	9	Sydney South	244	317	406	495014	521685	94489	106795	64	78	3.36	3.80
1	10	NSW Central Coast	205	328	432	341821	373544	77607	89161	96	116	4.23	4.84
1	11	NSW Central West	59	91	130	186031	190004	44098	48472	49	69	2.06	2.69
1	12	NSW Illawarra	194	289	424	307995	332506	79547	89378	94	127	3.63	4.74
1	13	NSW Mid North Coast	100	152	184	272544	293995	61643	71097	56	63	2.47	2.59
1	14	NSW Murray Far West	46	58	70	134871	137297	36542	40597	43	51	1.60	1.73
1	15	NSW Newcastle	326	491	621	509215	556575	130570	149505	96	112	3.76	4.16
1	16	NSW Northern Inland	46	69	100	184724	184987	44911	48783	37	54	1.54	2.04
1	17	NSW Northern Rivers	85	132	164	304233	326363	71425	82815	43	50	1.85	1.98
1	18	NSW Orana	52	77	103	121827	121247	34331	37732	63	85	2.25	2.72
1	19	NSW Outer Hunter	84	137	179	181930	192604	53787	60473	75	93	2.54	2.95
1	20	NSW Riverina	62	89	116	140900	144415	34842	38373	63	80	2.55	3.02
1	21	NSW South Coast	87	131	197	179410	196307	45722	53097	73	101	2.86	3.72
1	22	NSW Southern Inland	43	64	96	221783	234460	66476	79352	29	41	0.96	1.21
2	23	Melbourne City	429	608	782	150766	204334	96033	118458	404	383	6.34	6.60
2	24	Melbourne Eastern Inner	179	234	294	557630	630336	119523	140545	42	47	1.96	2.09
2	25	Melbourne Eastern Outer	130	184	242	563503	610694	118279	139787	33	40	1.55	1.73
2	26	Melbourne Northern Inner	272	362	454	572828	646398	112362	132209	63	70	3.22	3.44
2	27	Melbourne Northern Outer	237	353	470	474904	553489	94723	116149	74	85	3.73	4.05

Table A.2	High scenario forecast (continued)												
				Firefighters		Population		Assets ($m)		FF per 100,000 residents		FF per $bn assets	
State	SOR	SOR Name	2011	2020 Low	2030 Low	2020	2030	2020	2030	2020	2030	2020	2030
2	28	Melbourne Southern Inner	215	284	356	808917	898445	186902	220713	35	40	1.52	1.61
2	29	Melbourne Southern Outer	98	142	186	704581	796970	139951	167050	20	23	1.01	1.12
2	30	Melbourne Western	347	549	766	892145	1037295	172035	208458	62	74	3.19	3.68
2	31	VIC Geelong	101	142	187	239815	269237	56744	67249	59	70	2.51	2.79
2	32	VIC Gippsland	129	203	298	285714	317967	98619	117600	71	94	2.06	2.53
2	33	VIC Grampians	105	148	193	244406	268610	53943	62440	61	72	2.74	3.09
2	34	VIC Hume	111	164	220	291701	327668	72330	86299	56	67	2.27	2.55
2	35	VIC Loddon Mallee	90	130	168	328880	356966	73609	85142	40	47	1.77	1.98
2	36	VIC South West	45	62	80	159312	173313	38716	45127	39	46	1.59	1.78
3	37	SEQ Brisbane City	731	1049	1364	1267527	1379525	370209	469114	83	99	2.83	2.91
3	38	SEQ Gold Coast	241	354	482	645475	793369	162262	210050	55	61	2.18	2.29
3	39	SEQ West Moreton	160	264	399	361630	512150	76129	112679	73	78	3.47	3.54
3	40	SEQ Logan Redland	161	236	311	513648	593206	110130	143719	46	52	2.14	2.17
3	41	SEQ Moreton Bay	110	161	212	478055	546506	95883	122376	34	39	1.68	1.73
3	42	SEQ Sunshine Coast	122	176	237	386879	463781	91632	118150	45	51	1.92	2.00
3	43	QLD Darling Downs South West	101	180	280	303635	343148	82395	105352	59	82	2.19	2.66
3	44	QLD Far North Torres	182	254	332	312204	345214	78004	97352	81	96	3.26	3.41
3	45	QLD Fitzroy Central West	120	231	365	276760	314440	133876	177965	83	116	1.73	2.05
3	46	QLD Mackay	83	138	212	218437	257144	83329	110275	63	82	1.66	1.92
3	47	QLD Townsville North West	201	321	450	315464	366921	100747	130923	102	123	3.19	3.44
3	48	QLD Wide Bay Burnett	101	164	247	326465	375136	77191	99115	50	66	2.12	2.49
4	49	Adelaide South	499	700	948	600391	662681	147315	166479	117	143	4.75	5.70
4	50	Adelaide North	266	386	523	612452	678370	139870	160357	63	77	2.76	3.26
4	51	SA East	10	13	16	135223	138705	33642	36021	10	12	0.39	0.45
4	52	SA Far North and West	11	15	18	89996	92975	32933	36646	16	19	0.45	0.49
4	53	SA Fleurieu	17	25	35	125455	133661	28138	31945	20	26	0.88	1.10
4	54	SA North	43	57	70	148481	160409	38160	42942	38	44	1.49	1.63

Table A.2 High scenario forecast (continued)

				Firefighters		Population		Assets ($m)		FF per 100,000 residents		FF per $bn assets	
State	SOR	SOR Name	2011	2020 Low	2030 Low	2020	2030	2020	2030	2020	2030	2020	2030
5	55	Perth Central	441	712	977	728865	882187	300992	400017	98	111	2.37	2.44
5	56	Perth Outer North	199	348	510	694295	871435	181849	249934	50	59	1.91	2.04
5	57	Perth Outer South	210	368	533	712297	878460	206998	282087	52	61	1.78	1.89
5	58	WA Gascoyne Goldfields	41	74	110	139309	148444	72748	93072	53	74	1.01	1.19
5	59	WA Peel South West	80	147	223	357381	475686	106755	148852	41	47	1.38	1.50
5	60	WA Pilbara Kimberley	28	49	65	129028	140882	167645	224540	38	46	0.29	0.29
5	61	WA Wheatbelt Great Southern	33	54	75	143086	146749	48273	60679	38	51	1.11	1.23
6	62	TAS Hobart South	178	194	240	269751	285725	63100	68234	72	84	3.08	3.52
6	63	TAS North	89	98	107	150962	157831	36616	39484	65	68	2.69	2.71
6	64	TAS North West	41	45	48	117270	118680	30054	31909	38	40	1.49	1.49
7	65	NT Darwin	155	257	383	152458	189505	67793	96925	169	202	3.80	3.95
7	66	NT Lingiari	84	125	177	116985	141601	43142	62464	107	125	2.91	2.83
8	67	ACT	316	455	656	404688	446654	107938	129092	112	147	4.22	5.08

Appendix 4: Creating the future scenarios

The method for creating future scenarios is described in detail in the report by Hennessy et al [2005]. A brief summary is provided here. Climate change projections over southeastern Australia were generated from two CSIRO climate simulations named CCAM (Mark 2) and CCAM (Mark 3). Projected changes in daily temperature, humidity, wind and rainfall were generated for the years 2020 and 2050, relative to 1990 (the reference year used by the IPCC). These projections include changes in daily variability, computed as changes in decile values. They are expressed as a pattern of change per degree of global warming. The patterns were scaled for the years 2020 and 2050 using estimates of global warming for those years. Hennessy et al [2005] used global warming values from the IPCC [2001] report, but in this study we use updated ranges of global warming 26 derived by CSIRO from the IPCC [2007] report, i.e. 0.4-1.0^{o}C by 2020 and 0.7-2.9^{o}C by 2050. This allows for the full range of SRES [2000] scenarios of greenhouse gas and aerosol emissions.

Four regional projections are given for each climate simulation: 2020 low, 2020 high, 2050 low and 2050 high. The low regional projections are based on low global warming, while high regional projections are based on high global warming. The modelled changes from the various scenarios are then projected onto the observed time series of temperature, rainfall, wind and relative humidity from 1973 to the present. This methodology provides an estimate, based on the observed past weather, of what a realistic time series affected by climate change may look like. By using this procedure, the natural inter-relationships between the variables which make up the FFDI are maintained. The tacit assumption is that the variability observed over the past 30+ years will be maintained. With climate change, this may not be the case, and our methodology will not reproduce such a change.

In both models the largest changes to the different variables comes in the spring, although changes are observed in all seasons. There are systematic differences in the various scenarios due to differences in the two models. CCAM (Mark 2) tends to have slightly higher temperature changes for a given decile/month combination. The number of rain days in both models is lower. CCAM (Mark 2) generally has lower monthly average rain totals in most months. However, at many stations, CCAM Mark 3) shows an enhancement of the heaviest (decile 10) rainfalls, while showing larger decreases in rainfall in most other deciles. This often results in monthly totals which are significantly higher than the present climate. There are also differences in wind speed and relative humidity. The CCAM (Mark 3) model tends to have positive (or less negative) changes in the wind speed compared to CCAM (Mark 2). The signs of the change in wind are often opposite between the two models. Something similar applies to relative humidity, where CCAM (Mark 3) tends to have more negative changes than CCAM (Mark 2). Changes to the very low humidity deciles are especially greater in CCAM (Mark 3).