Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009

Initiative of NCCARF – National Climate Change Adaptation Research Facility, funded by the Commonwealth Government of Australia.

October 2010

The Institute for Sustainable Resources, Queensland University of Technology (QUT) coordinated and managed the compilation and submission of this case study *Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009.*

Submitted to the National Climate Change Adaptation Research Facility (NCCARF) under the Synthesis and Integrative Research Program — October 2010.

Contributors

Executive summary and Section 1: Institute for Sustainable Resources, QUT
Jim Reeves
Colleen Foelz
Peter Grace
Peter Best

Section 2: Australian Centre for Sustainable Catchments, University of Southern Queensland
Peter Best
Torben Marcussen
Shahbaz Mushtaq
Roger Stone

Section 3: School of Geography and Environmental Science, Monash University
Margaret Loughnan

Section 4: Climate Change Adaptation program, RMIT University
Darryn McEvoy
Ifte Ahmed
Jane Mullett

Section 5: Risk Frontiers at Macquarie University
Katharine Haynes
Deanne Bird
Lucinda Coates
Megan Ling

Acknowledgements: John Nairn (Senior Forecaster in the Adelaide office of BoM) is thanked for his extensive discussions on the EHF and for providing as-yet unpublished diagrams for this report. Also acknowledged are Julie Arblaster of BoM/CSIRO and Rob Allan of the UK Hadley Centre for clarifying several aspects of climate modelling and forecasting of heatwaves; Professor Rod Keenan of the Victorian Centre for Climate Change Adaptation Research at Melbourne University for his assistance in the early stages of the project; and the anonymous reviewers for providing their insightful comments on the study.

Contents

Executive summary

From 27 January to 8 February during the summer of 2009, southern Australia experienced one of the nation's most severe heatwaves. Governments, councils, utilities, hospitals and emergency response organisations and the community were largely underprepared for an extreme event of this magnitude.

This case study, 'Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009' was funded by The National Climate Change Adaptation Research Facility under its Synthesis and Integrative Research Program. The study targets the experience and challenges faced by decision makers and policy makers and focuses on the major metropolitan areas affected by the heatwave — Melbourne and Adelaide.

This work resulted from collaboration between researchers from Risk Frontiers (at Macquarie University), Monash University, RMIT University and the University of Southern Queensland and was coordinated by the Institute for Sustainable Resources, Queensland University of Technology.

Broadly, the study examines the 2009 heatwave's characteristics; its impacts (on human health, infrastructure and human services); the degree of adaptive capacity (vulnerability and resilience) of various sectors, communities and individuals; and the reactive responses of government and emergency and associated services and their effectiveness. Barriers and challenges to adaptation and increasing resilience are also identified and further areas for research are suggested. This study does not include details of the heatwave's effects beyond Victoria and South Australia, or its economic impacts, or of Victoria's 'Black Saturday' bushfires.

Meteorological and climate characteristics

Key message

Compared to the 100–150 years of historical observations, the 2009 heatwave in southern Australia was exceptional — producing severe, extensive and prolonged heat exposure. It was a major and unexpected heatwave in both Australian and international contexts, with extreme heat stress in the first phase and a bushfire disaster in the second phase of the heatwave. Climate change over the next 30–60 years will make such events more likely, and test the resilience of the expanding metropolitan areas, unless forewarning and other adaptation strategies are successful.

Southern Australian metropolitan regions have experienced severe and widespread heatwave events in the past (e.g. 1908 and 1939). Events in the first decade of the 21st century have been unusually intense, long-lasting and extensive; the 2009 heatwave was record-breaking. Maximum daily temperatures were 12 to 15 °C above the seasonal average of 28–32 °C for many consecutive days. New daily maximum temperature extremes were observed for Adelaide (45.7 °C) and Melbourne (46.4 °C). Adelaide had eight consecutive days over 40 °C and Melbourne suffered an unprecedented run of three days above 43 °C. Night-time temperatures for both Adelaide and Melbourne were unusually high. Slow-changing synoptic conditions maintained a very hot air mass over south-eastern Australia. This heat build-up was made worse by exceptionally low surface moisture resulting from an extended drought over the previous month and years. There was also little temporary relief provided in these coastal cities by sea or bay breezes.

The heatwave began with an intense, long-lived Phase 1 (27 to 30 January) in Melbourne, and longer for Adelaide. This was followed by a briefer period (6 to 8 February) which overlapped with the 'Black Saturday bushfires' (February 7), and constitutes Phase 2. Phase 1 caused the most apparent distress from high temperatures, whereas Phase 2 saw extreme heatwave conditions combine with impacts from severe bushfires across both states.

The 2009 heatwave was well predicted in the 3–7 day lead up, but seasonal forecasts issued in November–December 2008 did not anticipate such severe conditions. Climate modelling predicts that heatwaves events for most regions will intensify and be longer lasting and more frequent as global temperatures increase. The likelihood of similar meteorological conditions to the 2009 heatwave occurring in future decades is difficult to estimate. CSIRO predicts that, for both cities, the number of days with maximum temperatures over 35 °C may increase by 25% by 2030 and double by 2070.

Key message

Urban heat island effects were evident in the land-surface temperatures of the Adelaide and Melbourne metropolitan areas for the 2009 event. Superimposed on the patterns of social and network vulnerabilities, these variations complicate predicting and assessing the responses of heat-sensitive groups and assets. Local-scale analysis and alert systems for emergency and short-term adaptation strategies need such knowledge and heat stress indicators predicted from Bureau of Meteorology 'forecast explorer' systems are now available in Victoria (and soon will be in South Australia).

The already super-heated conditions brought by the heatwave were further intensified, especially at night time, by localised, physical factors. These include factors such as the high thermal mass of buildings, structures which restrict airflow and velocity, and surfaces which radiate stored heat. Waste heat from the increased use of air conditioning would have further amplified this condition. Satellite observations of land-surface temperature show considerable differences in heat exposure across the metropolitan areas. Urban heat island effects on human temperature exposure are likely in night-time but are as yet unconfirmed for daytime conditions. Variability in exposure is likely to add to the complexities of socioeconomic vulnerabilities.

Key message

Heatwave impacts on many systems are often well characterised by a multi-day heat index based on daytime and night-time exposure to temperature (and, for some locations, to humidity and wind as well). Other factors are important for evaluating the details of various responses. The rapid increases in urban impacts with rising temperature may be poorly indicated by current regional weather and climate models, without additional tuning and inclusion of urban and local-scale influences.

The 2009 heatwave conditions had widespread impacts on the health and comfort of individuals and communities, overwhelmed some emergency services and lead to major disruptions to services such as electricity and transport. Several heat alert thresholds and heat indices for such effects are available but for the dry/drought conditions of southern Australia, those based on air temperature are sufficient at present.

For many impacts, temperature dependencies are non-linear above a certain 'threshold' temperature and vary between sectors. The detailed impacts are compounded by factors such as acclimatisation, location, health status and socioeconomic characteristics of the affected community group. They will be influenced by conditions such as level of preparedness, speed of temperature increase, predictability of the event, the ability to moderate the response (e.g. via air conditioning or mechanical cooling which then influences energy demand and network reliability) and, for some industries, the availability and effectiveness of weather risk products for reducing the financial impacts of heatwaves.

Weather and climate models do not yet encompass the structural and heat generation characteristics of cities and the local effects of humidity, which may ultimately limit the adaptation response of many communities and organisations in very built-up areas or those near water bodies.

Key message

Recent investigations suggest several potential causes and climate drivers for major heatwaves in southern Australia. Harnessing such knowledge will aid seasonal forecasting of heatwave likelihood (to aid planning preparedness and incident management in all sectors) and longer-term outlooks (to facilitate climate risk strategies including improving the safety, efficiency and financial resilience of infrastructure and other networks).

The major cities in southern Australia have highly centralised infrastructures set in a hot-summer, Mediterranean climate. Their extreme weather is unusually influenced by several climate drivers. Better knowledge of such links should improve seasonal outlooks and delineate the influence of climate change and variability on heatwave hazard risks. Southern heatwaves are rarely severe in El Niño conditions, for example.

The heat-sensitivity of interconnected systems such as transmission networks and supply chains will become more important as the urban areas expand into more heat-prone areas and the regional and local climates warm; these areas will also be more prone to heat-related issues such as photochemical smog, bushfires and breakdowns of transmission and supply-chain networks.

The meteorology of the 2009 heatwave may indeed be a harbinger of the future. By a wise incorporation of weather and climate knowledge in the guiding principles for adaptation measures, more heatwave-resilient urban systems in southern Australia are possible.

Human health impacts

Key message

The heatwave led to a sharp rise in heat-related illness and deaths among the most vulnerable groups.

Groups lacking capacity to avoid or reduce exposure to the heat hazard can be the most vulnerable. The extent of this vulnerability is determined by age, pre-existing illnesses and medication, physical activity, awareness of the risks, socioeconomic factors, housing, urban environment, degree of climate control available, race and ethnicity.

Following the initial build up of heat, the situation suddenly became more critical when power was lost on the evening of 30 January. Warnings from health authorities were broadcast through the media, primarily advising the elderly to stay indoors, reduce physical activity, and to keep cool and well hydrated. They also directed people to check on elderly friends, relatives and neighbours, especially those living alone. Response agencies were mobilised to phone or contact vulnerable groups or individuals.

Key message

The overall impacts on human health are evident from the dramatic increase in mortality and morbidity that correlate with the increasing temperatures and persistence of the event. In Melbourne there were 374 excess deaths (deaths above what would be expected for the period of the event) and in Adelaide estimates ranged from 50 to 150, with more than 3000 reports of heat-related illnesses. Reports from Melbourne showed that the greatest number of deaths occurred in those 75 years or older. This confirms the expectation that persons with age-related chronic medical conditions have an increased risk of heat-related mortality and morbidity during heatwaves.

During the heatwave period compared with the same period in 2008, large increases were documented in emergency ambulance dispatches and attendances to heat-related conditions, as well as for presentations of heat-related conditions at emergency departments.

Infrastructure impacts

Key message

Both cities experienced costly service interruptions resulting from failures in the heat-sensitive components of power and transport infrastructure and systems; with electricity and train services being the most severely impacted.

Record-breaking daytime temperatures, cumulative days of heat and continuing high temperatures at night are problematic for critical infrastructure. Melbourne's infrastructure showed varying levels of impact to these heatwave conditions. For telecommunications, water and airports the impacts appear minimal; for trams and sea ports the impacts were relatively minor. The impact on roads (moderate) and the train system (moderate-high) was greater.

In Melbourne on 30 January, train cancellations peaked when more than 24% of services did not run. Train services were vulnerable to physical impacts such as buckling, power failures, or failure of components such as air conditioners.

The city's electricity sector stands out as being the most vulnerable to heat, with the transmission (due to faults with transformers) and distribution systems being particularly affected by the extreme event of January – February 2009. In Melbourne, the sector was under severe stress and in a state of near collapse.

A vicious cycle developed during the heatwave, exposing high levels of sensitivity across systems to changes in the operating conditions. The electricity system operates with little spare capacity or redundancy and has a consequent lack of resilience to unexpected perturbations such as the heatwave. The heat-induced shutdown of Bass Link (from which Victoria gets about 6% of its power supply) seriously compromised the supply capacity. This occurred during a period of high demand across the national grid, reduced transmission efficiency and heat-related asset failures (transformers). This 'perfect storm' led to outages of major transmission lines, resulting in load shedding and, ultimately, power blackouts. In Melbourne on the evening of 30 January more than 500 000 residents were without power and the system was extremely vulnerable to further and potentially system-wide failure.

Financial losses from the heatwave mainly resulted from these power outages and transport service disruptions, as well as response costs, and have been estimated at $800m (CSIRO 2010).

Key message

Given the experience of the 2009 heatwave, scenario testing should be undertaken for potentially hotter and more prolonged events on service continuity by infrastructure and essential service providers. Such analysis needs to be system wide to explicitly account for cascading effects.

Factors contributing to the vulnerability of urban infrastructure include:

- systems such as power generation and distribution operating at full capacity and being highly vulnerable to external 'shocks'
- narrow climatic operating bands for plant and infrastructure that rely on atmospheric cooling
- rapid spikes in temperature creating record demands for electricity (resulting from a combination of population growth and significantly increased deployment of air conditioners)
- critical dependencies at a system and operational unit level (e.g. transport assets that become unserviceable because heat affected components fail such as air conditioners on trains)
- the predicted increase in frequency and severity of climate-related extreme events.

Emergency management responses

Key message

The unprecedented events of the 2009 heatwave found many of the emergency management response services underprepared and relying on reactive solutions to the emerging impacts caused by the heat.

While responses by the emergency services to the heatwave were generally reactive and not well planned, taken individually, agencies tended to cope. Communication and cross-agency cooperation and coordination generally lagged behind the demands from the overwhelming situations that emerged during the heatwave.

Key message

There was an overall lack of surge planning. The general contention was that the services were fortunate that the cool change arrived when it did — services such as ambulance and paramedics, emergency treatment and mortuary capacity were under severe strain.

Despite progress in the pre-planning prior to the 2009 heatwave and greater awareness of the impacts of extreme heat on vulnerable groups, Victoria's Department of Health was still challenged by the rapidly escalating fatalities and demand for health services during the event. For most agencies in Victoria, in the lead up to the heatwave, planning for bushfire risks had taken precedence over planning for extreme heat.

The Department of Health and Ambulance Victoria engaged in significant media communication in the lead up to and during the event. The emergency management branch of the department worked with Ambulance Victoria and the hospitals to help them cope with increased demand brought on by the heatwave. However, the Victorian response to actively reduce the risks to the community from heat lacked cross-agency coordination.

No plans or arrangements for reducing the risks associated with extreme heat or to responding to a heatwave emergency existed officially in their South Australian emergency response services. Key agencies only recognised the problem once there was a situation of rapidly escalating deaths, ambulance calls and hospital admissions — in addition to mass utility and infrastructure problems. Once the emergency situation was acknowledged, all responsible organisations recognised the seriousness of the heat event and responded with a coordinated cross-agency approach.

Key message

Both the Victorian and South Australian emergency response sectors faced a diverse and complex array of challenges during the heatwave.

Challenges encountered by both states included dealing with inadequate response planning; assessing the severity and degree of threat posed by the heatwave; coordinating management across relevant organisations; determining the timing, consistency, frequency, mode and content of internal and external communication; resourcing and training personnel and volunteers to meet surge capacity; obtaining timely access to accurate information; reaching the vulnerable; managing public attitudes and behaviour in the heat; and encouraging the public to take personal responsibility.

Key message

The major public health concerns stemming from the impacts of the 2009 heatwave have acted as a catalyst for the evaluation of heatwave planning policy and for the development of more comprehensive plans.

A major failing during the heatwave was the absence of comprehensive response plans to manage the hazards and risks specific to the event. While there were some generic disaster response plans in place, the heatwave posed a more specific set of problems than allowed for by these plans.

However, heatwaves and their relation to human health are receiving increased attention from public health, emergency response and disaster management authorities. Stakeholders now largely realise that the impacts from extreme heat events can be considerably reduced with appropriate planning that involves effective communication, coordination, cooperation, collaboration, training and education. More proactive management of future events brings the expectation of reducing the adverse health effects experienced during the 2009 heatwave.

Based on the impacts and experiences of the 2009 event, both states have improved their planning, and newly developed documentation includes the 'Heatwave Plan for Victoria 2009–2010' and South Australia's 'Extreme Heat Arrangements Plan'.

One aspect of this planning has lead to clearer threshold temperatures for activating and escalating coordinated responses in the lead up to and during a heatwave such as issuing heatwave alerts, and for declaration of an actual heatwave emergency. It has also resolved some of the uncertainties concerning which agencies would lead and/or coordinate the heatwave response.

Key message

By identifying vulnerable groups within the community and the extent to which existing capacity was able to cope, the event has accelerated initial improvements to heatwave planning, education, communication and service capacity.

Some of the measures taken by each state to shift from a reactive and response-driven approach towards avoidance and risk reduction are comprehensively outlined in Section 5. Some of the key mechanisms implemented in Victoria are listed below.

Department of Health:

- is working with Personal Alert Victoria to provide additional support during a heat event to over 22 000 vulnerable clients
- is expanding the ‘Keeping in Touch’ weekly telephone program to include all 7000 public housing tenants aged 75 years or over
- is providing bushfire and heat advice for Home and Community care organisations
- is delivering public health messages and communications delivered through a range of community-based organisations
- is establishing a system of consultation with health and community service providers
- has fast tracked funding for councils to develop heatwave plans for addressing preparedness
- is further reviewing its heatwave planning through an external consultant
- has further developed its Heat Health Intelligence Surveillance System in order to track and report on the health impact of heatwaves
- is targeting large bodies working with the community that sit outside the responsibility of local councils and assists them to increase their capacity in response to a heat event
- has developed programs to maintain public drinking fountains, and lighting parks in the evenings so people can cool off and also be safe
- is developing a strategy for educating health professionals on heat issues, with an emphasis on dealing with the homeless and mental health.

Victoria Police:

- has modified its ‘Emergency Management Plan’. Although this is in response to the 7 February ‘Black Saturday’ bushfires, the new management arrangements will have an impact on the response to all future incidents and emergencies has refined its roles and strategy and developed a better structure so for dealing with social issues and problems arising from power cuts
- has directed officers to take more notes about the circumstances in which bodies were found
- is using a web-based, real-time information management system that provides a single access point for the collection and dissemination of emergency or event-related information
- has new command and control arrangements to improve its internal emergency management and communication.

Red Cross:

- has developed a protocol around an internal early warning system for heatwaves, whereby heat health alerts broadcast by DH would trigger a series of events and initiate communication strategies
- has partnered with other organisations to augment its capacity during emergencies
- is conducting preparedness work with vulnerable community groups.

Ambulance Victoria:

- is adjusting its triggers to make them more relevant to the situation to avoid over notifying or over preparing
- has improved call monitoring and activation and coordination of the emergency management centre.

Barriers to adaptation

Key message

A range of barriers has been identified that could impede progress toward adaptation and improved resilience to heatwave events.

Attitudinal

There was widespread resistance to recognising the heatwave as being beyond the bounds of a normal hot weather event, until it had escalated to dangerous levels.

Despite the devastating impacts of the heatwave, there remains an attitude that heatwaves do not specifically require a planned response mechanism and that the existing generic template for disaster management is adequate. Some key stakeholders did not acknowledge that there was a problem during the heatwave and believe that existing plans were adequate to manage it. Heatwaves/extreme heat events remain unlisted within the emergency arrangements of some jurisdictions.

For many people in the community, living in a warm country such as Australia does not create the sense that excessive heat can be, and is, a threat. Indeed, it is generally more welcomed and celebrated than avoided. This has implications for the approach taken in public awareness and education programs targeting heatwaves. Public education campaigns similar to those related to sun protection should be developed.

Socioeconomic

The most vulnerable are the least able to mitigate or adapt to extreme heat due to the underlying socioeconomic factors. Their ability to access affordable, appropriately designed and constructed housing, including public housing is also limited. They are also the group least likely to access some forms of public education programs unless specifically targeted at them; and most likely to experience occupational exposure through unskilled or blue-collar employment.

Behavioural

Climate control of our private and public environments (homes, commercial buildings, work environments, cars and public transport) is increasingly common. Exposure to the unmitigated ambient effects of weather is more discretionary and intermittent. With this increasing isolation from the climate, our ability to acclimatise (psychologically and physically) is likely to become diminished over time.

Financial and regulatory

Ageing, heat-sensitive infrastructure will remain vulnerable to future heatwaves without significant investment. Increasing the operating band of systems and system components is costly and investment in these areas will have to compete with other capital priorities and costs will ultimately have to be passed on to consumers.

Given the nature of economic regulation of the electricity industry, there needs to be an appreciation of the particular risks it is exposed to throughout the heatwave. Capital programs must factor in the cost of adaptation to climate change and the prospect of more frequent and intense heatwaves. This is even more imperative given the extraordinarily high economic, social and health impacts of widespread power disruptions caused by and combined with extreme heat events.

Under the federal 'Natural Disaster Response and Recovery Arrangements', heatwaves are not a recognised emergency. This prevents state governments being able to claim reimbursement for 50% of certain response and recovery costs during a heatwave.

Much of our existing residential and commercial building stock is not designed to cope with extreme heat events. The cost of adapting it could be seen as preclusive.

Information and education

There are currently no quantitative measures of the extent to which various adaptations (e.g. increased water cooling, provision of extra shading, use of alternative time schedules for activities or shifting to alternative locations or operating regimes) reduce discomfort or improve thermoregulatory performance. Without such measures the effectiveness of adaptive changes implemented to mitigate the impacts of heatwaves will be difficult to determine and hence they are less likely to be supported or act as catalysts for further adaptation initiatives.

There is poor availability within the Australian insurance industry and government agencies of adaptation-related insurance innovations for heatwave risks.

The location of affected persons, characteristics of the place in which they died or became ill, or the cause of death was not accessed in either capital city for the 2009 heatwave. Such information would help inform authorities developing heatwave management plans. Improvements in police reporting procedures, a greater awareness of the impacts of extreme heat and improved reporting systems for monitoring mortality and morbidity should improve the accuracy of the statistics collected at future events.

Managerial/Institutional

Without a whole-of-system approach, the segmentation within the electricity sector will leave this critical infrastructure vulnerable to 'systems failure' under extreme conditions such as a heatwave.

Critical roles and responsibilities of those directing the heatwave response are often ambiguous. This threatens the ability of organisations to improve governance arrangements regarding emergency management and other adaptation responses.

Technical

Equipment and materials not suitable for extreme temperatures, and new investment for upgrading and maintenance will be needed.

Key message

The standard approach of making relatively small adjustments to existing management processes is unlikely to be successful. Fundamental shifts in thinking are needed that explicitly acknowledge the new and uncertain risks that a changing climate is likely to bring. Processes for bringing together stakeholders and key decision makers with the scientific community could help promote new forms of dialogue and consensus building.

Research directions

Adaptation is a relatively new, complex and challenging field and, as such, demands practical, timely research outputs to guide future policy and decision making. Detailed research directions are made throughout the case study. Broadly speaking, they relate to:

- heatwave predictions over a range of time and space scales
- understanding the effect of extreme heat on urban heat islands and the heat-sensitive components of critical infrastructure
- the development of heat stress indices and air quality impact models for various urban sub-groups
- the interaction between heatwaves, air quality and urban form for Adelaide and Melbourne establishing a better understanding of sub-groups vulnerable to temperature extremes and characteristics that increase vulnerability
- assessing how populations, especially the vulnerable, will adapt to changes in local climate
- identifying characteristics within populations that increase vulnerability to temperature extremes
- the relationship between heat, mortality and morbidity
- the compounding effect of air quality during heatwaves
- weather-index insurance for heatwave effects in a variety of industrial, commercial and community situations
- the risks of multi-city heatwave events and their effects on emergency services, insurance and disaster relief
- determining the weak links in interconnected systems affected by heatwaves
- adaptation and resilience to extreme heat including risk perceptions of populations, current knowledge of behaviour and risk in high-risk groups.

Concluding comments

Although opportunities to improve the biophysical thermal capacity of humans are limited, exposure to extreme heat can be mitigated through behavioural adaptation and technological change.

Understanding the impacts of climate change and the vulnerability of different elements at risk to high intensity weather events such as heatwaves should be core drivers in understanding risk and investment in building adaptive capacity in our cities.

The experience from the 2009 southern heatwave and the stress it placed on key elements of the health, power and transport systems points to a system that is highly vulnerable to direct and indirect impacts of such an event. The interdependency of systems compounds the impacts, and results in knock-on effects which are transmitted through system linkages.

Even prior to the tragic loss of life and property from Victoria's Black Saturday bushfires, the focus during the heatwave build up was on the impacts and risks from bushfire, which diverted attention from the extreme heat.

The timing of the Black Saturday bushfires during Phase 2 of the heatwave eclipsed the heatwave event and thus reduced opportunities for publicising its impacts and for reflection and learning. Social memories of that time will be overshadowed by the graphic, intense, destructive and traumatic events of the bushfires. However, it should not be overlooked that as many as 500 people may have died as a result of the 2009 heatwave in Adelaide and Melbourne. It is feasible that, had the Black Saturday bushfires not occurred, an inquiry and much greater emphasis would have followed in terms of heatwave policy change and defined roles and responsibilities.

The cumulative impacts arising from the coincidence of multiple climate-related hazards (such as heatwave and bushfire) and their potential combined effect on critical elements of the urban system has not been well examined. Such a coincidence would also demand greater surge capacity from emergency response services than either event alone. Specific conflicts could arise such as balancing the need for evacuations during high fire danger days with the need for vulnerable individuals to remain cool. Therefore, bushfire management policy needs to consider the potential heat impacts on vulnerable groups as well as combined bushfire and heatwave risk reduction, more prone to heat-related problems such as photochemical smog, bushfires and network breakdowns.

Both cities had experienced severe and prolonged heatwaves in the past: it is worth asking why the 2009 heatwave resulted in the extent of emergency it did. There is the suggestion that people's vulnerability and expectations and dependency on emergency services had increased, adding to the impact of the extreme temperatures and hence to the extent of the overall emergency.

In addition to improving planning by moving beyond reactive responses towards greater emphasis on anticipatory planning, community expectations need to be addressed and capacities for self-reliance and resilience developed. This may be more problematic for those under the 40–50 age group, who are more reliant on technology and air conditioning.

The events of 2009 may indeed be a portent of the future but, with the use of current and forthcoming weather/climate knowledge as part of the guiding principles for prioritisation of adaptation measures, there is a considerable potential for ensuring more heatwave-resilient urban systems in southern Australia.

Strengthening the resilience of vulnerable infrastructure will be vital if we are to successfully adapt and build in resilience to Australian cities to cope with future conditions. Ultimately, effective adaptation responses will need to take account of a range of different risks, both climatic and non-climatic, as well as preparing for the potential impact of simultaneously occurring climate-related hazards. To that end, a greater emphasis needs to be placed on the urban system as a whole when considering future risks and appropriate resilience enhancing measures.

Section 1 Context and overview

1.1 Context and approach

Heatwaves can inflict major human and economic costs on communities and, under the influence of climate change, are seen as an increasing threat in terms of frequency, severity, duration and spatial extent.

During the summer of 2009, south-eastern Australia experienced an extreme heatwave between 27 January and 8 February. In the context of previous heatwaves, the event registered as one of the nation's most severe episodes of high temperatures over an extended period of time, with record temperatures approached or exceeded in Adelaide and Melbourne in the same three-day period. Governments, councils, hospitals and emergency response organisations and the community were largely underprepared for a heatwave of this magnitude.

Both to improve the preparedness of these critical stakeholders and to reduce the potential economic and social costs of heatwaves, access is needed to comprehensive, current and authoritative material for planning and decision making and for informing the development of future policy.

To address this shortfall in available information, the National Climate Change Adaptation Research Facility (NCCARF) funded the production of the case study 'Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009' under their Synthesis and Integrative Research Program.

NCCARF contracted the Institute for Sustainable Resources (ISR) at the Queensland University of Technology to coordinate the case study report. Other research partners in the project were Risk Frontiers (at Macquarie University), Monash University, RMIT University and the University of Southern Queensland.

Producing this report required not only a multidisciplinary research team, but also one with capabilities in a range of research methods for sourcing and compiling 'on the ground' accounts. These strategies included interviews with key personnel from more than 40 organisations, focus groups, media and database analysis and literature reviews (particularly of grey literature).

The five sections of the report examine the heatwave's meteorological characteristics; its impacts (on human health and loss of capacity, services, productivity and human services); the degree of adaptive capacity (ability to make heat-sensitive systems more resilient) for various sectors, communities and individuals; and the adaptation responses and strategies of government and emergency and associated services and their effectiveness. Barriers to adaptation and increasing resilience are also identified and further areas for research are suggested.

The report's focus is on the main metropolitan areas affected by the heatwave — Melbourne and Adelaide — where major impacts and disruptions were experienced and where most information exists. Reference is made to pertinent material from regional and local government levels where relevant.

The case study details what occurred during late January and early February 2009 in south-eastern Australia with a view to alerting managers and policy makers to the nature of the event, its impacts and repercussions. The report also seeks to describe the complex relationship between prolonged, unremitting high temperatures and the resilience of the systems and services that underpin the functioning of major cities and the welfare of their inhabitants.

Related factors outside the scope of the report are the heatwaves impacts beyond Victoria and South Australia, an economic analysis of the effects of the heatwave and Victoria’s ‘Black Saturday’ bushfires that occurred in February 2009 at the end of the heatwave.

1.2 Report structure

The case study includes an executive summary outlining the key messages.

The general content and research approach for the five sections of the study are outlined below.

1 Introduction and overview

Section 1 discusses the characteristics of severe heatwaves that tend to set them apart from other natural disasters. The hazards are extremely pervasive and difficult to avoid. The insidious nature of heatwaves meant that the 2009 event was well advanced before the extent and seriousness of the impacts were fully comprehended.

2 Meteorological and climate characteristics of the 2009 heatwave

Section 2 reviews the state of knowledge on and the significance of heatwaves in southern Australia from meteorological and climatic perspectives, derived from published accounts and analyses of previous ‘great heatwaves’ in Australia and other countries.

It provides an overall description of the heatwave (including time development, spatial extent, causal factors, diurnal profiles, presence of night-time and sea breeze cooling, heat comfort and air quality characteristics). It compares the heatwave with past events and uses a range of techniques to examine heatwaves in the context of potential near- and medium term futures as climate and urban forms change. The weather-related risk management of heatwaves is discussed in terms of vulnerability issues, the skill of forecasts at various time horizons, potential improvements in heatwave warning systems and the utility of weather risk products to foster economic resilience.

3 Human health impacts of the 2009 heatwave

Section 3 reviews the international and Australian literature documenting the impact of heatwaves on human health and the risk factors affecting vulnerability. The review of relevant Australian information focuses on the 2009 heatwave in Melbourne and Adelaide and examines the available data on the heatwave’s impact on mortality and morbidity.

This literature review covers material retrieved from peer-reviewed journals from an extensive range of databases. Additional information was sourced directly from government department websites, as well as grey literature from government and other international agency reports. Specific attention was given to government health departments in Australia, Europe, the United Kingdom, the United States of America and Canada.

4 The impact of the 2009 heatwave on critical infrastructure

Section 4 covers the heatwave's impact on the critical infrastructure of Melbourne, being the much larger city and more comprehensively documented. The infrastructure includes energy (electricity generation, transmission and distribution, and gas), transport (road, rail, air- and sea- ports), water (storage, supply and wastewater) and telecommunications. The study identifies the direct impacts of heat on these infrastructure types, as well as any indirect or 'cascading' effects that emerged. The analysis also includes a review of risk management and adaptation responses, both before and after the 2009 heat event, as employed by the infrastructure owners and managers in question.

This section examines the information compiled from a literature review and contact with key personnel in Victorian organisations. The majority of the content stems from interviews held with more than 30 key stakeholders and experts (from a range of institutions, companies and authorities) as well as from valuable 'grey' material obtained in the engagement process.

5 Emergency management response to the 2009 heatwave

Section 5 is based on information gathered from the emergency management response organisations in Victoria and South Australia including state emergency services, the police force, Red Cross and government departments. It examines policies in place prior to the 2009 heatwave, organisational experiences of the heatwave event, lessons learnt, policy changes subsequent to the heatwave and future challenges.

Seven interviews were based in Adelaide and six in Melbourne. Two focus group discussions were conducted with community/health workers in Melbourne. Where possible, interviews were supplemented with policy documentation.

1.3 The heatwave event — an overview

The southern Australian heatwave affected Victoria, eastern South Australia and northern Tasmania in late January/early February 2009. The heatwave registered as one of the most severe since records have been kept and had significant impacts in the capital cities of Melbourne (population 4 million) and Adelaide (population 1.19 million).

There is no standard definition of a heatwave. The Australian Bureau of Meteorology (BoM) provides the following high-level definition on its 'a period of abnormally hot weather lasting several days' website (www.bom.gov.au/lam/glossary).

An easily understood definition requires a heat index based on suitable temperature thresholds and which reflects both the lack of remission and the perseverance of the conditions over time. Impacts can be amplified or reduced by localised factors such as humidity, lead-up weather which may contribute to effective acclimatisation and features of the local built and natural environment.

In simple terms, most heatwave events in southern Australia result from the confluence of three factors, all of which were present in the 2009 event:

- high daily maximum and high daily minimum temperatures, leading to high daily average temperatures
- the reduced influence of the normal diurnal pattern of night-time cooling (reduced diurnal range)

- the persistence of these conditions over consecutive days, resulting in the absence of any real remission from heat stress.

In the lead-up to the 2009 event, most of eastern Australia had experienced 5–10 years of drought, more associated with historically low rainfall than excessive heat and evaporation (although ground conditions were very dry).

Meteorological conditions were exceptional during the 2009 heatwave. The heatwave spanned across two phases when temperatures peaked from 27 to 31 January (referred to in this report as Phase 1) and from 6 to 8 February (Phase 2).

Much of southern Australia experienced temperatures 12–15 °C above normal, the effects of which were accentuated by unusually hot night-time conditions which in Adelaide hovered around 30 °C and in Melbourne between 20 °C and 25 °C. In addition to record-breaking daily maximum temperatures, runs of successive hot days were also exceptional — Melbourne recorded an unprecedented three consecutive days above 43 °C.

The impacts on human health are reflected in the dramatic increases in mortality and morbidity that occurred with the increasing temperatures and persistence of the event. In Melbourne there were 374 excess deaths (deaths above what would be expected for the period of the event). This represents a 62% increase in total all-cause mortality. Similar estimates for Adelaide range from 50 to 150, with more than 3000 reports of heat-related illnesses.

Both cities experienced failure and service interruptions to heat-sensitive components of power and transport infrastructure and systems. In Melbourne on 30 January, train cancellations peaked when more than 30% of services did not run. That evening more than 500 000 residents were without power. The power generation, transmission and distribution systems were under severe stress and vulnerable to collapse.

This report looks at the complex interactions that led to this situation, areas of vulnerability and susceptibility to heat hazards and the range of direct and indirect impacts experienced.

1.4 Climate change and heatwaves

The recent heatwaves occur in a context where the scientific consensus is that such events will become more prevalent.

The International Panel on Climate Change (IPCC) noted in the Fourth IPCC Assessment on Climate Change (IPCC 2007a), that there will very likely be increases in the frequency of hot extremes, heatwaves and heavy precipitation with increased mortality/morbidity due to heatwaves (IPCC 2007b). The changes predicted in temperature-related phenomena outlined in Table 1.1 suggest that higher maximum temperatures, more hot days and heatwaves over nearly all land areas are very likely.

It is estimated that, for major cities in southern Australia, the number of days with temperatures over 35 °C and the frequency of heatwaves will double by 2030, and triple by 2070 (CSIRO 2010).

Table 1.1 Confidence in projected general changes of temperature-related phenomena (modified from IPCC 2007a, Working Group I, Chapter 11)

Temperature-related phenomena	
Change in phenomena	**Projected changes**
Higher monthly absolute maximum of daily maximum air temperatures (maxTmax); more hot/warm summer days	**VL** (consistent across model projections) **L** (fairly consistent across models, sensitivity to how the land surface is represented) **L** (consistent with large projected increase in mean temperature) — large increase in probability of extreme warm seasons.
Longer duration, more intense, more frequent heatwave/hot spells in summer	**VL** (consistent across model projections)
Higher monthly absolute maximum of daily minimum temperature (maxTmin); more warm and fewer cold nights	**VL** (consistent with higher mean temperatures)
Higher monthly absolute minimum of daily minimum temperature (minTmin)	**VL** (consistent across model projections)
Reduced diurnal temperature range	**L** (consistent across model projections)

VL – Very likely, **L**- Likely

The IPCC indicated that impacts of higher temperatures and increased frequency of heatwaves include:

- increased incidence of death and serious illness in older age groups and urban poor
- increased heat stress in livestock and wildlife
- shift in tourist destinations
- increased risk of damage to a number of crops
- increased electric cooling demand and reduced energy supply reliability.

As well as becoming more frequent, heatwaves are likely to increase in intensity and be longer in duration. Intensity and duration are key factors which dramatically increase the risks of higher rates of morbidity and mortality, and severely stress critical heat sensitive infrastructure and systems.

1.5 The 'passive crisis'

Heatwaves represent an interesting variation on the characteristics often associated with natural disasters. High intensity weather events such as cyclones, major storms and floods can result in extensive destruction of property, infrastructure, and the environment, disruption to services, and significant risks to human health and wellbeing. Disasters such as earthquakes which are largely unpredictable can result in high mortality from the catastrophic failure and collapse of buildings and infrastructure.

Heatwave phenomena are more insidious and the impacts less manifest when compared to the mayhem associated with other natural disasters. They are not photogenic disasters and have been referred to as 'passive crises'.

Globally, however, major heatwaves have resulted in very high levels of mortality. The European heatwave of August 2003 resulted in more than 45 000 deaths across 12 European countries — a catastrophic event by any measure. Indeed, the mortality for the whole summer has been estimated at up to 70 000 excess deaths across the affected countries.

When a severe heatwaves strikes, hot days are followed by hot nights, and humans, animals, plants, crops and critical components of our urban infrastructure receive no significant relief from high temperatures. During the heatwave medical facilities, support services, power supply and transport infrastructure are placed under increasing demand-side pressures and, as the event continues, supply-side pressures caused by supply chain failure and capacity constraints. This was the case in both Melbourne and Adelaide as the heatwave conditions set in on the 27 January.

As the functionality of systems starts to falter, people can also experience a reduction in options available to control their environment. This can be related to housing type, access to mechanisms to cool or ventilate living environments and the thermal response of buildings. These impacts become more widespread as the intensity, duration and spatial extent of the heatwave increases. In addition, incremental heating from the local environment particularly in cities (the enhanced heat island effect) can contribute amplification of ambient temperature or reduction of effective cooling of the embedded systems.

Investigations in this case study reflect a low level of active preparedness and understanding of the implications of the weather conditions being encountered. While there were generic disaster response plans in place, the heatwave posed a more specific set of problems than these plans anticipated.

The emergency response systems coped well overall notwithstanding that the response was reactive and largely uncoordinated. This has been acknowledged and addressed through a number of reviews of the 2009 event and the development of comprehensive plans for dealing with future heatwaves in Victoria and South Australia.

Phase 2 of the heatwave coincided with the disastrous Victorian 'Black Saturday' bushfires, which resulted in the death of 174 people. It was a catastrophic event — graphic, intense, destructive and traumatic. There is no contention that the two events are equivalent or comparable. However, in the case of the bushfires, the dramatic manner way in which lives and homes were lost, and the individual and community dislocation resulted in long-lasting psychosocial, economic and community impacts that are not associated with heatwaves.

An estimated 500 excess deaths occurred in Victoria and South Australia during the heatwave; that is, people who died of heat-related conditions or whose death was accelerated through exposure to the relentless hot conditions.

Financial losses mainly as a consequence of power outages, transport service disruptions and response costs have been estimated at $800m (CSIRO 2010). Heatwaves cannot be heard or seen and there is no sudden stimulus or sensation which leads to a quick response and avoidance — it is an event that fits 'the boiling frog syndrome'. Notwithstanding that the heatwave was overshadowed by the bushfires, the level of mortality and morbidity experienced warrants much more attention.

1.6 Vulnerability and adaptation

Climate risk management and adaptation involves understanding and quantifying: the weather risks, the vulnerabilities of the receiving environment and inhabitants (including their spatial and temporal complexities) and the effectiveness of remedial measures.

Preparing Australia for the unavoidable impacts of climate change is imperative. Adaptation measures for heatwaves include risk minimisation (e.g. reduce exposure via use of air conditioning and 'cooling' centres), storage and wise use of resources (e.g. water and available energy), forewarning and adaptive forecasting of outcomes (such as health service requirements and bushfire potential) and the use of various types of insurance measures and financial innovations (such as weather derivatives) to offset the financial losses experienced by the affected parties. Of particular interest are the multiple and possibly connected extreme events such as when hot weather amplifies bushfire damage or resource shortages.

The performance of key elements of the health, power and transport sectors points to systems that are highly vulnerable to direct and indirect impacts of the 2009 event. The interdependency of systems compounds the impacts, and results in knock-on effects which are transmitted through supply chains. The variable which acts to magnify impacts is the duration of the event. If the heatwave had persisted for several more days the impacts would have grown exponentially.

A framework for external drivers, vulnerabilities and adaptation responses to extreme heat is summarised in Figure 1.1 (Wilhelmi & Hayden 2010) for urban communities and is enlarged in this study to include urban services, infrastructure and emergency response.

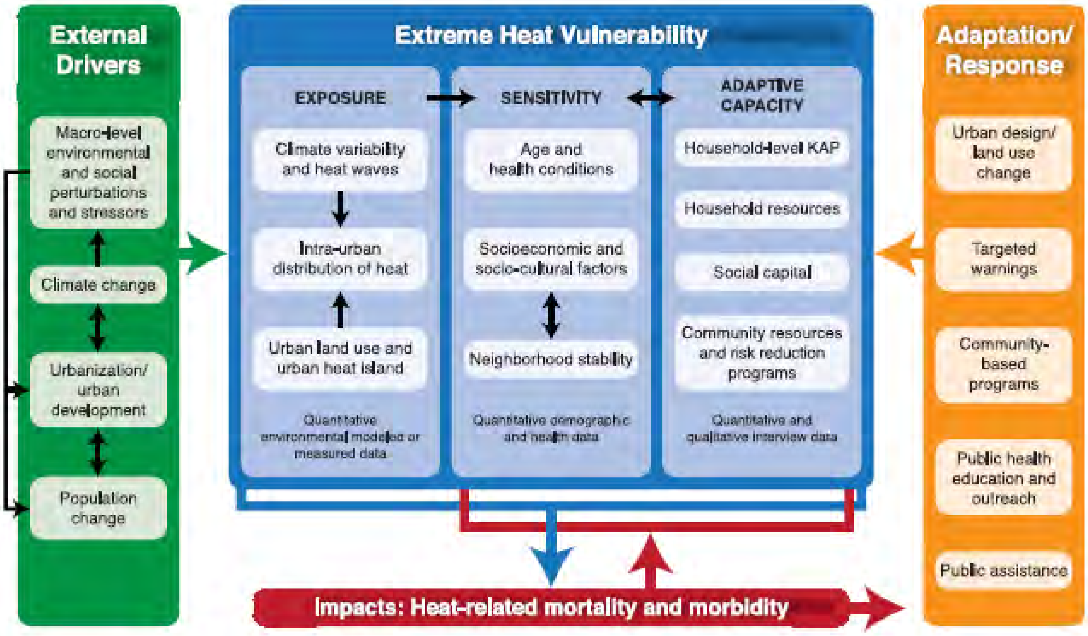


Figure 1.1 A framework for the vulnerability analysis of extreme heat; KAP denotes knowledge, attitudes and practices (Wilhelmi & Hayden 2010)

The response to a heatwave will depend on several factors:

- degree of exposure to the heat hazard
- sensitivity to changes in weather/climate (the degree to which a person or system will respond to a given change in climate, including beneficial and harmful effects)
- adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate (IPCC 2001).

1.7 Adaptive capacity

‘The ability of human systems to adapt to and cope with climate change depends on such factors as wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities’ (IPCC 2001).

In the Australian context there is significant adaptive capacity to respond to increased global warming and high temperature events.

At the level of the individual there are many factors that determine adaptive capacity, particularly during an event such as a heatwave. Biophysical, social and economic factors underpin the ability to be in a position where threats posed from heatwaves are minimised, or where threats are effectively managed during the event.

With infrastructure and services, adaptive capacity is primarily a function of good planning and preparation to respond to a variety of probable threat scenarios. The degree to which service continuity is maintained, or assets remain in service during events will reflect high levels of adaptive capacity.

Understanding the impacts of climate change and the vulnerability to high intensity weather events such as heatwaves should be core drivers in understanding risk and investment in building adaptive capacity in our population centres.

1.7.1 Human health and support services

The interviews and group discussions elicited a number of common themes which applied to the 2009 heatwave. A central issue relates to the absence of a defined threshold for triggering a planned response to what was clearly a situation well outside the bounds of a ‘normal hot weather event’.

Heatwaves have not generally been considered as an ‘emergency’ in the sense that other natural disasters are. There was no declaration of a ‘state of emergency’ with a commensurate response. As a consequence there was little formal coordination in the way that the event was managed.

Victoria and South Australia now have well developed heat response plans in place, built around:

- a thorough assessment of the hazards and vulnerability exposed by the 2009 event and the subsequent building of capacity to manage future events more comprehensively.
- strategies to reduce the impact of the hazard; where possible through adaptive measures, improved prediction, early warning, and emergency management processes
- building capability to help reduce vulnerability through the development of strategies to identify, monitor and support vulnerable groups during the event.

The plans adopt a range of approaches including:

- trigger points for implementing and escalating the plan, linked to weather prediction (for awareness and preparation) and agreed temperature parameters and thresholds
- strategies to deal with the welfare and safety of staff and service providers during the event
- clearly defined roles and responsibilities between and within agencies
- targeted community-level interventions by local government, specialist local agencies and volunteer networks.

Further investigation is warranted into the development of education campaigns targeted at vulnerable groups indicating what strategies can be adopted to mitigate harmful impacts of (or reduce exposure to) extreme heat.

Service providers such as ambulance paramedics and emergency medical workers need to have provisions for monitoring and reporting occupational exposure to extreme heat. This is both a workplace health and safety issue and one of resource planning for the surge in demand experienced during heatwaves.

1.7.2 Environmental considerations

The built and natural environment can combine at a macro and micro level to increase the risk of harmful impacts. The urban heat island (UHI) impacts need to be better understood as do opportunities to mitigate them.

At the dwelling level, micro-climatic impacts of access to natural ventilation, thermal retention and insulation in building structures and access to (and operability of) air conditioning and mechanical cooling can either amplify or reduce the heating or cooling of internal spaces and subsequent exposure to extreme heat.

With the increased possibility of power outages/disruptions, the impacts of loss of power on internal conditions need to be understood.

The ability to access 'cooler' environments will depend on such factors as location, physical mobility, social connectedness and awareness of alternatives.

Sub-groups such as the homeless have restricted opportunities and require tailored strategies to provide remission from high temperatures and access to basic requirements such as hydration.

1.7.3 Adaptive networks

With network systems such as power and transport systems comprising a myriad of active and static components, overall adaptive capacity is dependent on the sensitivity and criticality of the individual components. Other factors are important such as built-in redundancy and the ability to manage or modulate the system while maintaining operation.

There are many lessons from the heatwave in terms of inter/intra/co-dependency of systems. There are also feedback systems intrinsic to the heat event which increase sensitivity and reduce adaptive capacity.

The issues identified, particularly in the electricity and rail sectors, are significant. These systems were found to be highly susceptible to complex interactions between heat and both the demand (e.g. increased demand for power for cooling) and supply (reduced efficiency in generation and transmission due to heat) impacts of the event.

Both Melbourne and Adelaide suffered blackouts and load shedding caused by local equipment failures; service interruptions were exacerbated with the loss of the 'Bass Link' connection between Tasmania and Victoria at a crucial point during the heatwave. The failure on the Tasmanian side was heat induced — northern Tasmania was also experiencing the same conditions as Victoria and South Australia.

To address the vulnerability of the electricity system to heatwaves and climate change will require significant investment. Given the nature of economic regulation of the essentially privatised industry, there needs to be an appreciation of the particular risks exposed throughout the heatwave. Capital programs must factor in the cost of adaptation to climate change and the prospect of more frequent and intense heatwaves. This is even more imperative given the extraordinarily high economic, social and health impacts of widespread power disruptions. Resilience will also be improved by energy efficiency measures and more in-grid micro-generation facilities now being encouraged.

The same could be said about facets of the transport infrastructure such as rail systems which are prone to buckle in high heat. Heat-sensitive components of the system need to be addressed.

Power utilities and transport providers are subject to pricing regulation; there is a growing need for regulators to address the cost of investment in adaptation to climate change as a recoverable cost.

1.8 The challenges of adaptation in an era of climate change

Debate around the extent, causes, pace and impacts of climate change will continue. This study examines an event that did occur, that was severe in its impact, and which, according to the best science is predicted to occur more frequently.

It is difficult to enunciate a set of policy prescriptions to address the issues that emerged. Given the nature of the event, a precautionary approach is required which dictates a thorough analysis of the risks and mitigation opportunities available across a range of scenarios and sectors. This has been undertaken in the human services area incorporating strategies to improve resilience, particularly among vulnerable groups, with the development of more effective systems for proactive management of the event.

A broader challenge relates to understanding the interdependencies. The experience of this heatwave highlighted the relationships which exist between excess heat and the functionality of critical systems such as power supply, mechanical cooling (air conditioning) and the disruption of normal patterns of thermal absorption (heating) and radiation (cooling) of the urban environment and threats to human health and welfare.

These relationships are complex and human impacts are dependent on individual circumstances in terms of health-related vulnerability and the environmental and social context (housing, social, connectivity, access to information and services).

Measures to reduce risk and vulnerability range from simple approaches aimed at increasing adaptive capacity and resilience through education, and response planning and preparedness at one end of the spectrum, to identifying and fully mitigating all risks at the other end. The event has demonstrated there are opportunities to work right across the spectrum. Measures taken will vary in terms of cost, feasibility and effectiveness.

General strategies that are being pursued include:

- public education and awareness
- vulnerability / risk assessments
- early alert systems
- disaster preparedness (e.g. including planned surge capacity)
- more climate-appropriate design of residential and commercial buildings, and urban environments
- reduced reliance on networks
- development of more distributed systems
- increased redundancy
- more resilient infrastructure
- better strategies to identify risk and manage threats.

At a macro level more work needs to be done to identify the factors that lead to heat island effects; identify measures that reduce thermal retention in the built environment and reduce heating, and optimise cooling structures and surfaces (including private dwellings) in extreme heat events. There are regulatory mechanisms such as development control and building regulations which can prospectively support these outcomes.

The core problem, however, is that many of the factors which influence the thermal performance of the built environment of our cities (buildings, infrastructure, roads and hard standing) cannot be easily changed.

Ambient heat impact on infrastructure is rarely given the same prominence as high impact events such as bushfires or flooding. Heat stress can have significant impacts both on human health, workplace health and safety as well as vulnerable elements of the urban services.

The insurance industry can act as a catalyst to encourage increased investment in risk mitigation. There is significant activity across the insurance industry in relation to the development of new risk transfer instruments related to climate change. Again extreme heat events pose different risks, when compared to other extreme weather-induced impacts. These risks would tend to relate to such issues as financial losses due to business disruption arising from power outages, or critical equipment failure as opposed to property damage or personal injury.

Insurance costs can also send important signals as to the degree of risk and the benefit/cost of investment in adaptation/mitigation measures. Many of the issues experienced with infrastructure and services during the heatwave can be addressed with engineering or technological solutions. The business case for investment needed will be weighed against other investment priorities.

Governments at all levels are usually seen as the funder of last resort for significant costs involved in managing and remediating impacts of natural disasters. Governments have a direct role in funding disaster response and management planning, as well as the delivery of strategies to reduce exposure and vulnerability of communities to natural disasters. There are also pricing and/or taxing measures that can finance increased reliability and resilience of infrastructure or services during extreme weather events.

1.9 The way forward

This case study details the reality of the heatwave and the complex events it set in train. There have been many responses proposed to assist in adaptation to our climate future:

- more climate-appropriate design of residential and commercial buildings, and urban environments
- reduced reliance on networks
- the development of more distributed systems
- increased redundancy
- more resilient infrastructure
- better strategies for identifying risk and managing threats.

These measures are expensive and to a very great extent we have to live within the context of the built environment we have now. Fully comprehending the direct and indirect cost of the impacts of climate change is a major challenge for both the public and private sectors.

Whilst personal experience of extreme events can be an important motivator of change, lessons can be quickly ‘unlearnt’. It is critical that there is an increased focus on heatwaves as a specific and destructive threat.

Successful adaptation to heatwave impacts requires organisations affected by this event to recognise that current policy and practice may be inadequate for future events. This is particularly so, given that of all the projections from climate change models, we can have most confidence in those of temperature. Adaptation measures will involve significant challenges in terms of cost, who pays, and where responsibility for risk reduction resides. The most important action is to fully comprehend the cost in human, economic and environmental terms of failing to take all practical steps to address the shortcomings observed in the response to the 2009 event.

Section 2 Meteorological and climate characteristics of the 2009 heatwave

Introduction

Section 2 reviews the meteorological and climate characteristics of the 2009 heatwaves in southern Australia (especially in the expanding metropolises of Melbourne and Adelaide). Section 2.1 outlines the nature of the 2009 heatwave from various perspectives; including synoptic conditions, contributing factors, spatial variability and heat comfort. Historical analogues and expected future heatwave characteristics are discussed in Section 2.2, together with the predictability of such events and the utility of knowing climate-driving mechanisms.

Section 2.3 sets a context for the weather and climate risk management of extreme heatwaves. A concluding summary (Section 2.4) includes a discussion of those barriers to adaptation that are based on meteorological uncertainties and information flow and recommends directed research to aid resolution. A supplement (see Appendix A, p. 120) elaborates on the spatial and historical variability of extreme heatwaves in south-eastern Australia.

The recent major heatwaves on several continents have led to more meteorological interpretation, modelling and forecasting of heatwave characteristics. This aids the design and successful implementation of future adaptation measures such as modifying physical and socioeconomic activities, efficiently deploying available emergency assistance and securing the physical and financial recovery of heat-sensitive communities and organisations.

Reviewing the detailed meteorology of the 2009 heatwave in southern Australia both informs other parts of this assessment and shows how heatwave characteristics can vary between different regions and rural/urban landforms. Historical information interpreted in several ways, sets the 2009 event as the most severe in modern times. Recent modelling gives useful perspectives on the changes in extremes and what can be expected as anthropogenic effects (both from the warming impact of greenhouse emissions and the direct effects of urbanisation) begin to dominate climate variability.

This study synthesises available observational studies and interpretative research on southern Australian heatwaves to evaluate those meteorological characteristics that affect adaptation measures.

The 2009 events were generally well anticipated, especially in the light of the long-lived drought across the southern states. Improved forecasts can be expected from better understanding and technology, both in skill, resolution and time of forewarning. This should improve planning and emergency response activities in many sectors. Better knowledge of the physical impact of severe heatwave events in Australia will aid decision making for financial resilience and strategic government actions in preparation for any future events.

A first step in this learning from past experience is to ask how the weather and climate risks of exceptional circumstances should be judged and quantified. Severe heatwaves in southern Australia are usually associated with very low humidity; impacts are amplified if very high dry-bulb temperatures are sustained for more than 2–3 days. For many systems (Table 2.1), maximum daily or three-day average temperatures (approximated by the average of maxima and minima) often indicate the onset and severity of the event. The system response may take up to three days to show and may be more U- or J-shaped than linear with temperature.

Heatwave indices are very useful for comparing different events or demonstrating the spatial variability of heat stress. Should system responses (e.g. excess electricity demand or health outcomes) correlate well with heat index, then fine-scale meteorological predictions of the indices can facilitate the provision of advice, undertaking risk assessment and scheduling emergency response capabilities.

More strategic planning, insurance and other risk management activities (preferably some months or seasons in advance) will need probability measures for heat indices or, alternatively, information on those climate drivers that have heralded past severe heatwave events.

Table 2.1 Examples of heat stress response functions based on temperature only

System	Threshold (°C)	Dependency, lags	Comments
Human mortality	T_{av}~30	Linear?, 1–3 days	Threshold varies with location, non-linear for severe episodes
Mental disorders	T_3~28–30	Quadratic, 1–3 days	Variable between disorders and medication
Electricity demand	T_{av}~25	Quadratic, 0–3 days	Variable between load and house types
Energy transmission	T_{max}~40	Complex	Basslink has different thresholds for Victorian and Tasmanian ends of link
Transport infrastructure	T_{max}~35	Unknown	Different for buckling and discomfort
Tourism demand	T_3~35	Unknown	Other weather factors important
Air quality (smog)	T_{max}~28–30	Exponential	Dependent on presence of hydrocarbons and moisture
T_{max} = max temperature	T_{av} = average temperature	T_3 = three-day average temperature	All air temperatures measured at 2 m

This review uses and recommends the Excess Heat Factor (EHF) index recently proposed by Nairn (2009); this can be readily used with the 6 km resolution, 7-day ahead weather forecasts now provided for Victoria (and being rolled out to South Australia in 2011) by the Australian Bureau of Meteorology (BoM).

The EHF profiles for 2009 effectively demonstrate the time sequence and regional variations in heatwave evolution. Estimates of EHF from historical observations pinpoint 2009 as very unusual; both Adelaide and Melbourne had then the highest or second highest peak EHF values on record, while the EHFs accumulated over the 2009 heatwave event were without precedent (Table 2.3, p. 21).

In the following, it should be noted that many Australian enterprises are accustomed to climate variability and risk management; weather and climate information is widely and cheaply available; web-based prediction services from BoM are well supported by public financing and are continually improved by concomitant research within BoM, CSIRO, universities and many private organisations (especially agriculture and mining); and that the geographical isolation of Australasia has inhibited the development of readily available weather-risk options.

2.1 Overall description of the 2009 heatwave event

2.1.1 Synoptic conditions and record temperatures

The synoptic conditions during the extreme heatwave of January 2009 comprised a slow-moving, high-pressure system over the Tasman Sea, an intense tropical low located off the north-west Australian coast, and a monsoon trough over northern Australia. The system directed a northerly airflow over south-east Australia, moving an extremely hot air mass over the south-east of the continent (Bureau of Meteorology 2009).

Temperature time series for Melbourne City for 22 January–11 February (Figure 2.1) and the diurnal temperature ranges for Melbourne Airport and Adelaide (Kent Town) can be compared to their long-term averages (Appendix A, Figure A2.7, p. 127). This suggests an intense and long-lived Phase 1 from 27–30 January in Melbourne and longer in Adelaide. A briefer period leading up to the 'Black Saturday' bushfires of 7 February, constitutes Phase 2. Many hours of each phase had extremely low relative humidity (as low as 5%).

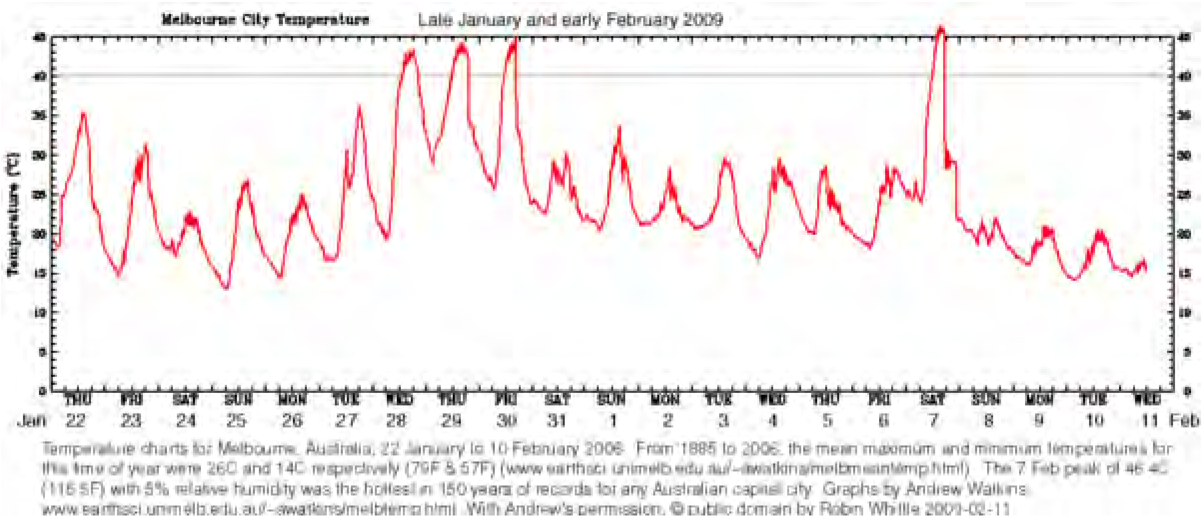


Figure 2.1 Temperature time series for Melbourne during the 2009 heatwave, showing the prominent Phase 1 period of 28–30 January (Wikipedia 2009)

In terms of the impacts examined by this case study, Phase 1 caused the most apparent distress to high temperatures, with unexpected disruptions to services leading to the rapid imposition of relief measures in many sectors (see Figure 2.2). Phase 2 dealt with the combined impacts due to extreme heatwave conditions and unexpectedly severe bushfires across both Victoria and South Australia. The lower, non-bushfire consequences of the second phase may be attributed to short-term behavioural changes and mitigation measures.

The heat began in South Australia on 25 January and became more widespread over south-eastern Australia by 27 January. The run of successive hot days recorded was exceptional and temperature records were eclipsed, not just broken (e.g. in Launceston, the record daily maximum 2 m (taken at 2 metre height) temperature for February increased by 2.6 °C to 39.6 °C, a very 'black swan' event). Over the course of the heatwave, much of southern Australia experienced temperatures 12–15 °C above normal, with unusually high night-time temperatures.

Melbourne recorded three consecutive days of temperatures above 43 °C (28, 29, 30 January) for the first time since record keeping began in 1855 and almost equalled the 1908 record of five consecutive days above 40 °C. It was also the driest January since 1932; only 0.8 mm of rain had fallen at the time of the 2009 heatwave, compared to 0.3 mm in January 1932.

The heatwave in Adelaide intensified on 27 January when temperatures tipped 43 °C. On 28 January the maximum temperature of 45.7 °C was the hottest day in 70 years. Night-time temperatures provided little relief, remaining close to or above 30 °C. On 29 January, the temperature did not fall below 33.9 °C, the hottest night on record in Adelaide. The city experienced nine consecutive days over 35 °C.

A weak cool change moved over the southern coastal areas bringing some relief on 30 January. In Melbourne, this cool change arrived that evening, dropping temperatures to an average of 30.8 °C (Bureau of Meteorology 2009). However, on 7 February (Black Saturday), new daily maximum temperature records were set for many locations (Trewin 2009) in South Australia, Victoria and Tasmania.

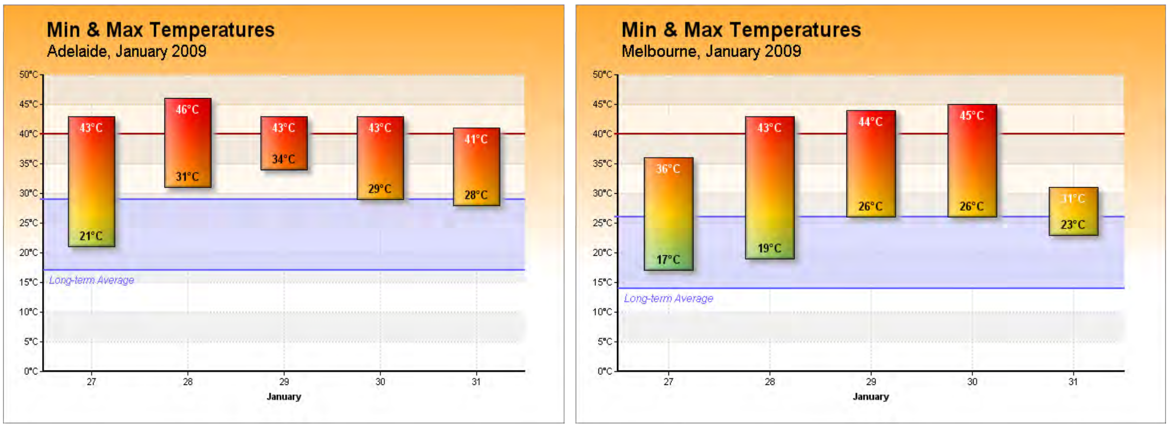


Figure 2.2 Minimum and maximum temperatures for Adelaide and Melbourne during the peak of 2009 heatwave (based on BoM information). Note that daily maximum and night-time minimum temperatures are taken at 2 m above ground level.

2.1.2 Spatial variability of heatwave characteristics

Adaptation measures need to accommodate the variability of heatwave intensity and duration across the general southern Australian region and within metropolitan areas. Much progress can be made from synthesising direct observations of surface air temperature with satellite images of land surface ('skin') temperatures and various studies on urban heat island (UHI) effects in Melbourne and Adelaide and elsewhere. The details for this case study are given in Appendix A (p. 121).

For informing emergency response strategies, the 2009 heatwave events were essentially widespread throughout south-eastern Australia. However, the amount of variability in meteorological conditions within the metropolitan areas of Adelaide and Melbourne is considerable and will interact with social variability (in terms of assessing differences in vulnerability based on socioeconomic status etc.), thereby complicating the selection of suitable adaptation actions.

It is likely that many suburbs experienced enhanced heat stress during the Phase 1 event. This however requires further 'ground-truthing' preferably over several types of heatwave events (as done in previous studies for Melbourne by Monash University researchers and now being undertaken for Adelaide by a research team from Flinders University).

2.1.3 Causal factors of extreme heatwaves

Determining causal factors of extreme heatwaves is a key to:

- assessing the physical and statistical exceptionalness of the event
- setting the event in terms of expected return frequencies to aid utility planning, insurance and weather derivative pricing
- estimating the relevant contributions from climate variability and change (and chance)
- developing prediction techniques for forewarning and/or strategic planning.

Causal factors for heatwaves can be attributed to:

i. 'blocking' mechanisms (here the presence of upper-level easterly winds around the latitude of Tasmania that stymie westward passage of synoptic systems)
ii. large-scale downward transfer of heat by tropical air subsidence
iii. advection and/or storage of heat in the lower boundary layer.

Pressure and trajectory reanalysis of the events of the past 50 years have identified at least 20 occasions when a single anticyclone has been responsible for concurrent heatwaves in Adelaide and Melbourne (van Rensch 2008). In strong heatwaves, there are indications of a feedback process between surface anticyclonic motion and an upper-level ridge to the west, with the onset of the heatwave increasing the intensity of the ridge (van Rensch et al. 2009).

For the summer 2009 events, proposed causes include subsidence as dominant (Kininmonth 2009), with others favouring sustained blocking. McBride et al. (2009) consider that the anticyclone in Phase 2 was at too low a latitude for operational monitoring to record a blocking event. Instead their trajectories suggest that a prolonged surface heating, allowed by an extensive and persistent gyre, provides a suitable mechanism. Several authors (Karoly 2009, Diamond et al. 2010) note the very unusual feature of exceptionally low surface moisture contents that had resulted from extended drought, both over the previous month and over the past several years.

There may well be several factors conducive to the heat equivalent of a 'perfect storm' in January–February 2009. This remains speculation until more detailed evaluations of this and other recent events (e.g. March 2008 and November 2009 events). In the near future, the 20th Century Reanalysis project (Compo et al. 2006) will provide a set of detailed weather reconstructions for 2009, including 56 different realisations (different outcomes consistent with observations of surface pressure and sea-surface temperatures) that may indicate how unusual the observed outcome was (i.e. how many of the 56 alternatives have worse heat stress exposures) and the importance of soil moisture effects.

For metropolitan areas such as Melbourne and Adelaide, very hot conditions can be set up quite rapidly and are generally associated with 'blocking' high pressure systems in the Tasman Sea (and sometimes in the Australian Bight). These cause both quasi-stationary weather patterns and sustained intrusion of desert (continental) air that restricts or denies the usual inland penetration of cooling sea breezes.

The causal factors for the 2009 events in Australia have considerable similarities with those for the European heatwave of 2003, where the strong role of soil and canopy moisture deficits has been demonstrated by detailed modelling (Fischer & Schar 2010, Garcia-Herrara et al. 2010). Such work suggests hot spots are likely in low-lying areas near coasts and major rivers, where local humidity effects provide considerable amplification of heat stress.

2.1.4 Diurnal profiles, night-time and sea-breeze relief

The diurnal variations in meteorological conditions are important for thermal comfort, electrical power demand, generating efficiencies and the provision of detailed advice on reactive measures. Available measurements suggest that consistent northerly winds during Phase 1 led to rapid temperature rises from high overnight values and sustained temperatures over 35 °C until late into the evening. Any bay or sea breezes would have been very weak, shallow and intermittent on these days, and of little use in providing relief to people seeking comfort in bayside suburbs.

2.1.5 Day of the week influences and memory effects

Phase 1 of the heatwave occurred on week days, when residential power demand was enhanced by industrial and transport/utility loads and hence electrical networks would be in a state of considerable stress. Phase 2 occurred on Friday and Saturday when the power system could be expected to cope better.

Short-term memory effects refer to the persistence of heat due to large-scale meteorological conditions, heat storage in urban canopies, brick and concrete buildings and the physiological impacts of heat events that have occurred on previous days (e.g. loss of sleep causing more proneness to next day impairment of immune systems).

Long-term memory effects include both the insidious influence of the previous season's rainfall on land–atmosphere interactions and the response of consumer behaviour to past events. Such memory effects are important for risk assessment and insurance purposes and for load forecasting (Lunney 2001), especially with the greater use of air conditioners in outer suburban and brick homes.

These memory effects are generally important in the forecasting and risk management of heatwaves. Whilst this is not yet confirmed for Australian conditions, events such as the 2003 European heatwave show that return periods (how long to expect before another similar event occurs) are quite sensitive to the interaction of increasing trends in mean temperatures and temperature variability and to the treatment of memory and 'noise' effects (Charpentier 2010).

2.1.6 Heat comfort indices

Conventional options for quantifying weather and climate risks for heatwaves include using a target threshold temperature (e.g. a 'heat health temperature threshold' is when the air temperature is likely to impact significantly on the health of the community), or a high percentile (such as 90th, that is, a day hotter than 90% of past days observed for a given period). These simple approaches (Kurbis et al. 2009) exclude geographical and socioeconomic factors such as heat sensitivity; acclimatisation; and the influences of age, gender, culture and social networks.

Further investigations into heatwaves may lead to a series of temperature thresholds (e.g. 30 °C for elderly mortality, 27 °C for hospital admissions for cardiovascular diseases Nicholls et al. 2008 and Loughnan et al. 2010, and a set of thresholds for mental health) and the inclusion of other weather factors such as the wind and humidity profiles over the event duration, the persistence of conditions, and the importance of antecedent events (such as a prior hot period, drought and general acclimatisation for the time of year).

Heat comfort indices currently in use, apparent temperature and wet-bulb globe temperature, indicate likely and considerable heat stress during the Phase 1 heatwave (see Table 2.2 for a Melbourne example). While apparent temperature and wet-bulb globe temperature factor in elements such as humidity, wind and radiation, they do not consider the effects on comfort of adaptation measures, such as drinking water.

Quantifying the relief obtained from adaptation measures has only been done for animal heat stress. According to studies by Gaughan et al. (2008, 2009) on Australian and American cattle, above a certain threshold for ruminants (HLI_R=86), accumulation of heat may lead to heat stress over a sustained period. The best recovery from heat load occurs when the HLI_R is below 77 for four to six hours during the night. However, longer periods may be needed following prolonged exposure to an excessive heat load. For ruminants, providing extra shading or adequate drinking water can each reduce the HLI_R by three units.

BoM forecasters have proposed the EHF for use in low atmospheric moisture contents. It is a simple measure, suitable for widespread use and provides a robust forewarning system (Nairn et al. 2009). It takes into account both acclimatisation (by looking at how the last three days differ from the average temperatures over the past 30 days) and the exceptional nature by comparing the three-day average temperature with historical records. In future, EHF could easily be adapted to account for humidity influences and adaptation measures, and become an alternative health-related measure.

Table 2.2 Heat comfort indices for Melbourne during Phase 1 of the 2009 heatwave

Index	Values (°C)	Interpretation
Maximum temperature	36, 43, 44, 45	extremely hot spell throughout urban area
Minimum temperature	19, 26, 26, 23	‘tropical’ nights
Apparent temperature*	40–43	heat cramps or heat exhaustion likely, heat stroke possible
Wet-bulb globe temperature^	32–36	extreme risk of injury
Heat Load Index (HLI_R)	80–91 (3 pm) 70–82 (9 am)	heat accumulation dominates in ruminants
Excess Heat Factor (EHF)	>50	severe heatwave much more significant than most previous episodes

* *Apparent temperature*: the temperature, at the reference humidity level, producing the same amount of discomfort as that experienced under the current ambient temperature and humidity (BoM website).
^ *Wet-bulb globe temperature*: a weighted average which factors in the effects of humidity, wind and radiation.

2.1.7 Air quality characteristics

Prolonged heatwave events (especially with desert winds and weaker and shallower sea breezes) are likely to increase the ground-level concentrations of both primary gaseous pollutants and fine particulates. Increases are also likely in secondary pollutants (e.g. ozone) that affect many asthmatics at concentrations below existing national guidelines. Some population groups will be especially antagonised by the combination of heat stress and increased pollutant exposure, especially those in peri-urban areas.

Neither the Victorian nor South Australian environmental protection agencies will formally publish their air quality monitoring reports for 2009 until late 2010 when data validation, interpretation and internal dissemination have been completed. Verbal advice received for Adelaide suggests that ozone levels during the 2009 heatwave were well below national guidelines, but slightly over levels experienced in summer 2008 (although this may be the result of many factors or natural variability). The presence of widespread smoke in Phase 2 (WMO MeteoWorld 2009) is likely to have produced enhanced ozone conditions in areas downwind of bushfires.

Cope (2009) and other studies have strongly suggested significant interactions of heatwaves and photochemical smog for the Sydney metropolitan area. Worsening conditions are expected over the coming decades with the outer parts of the metropolitan area being more susceptible. Health impacts due to these synergies will also become more prevalent, though detailed studies have not yet been done for Melbourne or Adelaide.

2.2 History and potential future for extreme heatwaves

Historically similar events to the 2009 heatwave can inform public discussions, the evaluation of potential adaptation measures and risk management procedures and the better delineation of meteorological determinants of heatwaves. Statistical analysis of historical time series of metropolitan temperatures can give insight into the temporal variability of UHIs at key locations, the economic evaluation of adaptation measures and the importance of low-frequency climate drivers (thereby informing and testing seasonal forecasting and insurance pricing of heatwave impacts).

2.2.1 Historical analogues, variability and trends

The meteorological conditions of 27 January to 8 February 2009 appear exceptional as judged from historical observations. The 2009 event ranked second for Melbourne after 1875, and highest in severity for Adelaide.

Table 2.3 summarises the temperature characteristics for major Melbourne and Adelaide heatwaves of 2009, 1939 and 1908; the overall heat exposure is greater for the Adelaide site. The EHF values are shown (Nairn 2010) for both the maximum value throughout the heatwave (to indicate the peak intensity of the heatwave) and for the integrated values (to indicate the overall heat stress for the event). According to nearly all measures shown, 2009 was the most severe event of the three heatwaves.

Table 2.3 General temperature-related characteristics of the severe heatwaves of 1908, 1939 and 2009 for Melbourne and Adelaide

Characteristic	**12–26 Jan 1908**		**5–14 Jan 1939**		**25 Jan–7 Feb 2009**	
	Melbourne	Adelaide	Melbourne	Adelaide	Melbourne	Adelaide
Days over 30 °C	7	9	4	10	9	13
Max/min temp °C	44.2/12.7	43.4/14.2	45.6/11.3	46.1/15.3	46.4/13.0	45.7/19.1
Days over 40 °C	5	6	3	4	4	8
Consecutive days over 35 °C	6	7	1	5	4	9
Consecutive days over 30 °C	6	9	2	10	6	14
EHF (max)	86	66	23	70	131	144
EHF (integrated)	84 & 378	239 & 323	54	355	391	541

The existing 120 years of observations of near-surface temperatures, may contain sufficient information to look for low-frequency oscillations (climate patterns that fluctuate on timescales ranging from seasons to decades) such as the influences of El Niño-Southern Oscillation (ENSO) and Southern Annular Mode (SAM). The data may also reveal trends in heatwave characteristics to illustrate the role of natural variability and determine which measures are showing signs of climate change.

The EHF has been applied to Adelaide City observations of temperature to produce some summary measures of severity and duration by year and decade (Appendix A, Figure A2.8, p.129). There were many events of note in the 1890–1900s, 1940s and in the first decade of the 21st century. Long-duration heatwave events (e.g. positive EHF lasting more than eight days) have become more frequent in the last 20 years.

2.2.2 Heatwave indicators, climate drivers and predictability

The time horizons required for predicting heatwaves varies according to the sector being considered. For example, forecasts and advice a week ahead is needed for health warnings and alerts, months ahead for planning and maintenance or seasons ahead for scheduling and trading. Others such as various types of risk management and infrastructure redesign require time horizons of a year to a decade. The confidence in forecasts decreases as the horizon lengthens (Figure 2.3).

The required spatial resolution also varies between sectors. Heatwave response plans need information at local government scales, while the energy sector requires multi-state information and dependencies. As the timescales lengthen, or the spatial scales decrease, prediction emphasis will change from time sequences to statements of probability.

Past information will guide adaptation measures as long as the database is long enough to encompass a significant number of extreme events and if the climate is sufficiently stationary for basic mechanisms and dependencies to be interpretable. Some researchers advise using only records since 1975 for future scenario planning, but this may discard useful information on linkages.

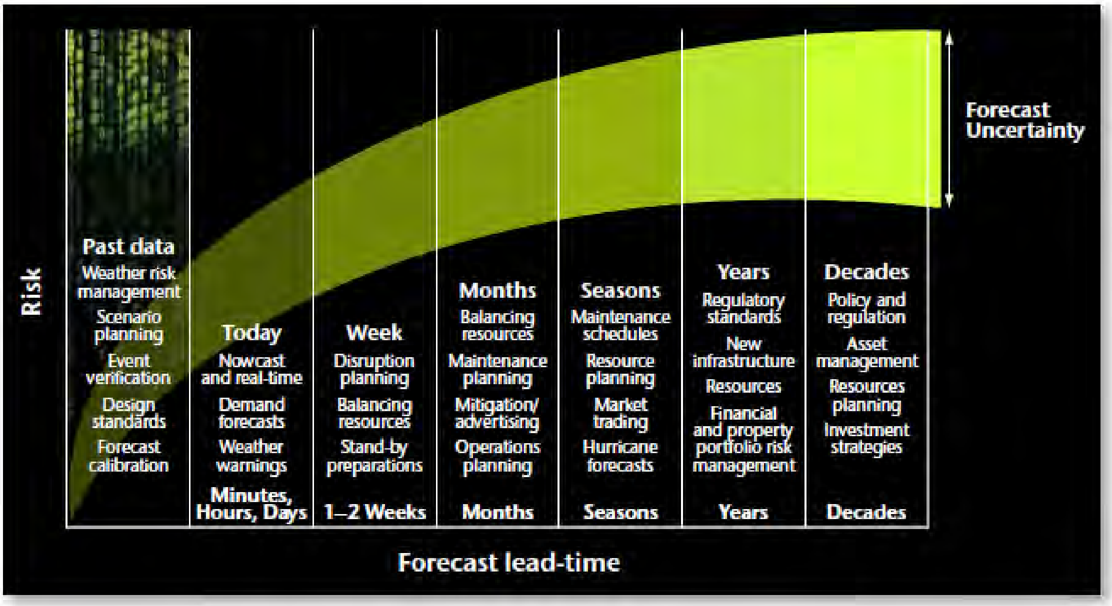


Figure 2.3 Prediction uncertainty and risk at various forecast lead times (Met Office 2009)

For Australian climates with good evidence of 15–35 year oscillations, this implies that over 120 years of heatwave statistics are necessary to reliably deduce dependencies. The 1880–1900 heatwaves deserve more attention, while forthcoming reanalysis projects will push the window back beyond 1850. Particular interests should include the clustering of heatwave events and the coincidence of high heat stress throughout two or more states (for evaluating emergency service strategies and studying the reliability of distribution networks).

Meteorological agencies are aiming for more reliable forecasts of heat stress conditions out to 7–10 days, especially once blocking becomes favoured. At coarser spatial resolution, useful forecasts out to 15–18 days may eventually be possible, but will be framed less deterministically.

Seasonal forecasting of heatwave propensity will continue to use both information based on climate drivers (e.g. the Southern Oscillation Index – SOI – and SAM) and numerical predictions of general ocean conditions. Being able to advise reliably on the unlikelihood of heatwaves may be as useful to many sectors as alerts of heatwave-conducive conditions. Recent research into the different types of El Niño and La Niña phases may be particularly useful.

Better heatwave predictions over time horizons of years to decades will aid the resilience-building of previously affected communities and sectors where recovery requires many seasons of favourable conditions.

Better statistical evidence on the influence of the various climate drivers together with advances in deterministic decadal modelling are likely to contribute to a better understanding of heatwave climatology.

2.2.3 Future heatwaves — causal factors and projected climate and urban characteristics

Global and regional climate modelling studies (e.g. Tebaldi & Meehl 2008) generally confirm that heatwave events will intensify, be longer lasting and more frequent as mean global temperatures increase over the current century.

Key issues include the changes in heatwave duration, the coincidence of ‘very hot days and tropical nights’, the role of humidity in amplifying macro scale heat impacts and the better modelling of convective processes in the atmosphere (Fischer & Schar 2010).

In Australia, the climate of the 21st century is virtually certain to be warmer, with associated changes in extreme events. What is not clear is the likely time path of these changes and whether the probability distributions of such events could undergo such significant changes as to make past direct observations of little guide to ‘king’ (much more severe than expected) events (Sornette 2009) and ‘virgin’ (never before experienced or anticipated) risks (Berger et al. 2010).

Despite this, rapid advances in atmospheric and related sciences offer improved tools and skill levels for synoptic and seasonal forecasting of ‘high impact’ weather. This will advantage various applications in reinsurance, emergency services, utility scheduling and local government preparations, with the enticement of imminent decadal climate prediction to aid strategic planning (Met Office 2009).

Most Australian climate change reviews treat heatwaves in a fairly cursory fashion, usually citing the number of hot days and warm nights per year as a measure of heat extremes. These measures have clear upward trends over the past 50 years (Steffen 2009) and are predicted to increase substantially in the next 20–60 years.

For example, predictions have been made under various global emission scenarios (each making different assumptions for future greenhouse gas emissions, land-use and other driving forces) as proposed by the IPCC in the ‘Fourth Assessment Report’ (AR4). CSIRO (2007) cites the number of hot days over 35 °C for Melbourne as rising from the current 9 to between 11 and 13 for 2030, and between 12 and 26 for 2070. For Adelaide, the predicted rise in these hot days is from the existing 17 to between 21 and 26 in 2030, and between 24 and 47 in 2070. These figures reflect the change in mean temperatures, but may not account for changes in variability. The measures are of marginal value in evaluating near-future adaptation measures.

Over the last decade, discoveries in southern hemisphere meteorology challenge the power of existing predictive climate models. There is now some good evidence for the change in intensity and/or poleward shift of the subtropical ridge as global warming proceeds (Williams & Stone 2008, Rakich et al. 2008). This will cause a shift of anticyclone trajectories over southern Australia and may alter the areas adversely affected by blocking and extended heatwaves.

Climate modelling of heatwave measures for a metropolitan region is, as yet, not very easy or successful, even with the use of recent coupled atmosphere—ocean models. Challenges include the achievable spatial resolution being too coarse; the difficulties in simulating local circulations (likely to determine heat relief) or UHI effects; and the representation of synoptic a blocking, heat storage and memory effects.

The current generation of models has been used to determine gross characteristics of heatwaves characteristics, typically over a 200 x 200 km grid square. They also often only achieve this in a relative manner between future scenarios and the present, or in a rough comparison with historical observations. In the lead-up to the IPCC Fifth Assessment Report (AR5) report in 2013, much emphasis is likely on improving coupled models, the downscaling of model outputs to give local estimates of complex extremes and the coupling with models of urban-scale meteorological processes. For heatwaves in southern Australia, the last five years has seen some progress in these directions.

Alexander and Arblaster (2009) have reviewed the success of the models used in the IPCC AR4 assessment for various extreme measures (including heatwave duration and percentage of warm nights), both judged against the 1961–1990 reference period. Compared to observations over the 1960–2000 period, the values and trends in heatwave duration are underestimated by all models for various technical reasons. Nevertheless, the modelled results for relative increases over time are useful. These show (Figure 2.4) significant increases in warm nights and heatwave duration for the IPCC B1, A1B and A2 emission scenarios. Regional models giving the number of days with temperatures over 30 °C predict significant increases as the mean temperatures increase.

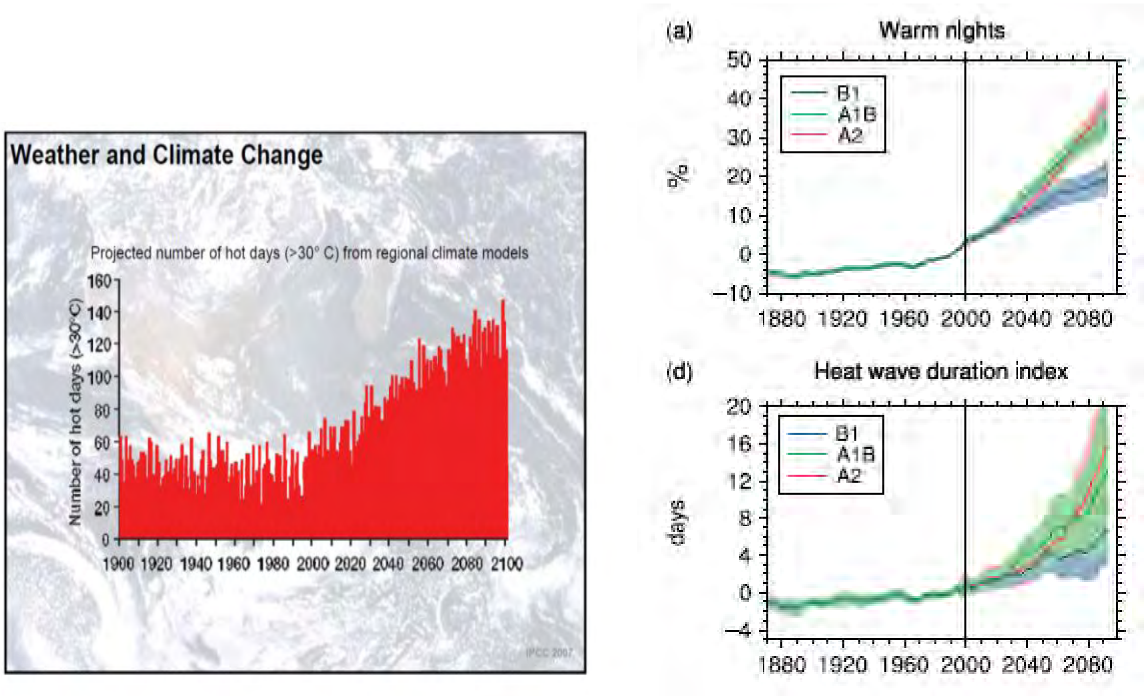


Figure 2.4 Extreme heatwave characteristics and expected climate change (Alexander and Arblaster 2009)

Using selected sites and reanalysis information since 1950 and global modelling results, Tryhorn and Risbey (2006) have shown that the climatology and prospective changes to 2100 vary across Australia and between different indices. Heatwave events along the southern coast tend to be shorter lived but greater in number. The longest events are more than twice the duration of the average event. The Global Circulation Model (GCM) results project more intense and longer heatwaves (with large increases in overnight minimum temperatures) with continued anthropogenic forcings.

A comparison of model outcomes for heatwaves in 2080–90 to 1961–90 for 200-km grid squares close to various cities (Tebaldi & Meehl 2008) has indicated that Melbourne may be much less affected than London, Tokyo, Santiago and three cities in USA. For Melbourne, the mean number of heatwaves per year should increase by 6%, while the mean duration should increase by 35%. These comparisons between cities will improve with the use of multiple reliable models, increases in model resolution and a better understanding of model biases and their effects on the assessment of extreme events.

Current climate models are less reliable in simulating rainfall and soil moisture; this complicates the assessment of future changes in relative humidity and other determinants of heat stress in Australia. Increasing night-time temperatures may increase local humidity near coasts and low-lying areas near rivers and other water bodies, as suggested in recent studies of the Mediterranean cities in Europe (Diffenbaugh et al. 2007, Fischer & Schar 2010). Humidity changes may also influence urban heat islands and pollutant formation.

Recent 25-km resolution modelling of hot extremes in the United States (Diffenbaugh & Ashfaq 2010) has suggested substantial intensification over the next three decades driven by surface drying associated with anticyclonic circulation anomalies. There are also indications of the strong influence of internal climate variability on decadal-scale changes in regional- and local-scale hot extremes.

For Melbourne, detailed simulations of summer days using the anticipated urban form in 2030 and a detailed meteorological simulator (Coutts et al. 2008) have investigated the change in UHI characteristics, but without yet including the influences of the expected global warming trend.

In this Australian context of heatwave adaptation planning, many questions are pressing:

- How will the dominant ocean modes of temperature respond to a warming world? Will the dependencies on climate drivers be stable?
- How will heat island severity and extent change, especially in expanding metropolises?
- How will the effects of changing synoptic patterns, alterations in urban fabric and regional warming affect the characteristics of heatwaves in the southern cities?
- Will these effects negate the likely gains in adaptive capacity?

2.3 Weather and climate risk management of heatwaves

2.3.1 Key features to be included in vulnerability analysis

Extreme heat is a leading cause of weather-related mortality in many countries; severe heatwaves cause an estimated economic loss of $1.27 billion per event in Australia (Capital Hill Consulting 2010). The social vulnerability to extreme heat events may increase as metropolitan areas expand in size and population, as the proportion of over 65-year-old people rises (especially the elderly without good support mechanisms) and as a warming climate increases the likelihood of events (Kalkstein et al. 2009).

These issues have to be addressed as part of a top-down, bottom-up approach to heat vulnerability (see Figure 1.1, p. 7 and the various reports from the EUROHEAT project) and in the provision of suitable advice and warning systems for human health (and infrastructure). For a recent example of a heat warning scheme, England has a four-level system (Figure 2.5):

- level 1 for seasonal advice
- a level 2 alert if there is a 60% chance of health-affecting temperatures in the next 2–3 days
- level 3 heatwave actions if region-specific daytime and night-time threshold temperatures are exceeded
- emergency level 4 if the heatwave extends to four days in two or more regions.

In line with nation-wide heat studies, particular attention is paid to the elderly in residential care and hospitals and other high-risk groups, and to the implementation of building heat-reduction schemes on a long-term basis.

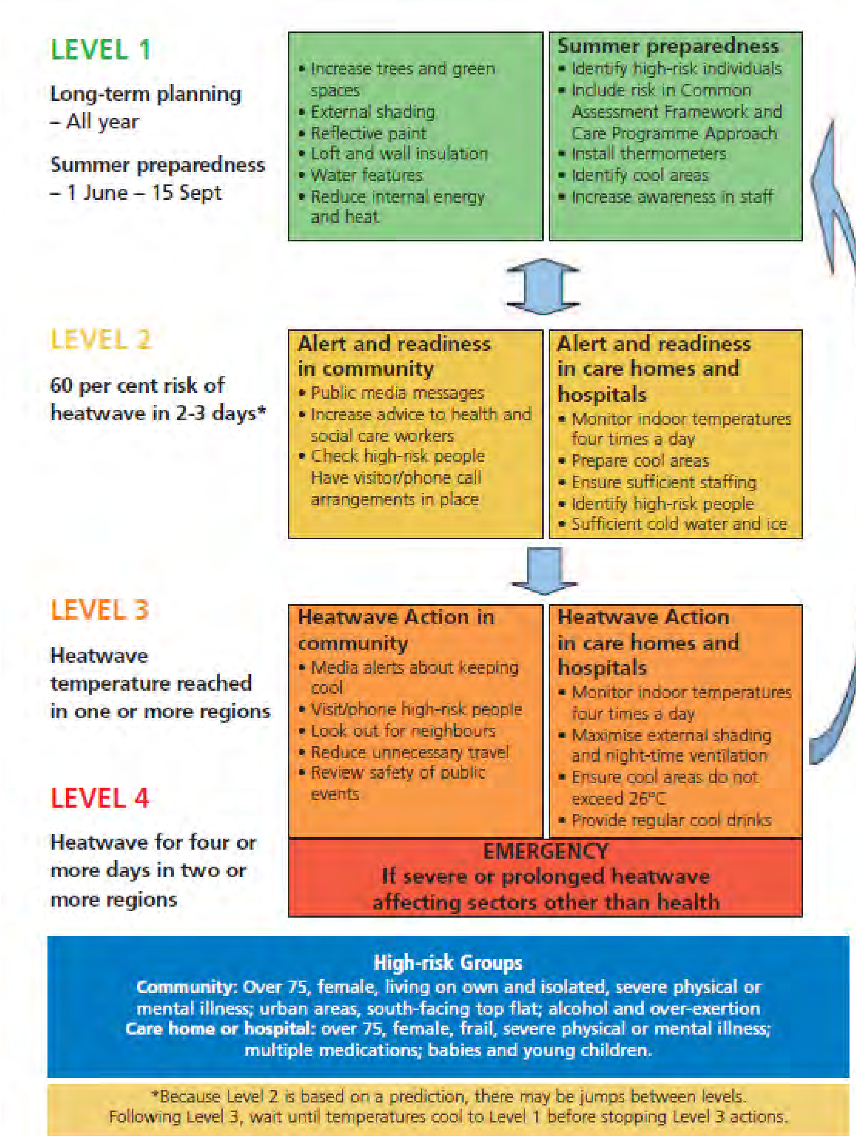


Figure 2.5 Heatwave plan for England (NHS 2009)

A concerted effort has identified vulnerability hotspots for human health in Victoria, both from socioeconomic surveys and health statistics for heatwave periods (Loughnan et al. 2010). Weak spots in infrastructure may be less obvious, except for some areas such as transmission links (AEMO 2009).

The vulnerability of emergency services themselves and supply chains are of obvious importance for extended heatwaves, experienced more frequently in the Adelaide metropolitan region. These are fertile areas for further investigation.

2.3.2 Synoptic and seasonal forecasting in heat stress warning systems

The Victorian heat warning system in place for the 2008–09 summer season uses 7-day-ahead synoptic weather forecasts at fine resolution to give:

- a ‘heatwatch’ if the maximum temperature is expected to exceed 36 °C in the Melbourne area (40 °C in the Mildura region)
- a heat alert at 6 to 1 days out of the predicted heat event if daily average temperatures are expected to exceed 30 °C (Mildura 32 °C)
- emergency advice as necessary during a confirmed event.

This use of location-specific temperature thresholds is similar to systems recently developed in other countries.

High intensity and prolonged heatwaves, such as that of early 2009, present a significant challenge to numerical weather prediction. The use of 7-day-ahead forecasting schemes in Australia is a major advance and might be more reliable in blocking conditions. Most current models only go to time horizons of 5 to 7 days with reasonable accuracy. Retaining this accuracy for heatwaves of 14-day-duration (particularly useful for Adelaide) is still in the research phase.

The estimation of complex thermal comfort indices and conditions within an urban infrastructure requires a different scale of model and collection of additional input information. The synthesis of forecasts over different time and spatial resolutions is one of the major challenges for earth systems science. Nevertheless, many of the forecasts of extremes in the 2009 heatwave were very accurate, even at the 3–5 day horizon. Fawcett and Hume (2010) describe the new BoM system principally designed to forecast maximum and minimum temperatures throughout Australia at fine spatial and time resolutions.

For the 2009 Phase 2 event, Figure 2.6 shows that record temperatures were indicated five days in advance, while spatial patterns were well indicated two days in advance (except near the coast where the temperature observations exceeded the predictions). The warnings of the likely frontal movements for the weather changes on 7 February were a good depiction of what happened. The details of such surges and the influences of cumulonimbus clouds on heat balances need further attention (Bannister 2009).

The temperature forecasts and warnings were available to both the public and various agencies for the 2009 event. Victoria also has detailed pollution forecasts and is often the first state to trial new items on the Bureau’s web services. At the time of writing, consideration is being given to the introduction of a national heat stress warning system (short term), based on current numerical weather forecasting schemes (about to move to a resolution of 6 km and time horizon of seven days) and the use of the EHF. The major challenges for many potential users may be the incorporation of such forecasts into specific weather risk management schemes and the provision of suitable and clear advice to the public. Similar issues have arisen in warning systems for asthmatics and agri-industries, but Australian research groups are well known for their successful extension activities.

Seasonal outlooks can provide useful information on the probability of extreme events, especially as the many influences on the weather and climate of southern Australia become clearer. At present, publicly available seasonal forecasts are often criticised for not being sufficiently robust. The outlook issued in the summer of 2008–09 gave little indication of severe heat events until well into the season. Once the influence of climate drivers on heat extremes has been better delineated, specific seasonal heat stress outlooks could aid the strategic planning of emergency services and utility operations and also become an integral part of financial risk management of many sectors.

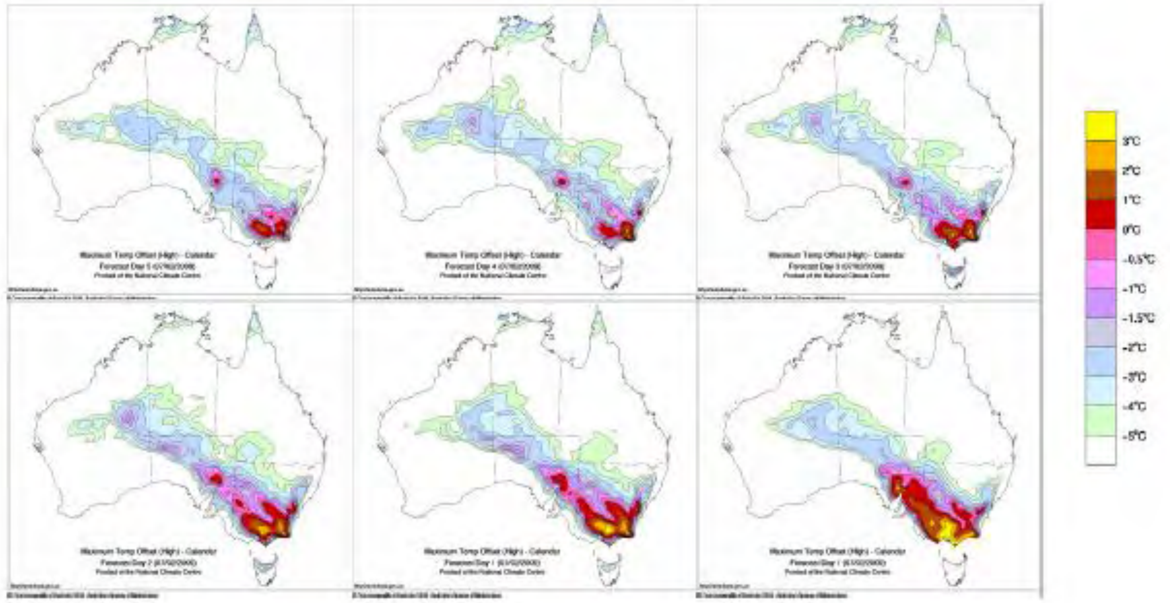


Figure 2.6 Reconstructed forecasts of Australia-wide maximum temperature anomalies for 7 February 2009 at prediction horizons of 5, 4 and 3 days (top row, left to right), 2 and 1 days (bottom row, left and centre) and day 1 outcome (lower right) (Fawcett & Hume 2010).

Seasonal heatwave warning systems of reasonable skill may be more difficult to achieve as the climate becomes more non-stationary and/or dependence on climate drivers changes. The recent spring and summer conditions of 2009–10 were unusual. Sustained heating of northern Australia affected pressure-based climate indices in an unexpected fashion and reduced the reliability of some seasonal prediction schemes. It is becoming more important to give warnings of unusually early heatwaves as these are often the most unexpected; coping strategies are often not yet in place for the coming season. The Predictive Ocean Atmosphere Model for Australia (POAMA) is a medium-term CSIRO/BoM numerical prediction model finding many applications. It may form the basis of the more integrated approaches needed to deal with the response of non-homogeneous populations to hot conditions.

2.3.3 Extreme weather events and high-impact weather

High-impact weather such as severe heatwaves in major urban areas is the current focus of much international research activity. This resulted from the several and diverse episodes occurring over the last decade and the expectations of climate change models. Research emphasis is required as much on determining response functions as on better weather observations and predictions. This is especially the case as the more vulnerable (e.g. homeless and poor people) may not have been well accounted for in past health studies on heat stress. Obvious candidates for detailed evaluation include:

- more thorough embedding of weather and climate forecasting products in both the risk management of power networks and in the planning of medical resourcing and emergency services, especially for more vulnerable and exposed communities

- the use of different simulations of past high-impact events to take into account what might have been and whether this would have resulted in more severe heat stress.

2.3.4 Weather-related financial risk management

There is a worldwide trend towards both governmental agencies and insurance companies being involved in emergency response, business recovery and adaptation incentives. The influence of heatwaves on financial risk management such as insurance is often not obvious. Whilst health costs due to heatwaves are eventually priced into the premia of private health insurance and public health financing, insurance and reinsurance considerations usually focus on associated hazards such as fire, lightning and hail damage. Insurance pricing and the sustainability of reinsurance activities may require a move to different types of measures if fat-tailed risks are to be accommodated (Kousky & Cooke 2009; 2010). Even small correlations across regions may them lead to significant systemic risks (larger losses than anticipated from past major catastrophes) and also affect the efficient deployment of emergency services (where available resources may be too quickly allocated to first-affected areas if downstream impacts are not anticipated).

Some Australian industries with high heat vulnerabilities are taking up weather risk management for heatwaves in terms of insurance options, such as weather derivatives and index-based insurance (Table 2.4). Using such measures as cooling degree days for an underlying, index-based insurance can aid the offsetting of risks of any activities where the volume of service or products is very temperature dependent. The functional forms of the relevant probability distributions (and good quality base data) become important factors in pricing and design for both insurance providers (Best et al. 2009) and, for severe events such as the 2009 heatwave, the activities of reinsurers (e.g. through stop-loss contracts). As with drought relief, government assistance in exceptional circumstances may usefully include such alternative risk management schemes with built-in adaptation incentives. Heatwave prediction and moderation of thermal stress vulnerabilities are likely to be important components of any such schemes.

Table 2.4 Alternative financial risk management strategies for extreme weather events

Heat vulnerability of sector	Index –based insurance	Business disruption insurance	Weather derivatives	Emergency relief	Government adaptation initiatives	NGO support
High	Yes	Expensive	Yes	Likely	Many	Likely
Moderate	Unlikely	Yes	Yes	Possible	General	No
Low	No	Low-cost	Yes	Unlikely	Voluntary	No

2.4 Overview and reflections

From the information available at May 2010 on the meteorology, climatology and modelling of heatwaves in southern Australia, the events of January–February 2009 have been assessed from a climate risk and adaptation perspective. This can inform the assessment of adaptive capacity in various weather-sensitive sectors such as health, infrastructure, transport, tourism and the production and distribution of food, energy and water.

Weather response in many of these areas is primarily determined by air temperature, especially in the dry/drought conditions of southern Australian summers. For many impacts, the dependence is non-linear above a certain ‘threshold’; these thresholds vary with sector, location and socioeconomic vulnerability of the affected community group. The responses are also conditioned by the:

- speed of onset, spatial extent and predictability of the event (influencing the degree of preparedness)
- intensity and duration of the events and the recovery time between major episodes
- ability to moderate the response (e.g. via air conditioning which then influences energy demand and network reliability)
- careful management of resources before and during the event
- utility of weather risk products for financial risk and emergency management.

The 2009 events were very extensive both in time and space, of record intensity and duration for many locations and, whilst well predicted (at least 3–7 days ahead), not indicated well by existing seasonal forecasting schemes. There are similarities to the heatwaves of 1939 and, more especially 1908.

Thermal comfort indices for the 2009 heatwave confirm the conditions for severe heat stress throughout the main period in late January. A non-linear temperature index usefully identifies past heatwaves (and demonstrates the considerable inter-annual and decadal variability in severe heatwaves); the 2009 heatwave had index values 50% greater than previously recorded heatwaves in Adelaide (and probably Melbourne). Comparable temperature excursions have occurred every 20–50 years throughout the direct observational records (and are expected in palaeoclimate records for the past millennium) and have caused ancillary major impacts such as catastrophic bushfires.

Several studies suggest that recent heatwaves including the January–February 2009 events have been exacerbated by long-standing droughts, both in heat build-up and associated effects such as bushfires. UHI effects are likely on ground and near-surface temperatures in night-time conditions but are as yet unconfirmed for daytime. Variability in exposure is likely to add to the complexities of socioeconomic vulnerabilities.

Current research into the climate drivers of extreme weather in southern Australia suggests many links with four or more ocean–atmosphere indices and should improve both seasonal outlooks and delineating the influence of climate change and variability on heatwave hazard risks. Southern heatwaves are rarely severe in El Niño conditions, for example.

Various types of climate modelling confirm that heatwave events (in the standard definition of consecutive very hot days and warm nights) will be more frequent and extensive features in the next 50 to 100 years; this will require a wider range of adaptive actions. The likelihood of similar events to 2009 occurring over the next two to six decades is difficult to estimate. The long-term thermal effects within an expanding metropolis may in some cases be equivalent to the influences of climate change on it.

There are strong prospects for improving the skill and utility of weather forecasts at all timescales, but especially the 7–15 day horizon and on a seasonal-to-decadal basis — this would facilitate all types of planning and improve infrastructure and financial resilience. Much more understanding of the heatwave response of various sectors is necessary, especially in determining the weak links of interconnected systems.

There is a need for a range of heat stress indices for assessing impacts (and the success of adaptation measures) and for use in public forecasting systems. From a national adaptation perspective, the risks of multi-city events and their effects on emergency services, insurance and disaster relief should be fully investigated. The heat-sensitivity of interconnected systems such as transmission networks and supply chains will become more important as the urban areas expand into more heat-prone areas and the regional and local climate warms; these areas will also be more prone to heat-related issues such as photochemical smog, bushfires and network breakdowns.

The southern Australian region is unusual in being influenced by several climate drivers and having highly-centralised infrastructure in a hot-summer, Mediterranean climate. The events of 2009 may indeed be a harbinger of the future but, with the use of current and forthcoming weather/climate knowledge as part of the guiding principles for prioritisation of adaptation measures, there is considerable potential for ensuring more heatwave-resilient urban systems in southern Australia.

2.4.1 Challenges, potential strategies and suggestions for further research

The above considerations suggest that, from a meteorological viewpoint, the main challenges to adaptation are:

- agreed definitions of heatwave characteristics as they affect health, utilities, recreational and commercial activities in the metropolitan areas, and their use in determining suitable response functions and the effect of adaptation measures
- availability of easily understood local forecasts of heat and pollutant stress to local government authorities, emergency services and sensitive groups, at various levels of severity and taking into account recent experience, time lags and memory effects for health risks, utility operations etc.
- deciphering spatial patterns of heat response due to multiple factors such as urban heat island variability, social vulnerability and knowledge of nearby less-affected areas
- incorporation of heat and pollution stress aspects into the planning of increasing populations in the peri-urban areas, and associated infrastructure
- insufficient knowledge of risk correlations (both for past events and future scenarios) for multiple risks such as heat stress, power and water shortages, availability of emergency services and for multiple disasters throughout the country
- poor availability within the Australian insurance industry and government agencies of adaptation-related insurance innovations for heatwave risks

To address these, extended analyses of the 2009 case study and other Australian heatwaves would be beneficial. Potential areas for analysis include:

- better understanding of past heatwave events, especially the influences of longer-period oscillations and recent climate change on the reliable estimation of weather-related risks
- better integrated numerical weather prediction techniques over the necessary spectrum of time and space scales
- behaviour of urban heat islands and various key sectors such as energy and transport in extreme heat conditions, especially during daytime conditions
- the role of moisture in heat stress and relief mechanisms
- development of integrated heat stress and air quality impact models for various urban sub-groups, including the economic benefits of response functions and adaptation measures

- heat sensitivity of future power networks that include more renewable sources and in-grid generation
- methods for reducing the degree of unexpectedness and loss of control caused by early season heatwaves through all sections of the communities of southern cities, especially those that are heat sensitive (direct and indirect)
- numerical studies of the interactions of heatwaves, air quality and urban form for Adelaide and Melbourne, both for the current and potential future climates
- evaluation of methods to enhance the availability and liquidity of weather-index insurance for heatwave effects in a variety of industrial, commercial and community situations
- catastrophe risk modelling of extensive (multi-city) extreme heatwaves and associated risks such as power failures and bushfire
- the development of heat stress indices for assessing impacts (and the success of adaptation measures) and use in public forecasting systems
- the risks of multi-city events and their effects on emergency services, insurance and disaster relief
- detailed modelling for Phase 1 using the verified spatial maps of land surface temperature would aid the estimation of actual human thermal comfort at typical locations in vulnerable areas
- heatwave response of various sectors is necessary, especially in determining the weak links of interconnected systems.

Section 3 Human health impacts of the 2009 heatwave

An examination of the human health impacts and vulnerability of urban populations to extreme heat, both in a broad international context and those experienced during the southern Australian heatwave of 2009 in Melbourne and Adelaide in particular.

Introduction

The impact of climate change on human health in Australia is a growing concern. Climate change projections for south-eastern Australia include an increase in the number of warm nights and an increase in heatwave frequency and duration. The effects of heatwaves on human health can be disastrous. These effects are determined by biophysical responses, behavioural adaptation and social vulnerability, modulated by exposure to the hazard and urban environmental design (McMichael & Woodruff et al. 2006; Menne & Matthies 2009).

Many studies relating health and temperature identify a U- or J-shaped temperature–mortality relationship, with an optimal temperature that corresponds to the lowest mortality and a threshold temperature above which heat-related mortality and morbidity increase above baseline levels. All studies have noted that the threshold temperatures are generally higher in cities in the warmer climate regions around the world. In addition to the effects of temperature during a heatwave, air pollution may enhance the temperature–mortality relationship (Basu & Samet 2002; Basu 2009).

Lessons learned from several heatwaves in the US over the last decade and the European heatwave in 2003, when over 45 000 people died, indicate that there are common themes in population vulnerability during heat events. The greatest risks appear to be for urban populations, the very young and elderly, persons with chronic disease or disability, and persons living in a built environment that amplifies the effects of local weather during heatwaves (Smoyer-Tomic & Kuhn et al. 2003). Individuals with pre-existing illness, either acute infections or chronic disease, are at a greater risk of heat-related illness (Kovats & Hajat 2008). Furthermore, people who are socially isolated are at a greater risk, as are people living in areas of lower socioeconomic circumstance. High urban and population density also contributes to the increased risk.

Whilst a rise in mortality is noted during heatwaves (Hajat & Armstrong et al. 2006; Le Tertre & Lefranc et al. 2006), mortality also increases during hot weather that occurs outside of 'heatwave' periods. The extent of this may rely on how a heatwave is defined. In Australia there is no universal definition of a heatwave. The Australian Bureau of Meteorology defines a heatwave as 'a prolonged period of excessive heat', which will vary according to the geographic location of cities.

With an increase in 'all causes mortality' of 374 in Melbourne and an estimated 50 to 150 excess deaths in Adelaide during the week of the heatwave, the 2009 southern Australian heatwave represents a significant natural disaster.

Human responses to the high ambient temperatures experienced during heatwaves can be sudden and life threatening (Figure 3.1). The ability to respond to or manage the threat depends on a range of issues related to the level and severity of morbidity being experienced, and the ability to access appropriate support and services. As with other impacts from heatwaves, the risk to human health is not incremental, but increases dramatically as certain thermal thresholds are reached in terms of temperature and lack of remission through cooling.

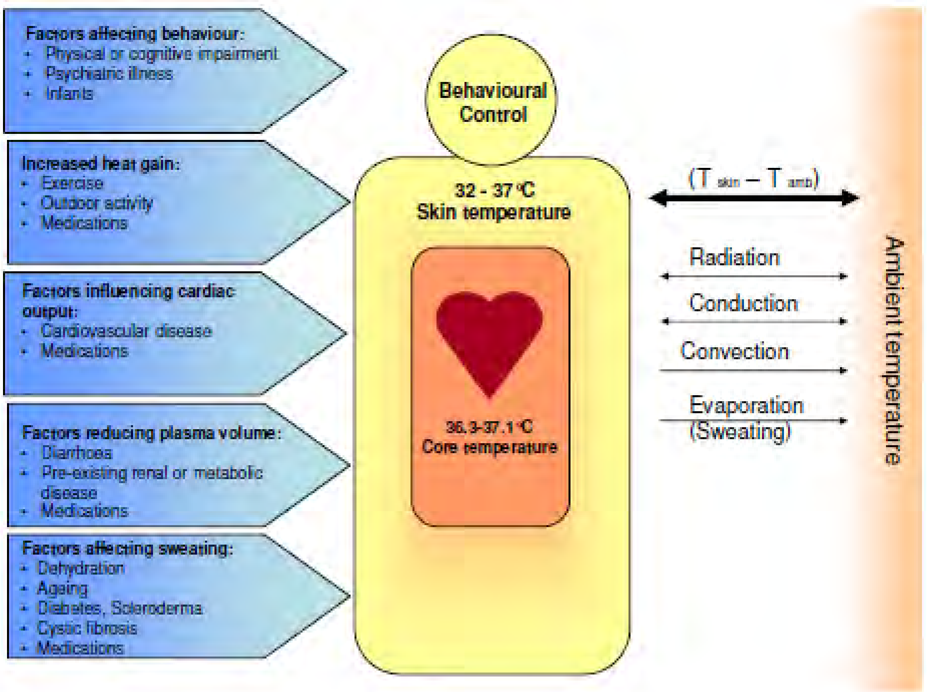


Figure 3.1 Adapted from Bouchama (2007)

Climate is one of many factors that can affect the health and wellbeing of Australians. The relationships between climate and health follow multiple pathways and complex interactions involving social and economic factors, heredity, and the provision of health services, education and literacy rates. It is however, necessary to understand these relationships in order to prevent adverse health effects associated with climate change. Extreme heat or heatwaves pose a risk to individuals especially to the elderly, the very young and the chronically ill. Few studies of climate health relationships have been carried out for Australia or more specifically for Melbourne. However, for cities worldwide there appears to be a point at which the number of adverse health effects start to increase as temperature increases; this is also the case in Melbourne (Loughnan & Nicholls et al. 2008; Nicholls & Skinner et al. 2008; Loughnan & Nicholls 2010; Loughnan & Nicholls et al. 2010).

The 2009 southern heatwave imposed significant stress on health and emergency services and has resulted in the development of strategies by agencies for the coordinated identification, mitigation and management of risk in vulnerable groups. The experience of 2009 has also led to a thorough review of the emergency response to human health impacts which emerged during the event.

3.1 Risk factors and vulnerability

Population risk factors can be classified as contextual (e.g. housing, human behaviour) and compositional (e.g. age, disability, chronic disease). Contextual and compositional factors are linked and population risk factors tend to vary according to location and the community's adaptive capacity to local weather. Listed below are factors that have been associated with mortality and morbidity in heatwaves.

3.1.1 Contextual risk factors

Socioeconomics

Whilst there is an extensive body of literature relating socioeconomic circumstance and health in general, there is less available information addressing environmental extremes such as heatwaves and health in relation to socioeconomic circumstance.

Sociodemographic characteristics can increase the likelihood of death associated with temperature extremes. Several studies from Europe and the USA have identified increased vulnerability for groups with low socioeconomic circumstance, low educational attainment and certain racial subgroups (Smoyer-Tomic 1998; O'Neill & Zanobetti et al. 2003).

Results from US studies indicate that population density, lack of vegetation, substandard housing, and lower socioeconomic circumstance were risk factors in heat-related death (Kinney & O'Neill et al. 2008).

The social factors that influence or shape the vulnerability of high-risk groups also governs their ability to respond to environmental threats or hazards. Furthermore, the quality of human settlements including dwelling size, housing density, housing type, housing structure, orientation, roadways and green space, all contribute to place vulnerability (Cutter & Boruff et al. 2003).

Housing and urban environment

Under extreme weather conditions, people spend most of their time indoors. In the 2003 heatwave in France, increased risk of mortality and morbidity was associated with brick houses (through their high thermal mass); houses with poor ventilation and poor or no insulation; multi-dwelling structures; those living above the second floor or with no green space/vegetation around the dwelling (Vandentorren & Suzan et al. 2004). Similarly, living in areas that demonstrate urban heat island (UHI) effects such as the inner city, areas of high urban density and industry has been shown to increase health risks (www.epa.gov/hiri/strategies/index.html 2008).

The physical environment and area characteristics such as air and noise pollution, high concentrations of industry, high-density housing, and reduced green space are characteristic of many urban spaces in rapidly expanding cities. These can all have a negative impact on health and health behaviour.

Climate control of internal environments

A decrease in heat-related mortality and morbidity over the past two decades in the US has been attributed to increased use of air conditioning (Davis & Knappenberger et al. 2003a; Davis & Knappenberger et al. 2003b). Lack of air conditioning may explain the increased risk of mortality in inner urban poor Americans during the Chicago heatwaves in 1995 and 1999 (Davis & Knappenberger et al. 2003b).

Concerns regarding reliance upon air conditioning include:

- power failures, either partial or complete, are common during heatwaves as increased energy demand outstrips supply
- reliance on air conditioning may alter physiological acclimatisation and increase the susceptibility of some people to heatwaves

- a high risk group, the urban poor, often does not have access to air conditioning or cooling centres, neither do groups with restricted mobility such as prisoners.

Homelessness

Whilst homeless groups are noted as being ‘high risk’ populations in terms of environmental exposures (Kosatsky & King et al. 2004), specific research describing the effects of hot weather on homeless people appears to be absent from the literature. This group may also be absent from standard mortality and morbidity heat-health estimates. The homeless are more likely to endure maximum exposure to weather and they are also at risk due to compromised health, limited access to care facilities, food and water insecurity (Green 2006; Green & King et al. 2009), and increased risks from exposure coupled with drug use (Wright & Oldham et al. 2005).

Race and ethnicity

Population segregation into neighbourhood groups based on race or ethnicity, can also affect health. Research in the US suggests that racial segregation results in the unequal distribution of economic resources, and institutional care (Maantay & Maroko 2009; Kalkstein & Davis 1989). African Americans are at a particularly high risk. However, a lower than expected risk was noted for Latino populations during the Chicago heatwave in 1995 (Dermatte & O'Mara et al. 1998; Golden & Hartz et al. 2008).

Physical activity

Participating in either occupational or recreational strenuous physical activity outdoors has been recognised as a risk factor for heat stress. The risk can be elevated for populations living in climates with high day-to-day variability which limits acclimatisation to particular excessive weather events such as excessive heat.

During heat events, there is only a limited ability to improve the physiological adaptive capacity of humans; however, responses to extreme heat can be better met through technological and behavioural adaptation (Menne & Matthies 2009). These measures are more effective when combined with improvements in design and planning for buildings and urban areas.

3.1.2 Compositional risk factors

Age

Age is an important determinant of population vulnerability during heatwaves as the very young and the elderly have a higher baseline mortality risk. Many epidemiological studies of heat-related mortality and morbidity have shown that a larger effect exists for persons over the age of 65. This is mainly due to changes in physiological thermoregulatory systems, and limited physiological reserve, as well as the presence of increased rates of chronic disease in older persons. In addition to biophysical reasons for increased risk, social factors affecting the elderly are also important in that they can increase vulnerability to the hazard (Kovats & Hajat 2008).

Infants and children are also at an increased risk of heat-related illness. This is due to inefficient sweating, higher metabolic rate, and their relative inability to control their environment. An increase in exertion also increases the risk for children as does pre-existing infection or illness. However, the effects of increased temperatures on child health have been less rigorously studied, especially the effects of increased temperature on children less than six years old.

A review of clinical presentations during an intense heatwave in Melbourne in 1959 showed pre-existing medical conditions, developmental state, acute illness, conditions of the home environment and ‘maternal ability’ were key risk factors (Danks & Webb et al. 2004). More recently, several new heat-related risk factors have been identified for young children, these include increased car travel, increased participation in competitive sports and obesity.

A study conducted at Westmead Children’s hospital in Sydney found more children presented to the emergency department with fever and symptoms of gastroenteritis as daily maximum temperatures increased (Lam 2007).

Pre-existing medical conditions

The risk of heat-related mortality and morbidity is increased for people with pre-existing illness. This may be an acute phase illness, particularly one associated with fever, or a chronic disease. There are some reports of disease-specific causes of mortality during heatwaves; however, there are few reports of cause-specific morbidity during heatwaves.

The pre-existing illnesses most notably associated with increased risk during heatwaves are cardiovascular disease; psychiatric, neurological and cognitive impairment; diabetes; cancer and obesity (Adcock & Bines et al. 2000; Vandentorren & Suzan et al. 2004; Schwartz 2005). Some medications used to treat these conditions may increase patient vulnerability by compromising thermoregulation, thermal awareness and mobility; and ability to control their environment in order to adopt protective behaviours.

Those with cognitive impairment such as dementia, and limited mobility may be at a greater risk of dehydration due to inability to access adequate fluids (Kwok & Chan 2005; Hansen & Bi et al. 2008). People with psychiatric conditions are at greater risk of death or heat-related illnesses during periods of hot weather. This may be due to decreased ability for self care, increased agitation, physiological effects of neurotransmitter activity, and anticholinergic effects of antipsychotic medication. People with pre-existing psychiatric conditions were 3.6 times more likely to die during the European heatwave in 2003 (Bouchama & Dehbi et al. 2007).

A recent study in Adelaide found that days above a threshold of 26.7 °C were associated with an increase of 7.3% in hospital admissions for mental and behavioural disorders (Hansen & Bi et al. 2008).

Medications

Ageing and chronic diseases, as well as their treatment, can considerably increase the risk of hyperthermia and heatstroke. Several drugs can impair thermoregulation during exercise or under conditions of environmental heat stress. Anticholinergic drugs inhibit sweating and therefore reduce heat elimination from the body. Some drugs such as narcoleptics and some antipsychotics have combined anticholinergic and central thermoregulatory effects (Kwok & Chan 2005). Overdoses of recreational drugs may also be linked to heat-related mortality and morbidity (Marzuk & Tardiff et al. 1998). Amphetamines and cocaine increase metabolic heat production and increase the risk of heat stress (Marzuk & Tardiff et al. 1998). An excessive intake of alcohol can lead to diuresis, dehydration, sedation and altered states of consciousness, all of which may exacerbate the potential impacts of heat stress.

3.2 Heatwave-related health effects in the 2009 Southern Australian heatwave

The relationships between climate and human health follow multiple pathways and show complex interactions between the contextual and compositional factors discussed above as well as others. Few detailed studies of the effects of climate and weather on health had been carried out for Australia prior to the 2009 event. However, there appears to be a point for cities when the number of adverse health effects start to significantly increase as temperature increases. The 2009 southern Australian heatwave provided stark evidence of the reality of this phenomenon.

This section looks at the upsurge in heat-related morbidity and mortality which occurred during the heatwave, including mortality displacement, that is, the hastening of death of those individuals who were expected to die shortly (in days to weeks) regardless of the weather.

3.2.1 Melbourne

The Victorian Department of Health (DoH) have conducted preliminary analyses on the mortality and morbidity associated with this event
(http://www.health.vic.gov.au/chiefhealthofficer/downloads/heat_impact_rpt.pdf 2009).

The population health impact in terms of mortality, morbidity and provision of services has been assessed by collecting data from five sources:

1. Assessments by Ambulance Victoria (AV) metropolitan paramedics
2. Locum doctor visits by the Melbourne Medical Deputising Service (MMDS)
3. Public hospital emergency department presentations as collected in the Victorian Emergency Minimum Dataset (VEMD)
4. Reportable deaths to the State Coroner’s Office (SCO)
5. Death registrations collated by the Victorian Registry of Births, Deaths and Marriages (BDM).

The key findings are outlined in Table 3.1.

Table 3.1 Comparative Melbourne Metropolitan health-related data for the week 26 January to 1 February 2009 compared with the same calendar dates in 2008 (based on data extracted from the ‘January 2009 Heatwave in Victoria: an Assessment of Health Impacts’ Victorian Government Department of Human Services, Victoria, 2009)

	2008	2009	Increase
Ambulance Victoria — Cases receiving an emergency ambulance dispatch in Melbourne			
Cases receiving emergency ambulance dispatch	5955	7008	+ 25%
Cases receiving emergency dispatch on three hottest days (28–30 Jan 2009)	2379	3467	+ 46%
Attendances for heat related conditions (heat stress (n = 284), heat stroke (n = 73) and dehydration (n = 157))	15	514	+ 3326%
Heat related cases > 75 years old		313 (61%)	
Total of all heat-related cases transported to hospital		80%	
Total attendances for cardiac arrest (of all causes)	69	192	+ 178%
Melbourne Medical Deputising Service (MMDS)			
Total attendances	1914	1955	+ 2%
Percentage seen in aged care facilities		53%	No change
Percentage females		62%	No change
Calls to attend a deceased person			
Attendances where person deceased	42	77	+ 83%
% of deceased > 75 years old	93%	84%	
% of deceased in aged care	93%	71%	
Patients diagnosed with direct heat-related illness included heat stroke, heat stress, heat exhaustion, heat syncope, heat rash and dehydration			
No. direct heat-related diagnosis	25	96	284%
No. > 75 years old	12 (48%)	62 (65%)	
The Victorian Emergency Minimum dataset (VEMD)			
Emergency department presentations	23 546*	26 366	12%
Emergency department presentations > 75 years old	2 607	3 568	37%
Direct heat-related conditions — including heat stroke, heat syncope and dehydration	85	714	740%
Number presenting with heat-related conditions >75 years old		325 (46%)	
Increase of patients requiring immediate resuscitation (excess of 92)			64%
Increase in emergency presentations (excess of 439)			26%
Increase in urgent presentations (excess of 1539)			25%
7% increase in semi-urgent presentations (excess of 839)			7%
Non-urgent presentations (reduction of 171 presentations) i.e. 4085 presentations compared to 4256 expected)			***Reduced by 4%***

* Average for the same week 2004–2008

Total all-cause mortality

There were 374 deaths in excess of what would be expected (known as excess deaths) — a 62% increase in total all-cause mortality. The number of deaths reported to the coroner increased as the temperature increased and peaked one day after the highest recorded temperature. The greatest number of deaths occurred in those 75 years or older, representing a 64% increase. The analysis does not indicate the extent to which some of these deaths may have been mortality displacement (advancement of expected deaths). There was a 46% increase in deaths of people aged 65–74 years and a 55% increase in the 5–64 years age group. Although 5–64 years is an exceptionally broad range, the unexpected increase in this younger group requires further investigation.

Included in these total deaths were 179 deaths reported to the State Coroner's Office, a 77% increase from the 101 deaths reported for the same period in 2008; reportable deaths in those 65 years and older more than doubled. There was no statistically significant difference in reportable deaths observed in those under 65 years.
(http://www.health.vic.gov.au/chiefhealthofficer/downloads/heat_impact_rpt.pdf 2009)

3.2.2 Adelaide

Published reports detailing the mortality and morbidity associated with the 2009 heatwave in Adelaide are still pending; therefore, the estimated human health impact could not be included in this report. Estimates for mortality in South Australia from the 2009 event range from 50–150 deaths.

In the absence of this information, heatwaves in Adelaide's recent past have been evaluated. In addition, selected extracts from the media analysis undertaken for this report are included in Appendix B.1, p.139.

Heatwaves in Adelaide during the period 1993 to 2006 were defined as three or more days of 35 °C or above. During these episodes there was a 4% increase in ambulance transports compared to non-heatwave periods (Nitschke & Tucker et al. 2007).

Emergency department presentations in four major Adelaide hospitals increased during the February 1993 heatwave, peaking following excessively high temperatures for four consecutive days between 31 January and 3 February.

Of those admitted to hospital, 17% required a higher level of care upon discharge and overall the mortality rate was 12% (Faunt & Wilkinson et al. 1995). Tables 3.2 and 3.3 show the breakdown of emergency department presentations and trends in hospital admissions over the 10-day period of the heatwave.

Table 3.2 Emergency department presentations during the 1993 heatwave (Faunt & Wilkinson et al. 1995)

Emergency department presentations	Statistic
Heat-related illnesses	94 patients (78% with heat exhaustion)
Ratio of women to men	1.29:1
Mean age	72 years (85% were 60 years or more)
Patients living alone	48% of total
Patients from institutional care	20% (11% from aged care facilities) of total
Patients with poor mobility	30% of total

Table 3.3 Hospital admissions during the 1993 heatwave (Faunt & Wilkinson et al. 1995)

Hospital impacts	Change over period of heatwave
Total hospital admissions	increased by 7%
Total renal hospital admissions	significant increase of 7%
Total mental hospital admissions	significant increase of 13%
Ischaemic heart disease admissions	increase of 8% in the 65–74 year group
Total ambulance transport	increase of 4% (95% confidence interval, 1%–7%),
Assault-related ambulance transport	significant increases for those 15–64 years
Cardiac-, sports- and falls-related events	decrease
Total mortality, disease- and age-specific mortality	no increase
Mental health-related mortality	small increase for 65–74 year group
Cardiovascular-related mortality	significant decrease (Nitschke & Tucker et al. 2007)
Kidney diseases	increase for working age range (35–64 years)

A key area of concern is occupational heat stroke risk during heatwaves. During heatwaves in Adelaide, men in the working age range 35–64 years had an increased hospital admission rate for kidney diseases. (Hansen & Bi et al. 2008). Hospital admissions for renal disease and acute renal failure increased during heatwaves compared with non-heatwave periods, with an incidence rate ratio of 1.100 and 1.255, respectively. There was no corresponding increase in hospitalisations for renal dialysis. Having diabetes did not increase the risk of renal admission; however, 'effects of heat and light' and 'exposure to excessive natural heat' were identified as risk factors (Hansen & Bi et al. 2008).

Occupational heat exposure was considered a potential cause for increased admissions to hospital in younger age groups. Similar reports affecting men 35–64 years were noted in the 2003 heatwave in France (Hémon & Jougla 2003). Using the Bureau of Meteorology Excess Heat Indice (EHI), the January 2009 heatwave was ranked as number 1 (EHI 120) in Adelaide's recorded history (http://www.cawcr.gov.au/events/modelling_workshops/workshop_2009/presentations/NAIRN_1Dec.pdf 2009). By comparison, the 2007 and 2008 heat events described above (Nitschke & Tucker 2007; Hansen & Bi et al. 2008) had an EHI of 40. It is quite possible that the human health impacts of the 2009 heatwave in Adelaide will be considerably greater than those in 2007 and 2008.

Maps of land surface temperature (LST) in Adelaide from January 27–30 indicated that areas within central Adelaide and the suburbs to the north of the city were hotter than areas to the south (coastal) or in the Adelaide foothills. There are no published maps of population vulnerability available for

Adelaide; however, the residents in the city and to the north would have experienced higher environmental temperatures. The average night-time temperature gradient across the Adelaide metropolitan area was 18.6 °C, and the average daytime temperature gradient was 18.3 °C. Therefore, where people live or work would definitely affect the heat load they experienced. More information on LSTs and heat island impacts is contained in Section 2 of this report.

3.2.3 Media reporting of health impacts

The print media survey conducted for this study (Appendix B.1, p. 134) shows that there was little awareness of the scale of the health impacts that were being felt. The fact that there were more than 370 ‘excess deaths’ in Melbourne during the period seemed to get under the radar of the Melbourne press, and it should be said the authorities involved. The extent and influence of the event was not fully understood and the signs were not as overt as with other natural disasters.

The following summarises reports from major metropolitan papers in both Melbourne and Adelaide on human health.

Human health: Melbourne

- *28 Jan* – 75-year-old man collapsed while walking 500 metres to his car; 24-year-old waiting for a tram also treated by ambulance service; paramedics called to 10 cases of heat exposure between 3-4 pm
- *29 Jan* – Ambulance Victoria flat out, with 75 heat-related calls between 9am and 5pm
- *30 Jan* – demand for emergency service leapt 50%. Ambulance Victoria attended 105 heat-related cases in Melbourne between midnight 29 Jan and 6pm 30 Jan. 60 patients needed ambulances in a 16-hour period after suffering the effects of heat exposure. Victoria Police said the heatwave was believed to have caused the death of six people
- *~4 Feb* – Deaths in Melbourne reached 19 on Wednesday
- Record temperatures resulted in Melbourne’s morgue reaching capacity well before the deadly fires began on 7 February.

Human health: Adelaide

- *28 Jan* – the SA Ambulance Service recorded an extra 79 call-outs and confirmed most of those would have been due to the hot weather
- *29 Jan* – Adelaide ambulance crews attended a record 1325 callouts in the 24 hours to midnight 29 Jan. South Australian hospitals admitted 86 people with heat-related illnesses. Near death: Ms Colleen Nun, late 60s, collapsed in her un-air-conditioned home, alone, in the afternoon heat of 43 °C after the extreme 45 °C of 28 Jan, and may have died if her son had not found her
- *30 Jan* – up to 19 dead as a result of heatwave conditions. 23 sudden deaths were reported to police in Adelaide, as opposed to just two the previous Friday, but four had nothing to do with the heatwave. Most (~14) of the remaining 19 deaths that were potentially heat related involved people 70-year-old or over; the oldest being 95. >105 patients required an ambulance after suffering heat exposure. SA hospitals admitted 80 people with heat-related illnesses before 3:30pm; 146 people admitted to hospital with symptoms of heat stress over 29–30 January. Christopher Swan, who had medical conditions and lived alone, was found dead at 11:30am: he had been sleeping on his back porch to escape the heat that had built up inside. Hazel Quinn, 82, died due to heatwave: her house was like a sauna when her body was found
- *31 Jan* – Mary Cahill, 78, dead: at her northern Adelaide one-bedroom unit, alone

- *1 Feb* – by 7pm there were 22 sudden deaths across SA (25 in total on the day?), bringing the total to 57 since 30 Jan.; many linked to heat-related causes. It is believed up to 12 heat-related deaths occurred on 1 Feb. and a few more on 31 January
- *2 Feb* – there were 15 sudden deaths reported up to 10:30pm, bringing the total to 75 since 30 Jan. Many of the fatalities have been linked to the heat but causes yet to be investigated
- *28-31 Jan* – The morgue normally holds ~25 bodies at any one time; has a capacity of 72 and by 2 February held 71 bodies. Adelaide recorded >75 sudden deaths since 29 Jan. but insufficient information to say how many were related to the prolonged heatwave. Health Minister John Hill told state parliament on 4 Feb. that 600 patients had been treated in hospital for heat-related illnesses
- As at *5 Feb* – Since the heatwave began on 26 Jan., 674 people have been admitted to the state’s hospitals with heat-related illnesses
- As at night of *6 Feb*, 690 people had gone to hospital with heat-related illnesses. Up to 80 sudden deaths have been reported in Adelaide since the heatwave began on 26 Jan
- SA Health had been prepared for the heatwave early: support agencies began calling pensioners, the elderly and the vulnerable when the temperatures began to rise. The Red Cross service phoning the elderly first picked up critical cases on 30 Jan.

Transport disruptions and power outages received more extensive coverage of issues than health in both cities.

3.3 Overview and reflections

Analysis of the 2009 heatwave health impacts in both Melbourne and Adelaide could not provide information about the location of affected persons, characteristics of the place in which they died or became ill, or the cause of death. However, the substantial impact upon the elderly suggests that persons with age-related chronic medical conditions such as cancer, heart and lung diseases, stroke and dementia experienced an increased risk of heat-related mortality and morbidity.

It is clear that the heatwave was severe enough to trigger significant, in many cases lethal health impacts in both cities. This was particularly the case among those groups who had high vulnerability due to lack of capacity to avoid or mitigate exposure to the heat hazard, and also those who had pre-existing conditions which were seriously exacerbated by the conditions. The other key factor is the period over which the event persists without any significant remission. The numbers impacted escalated with time. The concern is the potential for the impact to increase exponentially if the conditions persisted for even one or two more days.

These outcomes were generally consistent with international and previous Australian experiences.

As the crisis unfolded, authorities began to respond by providing numerous warnings in the media, particularly to the elderly to stay indoors, reduce physical activity, keep cool and well hydrated, for people to check on elderly friends, relatives and neighbours especially those living alone. There was also mobilisation of individual agencies to phone or contact vulnerable groups or individuals. The response however in both cities was not well planned or coordinated.

The major public health impact of the 2009 event may be the role it has played as a catalyst for the development of comprehensive plans for the coordinated and proactive management of future events.

The potential for heatwaves to have serious implications for human health is now a major focus for public health, emergency response and disaster management authorities. Many of the adverse health effects of heatwaves under current climate conditions are potentially preventable. Comprehensive heatwave plans have been developed in both Victoria and South Australia, and also in other jurisdictions across Australia.

The current predictions around climate change have added to the imperative to develop not just disaster management plans but also adaptation strategies aimed at reducing the risk in future events.

Adaptation is a complex challenge, in that it goes not just to those issues determining the health of individuals or groups, but the way cities are developed, the nature of our local environment, context and physical and social circumstance in which we live.

3.3.1 Challenges and potential strategies for resolution

Further research is needed to:

- establish a better understanding of vulnerable sub-groups in Australia
- examine the effects of heatwaves on rural populations
- determine the compounding effects that heatwaves have on mortality
- examine the additive effect of poor air quality during heatwaves. This reduction in quality can be brought on by the fires and dust storms that often accompany very hot weather, leading to increases in ozone or particulates
- investigate the urban heat island effect in cities to help identify populations at risk, the impacts of power and transport failures and their potential for related health impacts
- explore adaptation and resilience to extreme heat including risk perceptions of populations, current knowledge of behaviour and risk in high-risk groups such as the elderly
- identify characteristics within populations that consistently increase vulnerability to temperature extremes. This will help determine the best adaptation strategies
- better understand the relationship between heat and mortality and morbidity
- assess how populations, especially the vulnerable, will adapt to changes in local climate. This may include physiological adaptation, behavioural changes, or institutional interventions such as weather alerts or changes to urban planning.

Section 4 The impact of the 2009 heatwave on critical infrastructure

Introduction

Section 4 focuses on the impact of heat on the critical infrastructure of Melbourne (Figure 4.1), covering energy (Section 4.1), transport (Section 4.2), water (Section 4.3) and telecommunications (Section 4.4). It examines various adaptation measures and provides a concluding synthesis (Section 4.5) which outlines some of the challenges faced by these sectors in dealing with the effects of heatwaves.

In some instances important interactions exist with the fatal bushfire episode that affected Melbourne and its peri-urban area in February 2009. Such cumulative impacts are noted where they had the potential to affect the integrity of the urban system.

Figure 4.1 City of Melbourne at night (Source: Glowing home, Mugley, Flickr)

The historical importance of infrastructure in underpinning socioeconomic prosperity in Australia has long been recognised. In recent years (most notably since 2008), there has been a sharpening focus on ensuring the continued resilience of different types of infrastructure in the face of a number of diverse social, economic and environmental challenges. This is best illustrated by the establishment of *Infrastructure Australia*, whose remit is 'dedicated to the task of building an infrastructure platform for the future' (Infrastructure Australia 2008). Despite evidence of increased interest in this topic generally, the documentation reviewed (refer to Section 4 references p. 116) with some notable exceptions, either:

- pays scant regard to the issue of climate change
- highlights climate change as an important issue, though addresses it in terms of mitigation rather than from an adaptation or vulnerability perspective, or

- recognises the importance of enhancing resilience of infrastructure to climate change, though analysis remains relatively broadbrush (usually at the macro-scale) with little technical or real-world detail.

This recently published literature on urban and regional infrastructure highlights several points of significance to this case study. Future resilience will be impacted by a range of multiple stressors (Government of Victoria 2008e), with population growth and the impacts of climate change cited as two of the most critical challenges facing owners and managers of public and private infrastructure assets (Engineers Australia 2010). In the instances where climate change impacts are given prominence in reports, the hazards emphasised tend to be drought, flooding (including sea level rise), and bushfires (see for example: Government of Victoria 2008e). Due to recent experiences in Victoria, drought and bushfires have the highest profile. Heat stress does not figure significantly in any of the documentation though when it is mentioned it tends to be in relation to the energy sector, typically the vulnerability of electricity transmission and distribution components of the system (ATSE 2008; Maunsell 2008; CSIRO 2007).

Health publications attach much greater significance to heatwave episodes due to observed human fatalities. They raise concerns about the potential synergistic impacts on human health if substantial disruption to critical infrastructure occurred during another heatwave event (Government of Victoria 2009b). Such cascading or spillover effects are not limited to health, and also potentially resonate with other forms of emergency response, business productivity etc. (Maunsell 2008).

Although none of the reports provide any in-depth analysis, several do make mention of a perceived underestimation of the risk of total 'systems failure', with particular reference to the electricity sector. These concerns are partly attributable to:

- an inadequacy of infrastructure even for current needs (Engineers Australia 2010)
- the need for new infrastructure investment (Maunsell 2008; CSIRO 2007)
- uncertainty in climate change policy delaying investment in generation (ATSE 2008)
- a tendency to consider infrastructure projects as individual entities rather than as part of a larger integrated system (Infrastructure Australia 2008)
- traditional practice of looking to the past when planning for the future, rather than recognising (and factoring in) new and uncertain risks posed by a changing climate (CSIRO 2007), and
- concerns about potential cumulative impacts — in particular combinations such as drought, fire and heatwaves which are also co-dependent (ATSE 2008; CSIRO 2007).

Notably, Engineers Australia (2010) stress that important lessons need to be learnt from the 2009 heatwave, arguing that 'continuity risks to infrastructure became apparent' and that there were 'noticeable inadequacies that are related to the infrastructure's accessibility, age, condition, level of redundancy and tight supply–demand balance'. The City of Melbourne has already been identified as having a low security of energy supply (AECOM 2008).

Climate risk is still an evolving area of understanding, so it is perhaps of little surprise that there is not much explicit evaluation of adaptation options. One exception is that provided by CSIRO (2008), though discussion is limited to broad and generic categorisation rather than exploring evidence-based responses (options specified as: change in materials selection, design standards, maintenance regime, technology, culture, and planning). Perhaps the most common factor across all the reviewed documentation is that of building adaptive capacity, with particular emphasis placed on improving governance regimes. This is a reflection of the often complicated nature of public / private ownership and the desire for clarification of the roles and responsibilities of different actors. Along similar lines, Infrastructure Australia (2008, p. 2) notes '*there is sometimes confusion between government roles as policy maker, regulator and service provider'*. Others argue that there are also likely to be occasions when government intervention will be necessary to ensure that the future resilience of infrastructure is adequately addressed (CSIRO 2007), and that complex issues of legal liability about action and non-action are likely to arise in the future (ATSE 2008).

Bearing these broader issues in mind, the report now turns its attention specifically to the impact of the 2009 heatwave on Melbourne's critical infrastructure. For each type of infrastructure, discussion includes relevant context, consideration of the institutional dimension, and key findings on impacts and adaptation from both the literature and interviews (see Table 4.5, p.78 for details).

The commentary and input of all stakeholders interviewed for Section 4 is fully acknowledged, with any errors or misinterpretation being the responsibility of the authors.

4.1 Energy infrastructure

4.1.1 Electricity

Context

Several discrete components make up the electricity network (see Figure 4.2). These include power generation, transmission networks (which form the backbone of the system and move electricity across the State at high voltage), distribution networks (which are more localised and transport electricity at lower voltage), and finally the retail companies responsible for purchasing electricity on behalf of end users.

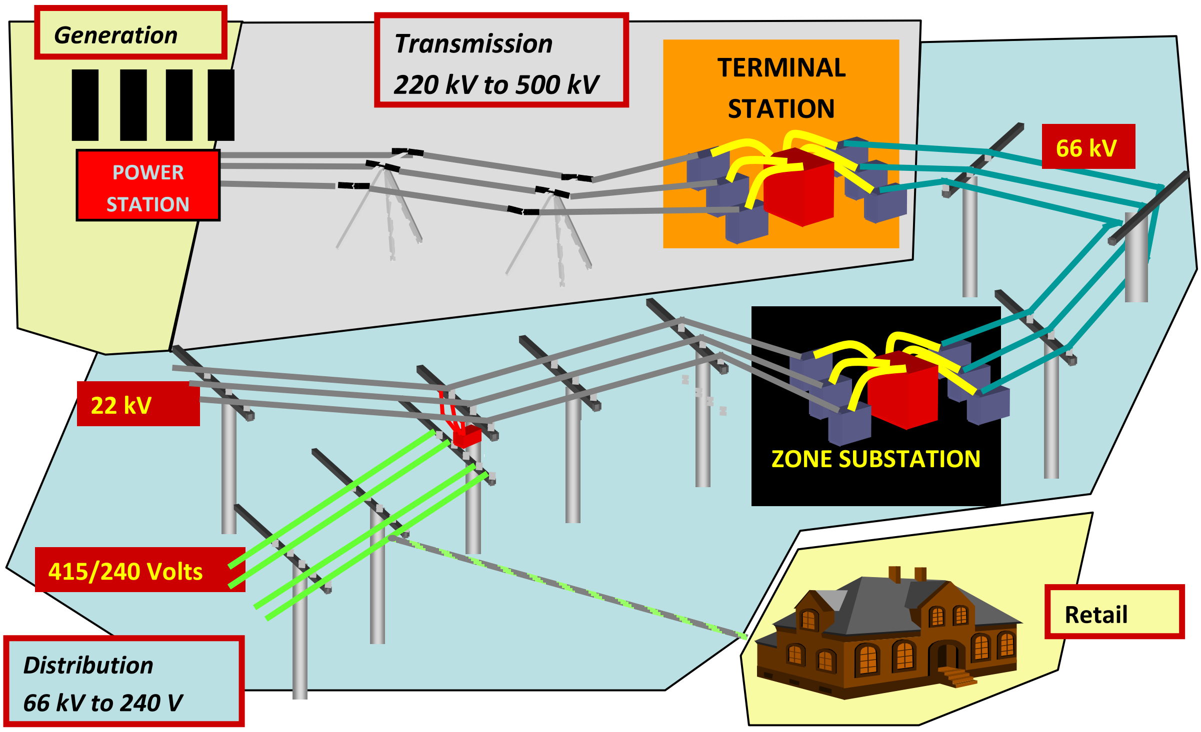


Figure 4.2 Electricity delivery in Victoria (courtesy of SP AusNet)

Generation

The majority of Victoria's electricity is generated by five coal power stations in the La Trobe Valley where there are significant brown coal resources. These generators act as the ‘base-load’ for the State’s electricity supply, providing over 6400 megawatts (MW) of capacity. This is supplemented by gas[1] (approx. 2300 MW), though hydro-electricity and wind power make further smaller contributions to the regional picture of summertime demand (approx. 1600 MW and 130 MW respectively) (Government of Victoria 2007, pp. 23–4). The electricity grid in Victoria is also ‘interconnected’ to similar grids in New South Wales, Tasmania, and South Australia.

Transmission and distribution

High voltage transmission lines link the major coal generating plants in the east of the State with the city of Melbourne, as well as connecting Victoria with other interstate power grids. These powerlines also link the gas, wind and hydro generators with terminal stations. They convert the high level voltage to a lower level before the electricity continues its journey through distribution networks to individual households and businesses. The majority of Melbourne's electricity is transported by overhead powerlines supported on poles or metal towers, though underground cables also play a role. Transmission and distribution lines are considered monopoly assets and are subject to economic regulatory oversight.

Retail

Electricity is sold to consumers through a number of commercial retail companies, who are responsible for organising the distribution companies to connect customers to the grid. The retailers deal with the energy producers and distribution companies, ultimately providing a ‘bundled’ service to the final user. Retailing in Victoria is now a fully contestable activity, enabling customers to choose between retailers and various retail offers.

Impacts and adaptation

The disaggregation of the electricity sector meant that it was necessary to interview stakeholders responsible for generation, high voltage transmission and suburban distribution. Further valuable insights were also provided by regulatory authorities AEMO and the Department of Primary Industries (DPI).

Heat and electricity

Interviewees were keen to stress that electricity and heat do not go well together, and that heat can often be the most difficult variable of electricity generation and transmission to control. All areas of the industry acknowledged that heat could cause problems within their individual areas of responsibility. Essentially, both the generation and transmission of electricity creates heat. On hot days this can be reinforced by positive feedback loops, most obviously the increased demand for electricity resulting from the greater use of air conditioners (which not only creates extra demand but also extra heat because of the way that the motors draw electricity from the grid).

The industry has a rough rule of thumb: ‘double the load, four times the heat’. As ambient temperatures increase and extra load is demanded by air conditioning, the ability to dissipate heat from parts of the system can become compromised. Continued high temperatures at night contribute further to this problem. However, the ability to dissipate heat is crucial to the continued effectiveness of generating and transmitting electricity. It is in such instances that robust risk assessment and risk

[1] Gas fired generation provides a valuable function during periods of peak demand due to quick start-up times.

management practices are required. For example, there are safety margins built into the electricity system at all points, resulting in an inverse relationship between the rising temperature and the amount of electricity that can be generated or transmitted. Put simply, as temperatures increase the ability to cool the system decreases, which therefore means that the system has to be managed in such a way that results in a reduction of the total amount of electricity it is producing and the capability to transport the generated energy to users in Melbourne, and other parts of Victoria.

Generation

Power systems generally don't handle high temperatures well. This is primarily due to how the heat generated from power creation is dissipated and the way the power created is transmitted through the conductors. The reduction in insulator capacity at higher temperatures (and a propensity to break down, particularly in smoky conditions) also contributes. A range of internal heat exchanges take place in power stations — from very large cooling towers down to small machines that provide cooling for miscellaneous assets such as motors, pumps and small transformers. Large or small, these operate to provide essential cooling and ensure that machinery is kept within safe operating temperature regimes.

Interviewees largely agreed that issues during the heatwave were not dissimilar to those normally experienced during summer, though the extreme conditions did need to be carefully managed for heightened risks. Internal hot weather procedures are already invoked during periods of extreme heat to ensure that risks are managed properly.

The interviews identified three further heat-related risks for the coal-fired power stations in Victoria. The first risk relates to coal’s combustibility, which minimises mine working on high-risk days. The second risk links to the bushfire issue, and the potential danger they pose to the power station sites in the Latrobe Valley. The third is again associated with the problem area of cooling. The steam turbines found in thermal coal-fired power stations are predominantly water cooled. Following successive hot days, the cooling water will continue to warm and hence be less effective in its role in removing heat from the system. This can have a significant impact on generating efficiency. Furthermore, motors and processes have temperature protection limits built into them, so they are essentially restricted beyond certain parameters. Heat, therefore, is a major obstacle to optimising the productivity of power stations.

Transmission

Once the electricity leaves the power station and is transported as part of the transmission network (Figure 4.3), another set of limitations becomes apparent. In this part of the system, the main equipment affected by heat is the transmission lines and the transformers. The larger transmission lines are made of steel-reinforced cables surrounded by strands of aluminium. The bulk of the current (AC) flows through the outer aluminium strands, and it is this part of the line that heats up. The hotter the lines, the more they expand. If they reach a point where they sag below the statutory limit on height for operation, the amount of electricity running through the system has to be significantly reduced. This intervention is managed remotely by computer modelling.

Figure 4.3 ‘March of the Tower Mans’, Harry Kontos Flickr

The composite ceramic insulators that support the cables are rated to handle a certain voltage. However, if the air is contaminated by moisture, smoke or ash etc., the insulating properties of the insulators can be degraded. The potential for leakage of current across the insulators is also monitored electronically, and the transmission lines can be shut down before serious incidents affect the insulators. As a result, not only does heat have the potential to directly affect transmission through sagging lines, but smoke associated with bushfires can also act as a constraint by causing leakage across insulators.

Transformers

Transformers are electromagnetic devices that change the voltage or current of electrical energy. Transmission networks use both power and instrumentation transformers. These large-scale transformers consist of metal coils mounted in a steel tank filled with oil, which is both an insulating and cooling medium. The oil passes through a heat-exchange process to keep the coils at an appropriate operating temperature. Transformers have insulators that connect the external circuits to their internal coils. These insulators can also fail due to atmospheric conditions. Instrumentation transformers used to measure voltage (Capacitor Voltage Transformers) are not affected by the load on them, but can be affected by the ambient temperature and heat from the sun heating up the oil. Smaller distribution transformers are directly affected by load which also heats the oil.

> '*Extreme heatwave events are likely to increase in frequency, generating an increase in the peak demand for electricity for air conditioning. At the same time efficiency of transmission is likely to be reduced due to the impact of likely higher summer temperatures on transmission line conductivity'* (CSIRO 2007, p. 3).

Evidence from the interviews, and relevant publicly available incident reports by the regulator — the Australian Energy Market Operator (AEMO)[2], show that a series of heat-related events on the 29 and 30 of January (maximum temperatures of 44.3 and 45.1ºC respectively) tested the electricity system across Victoria. By extracting and summarising some of the key events from these incident reports, the following picture of a system under stress emerges.

A system under stress: 29–30 January 2009

On 29 and 30 January, there were two different situations which resulted in rolling blackouts across much of Melbourne and Victoria. In one situation electricity demand, driven primarily by air conditioning, broke previous loading records for Victoria by approximately 7% (see Figure 4.4). Supply was compromised by a combination of a shutdown of the Basslink connection between Tasmania and Victoria (which provides Victoria with 6% of its electricity) and an inability of the generators to supply additional power. In the other situation, faults in instrumentation transformers (in one case an explosive incident) lead to outages of major transmission lines which restricted the ability to supply load to the Western metropolitan area and beyond. Faults in up to 50 local voltage transformers exacerbated the situation.

[2] The incident report page of AEMO (previously NEMMCO) reports on electricity outages and their causes – this information provides a useful insight into the severity of the 2009 heatwave. See: http://www.aemo.com.au/reports/nemreports.html#ops

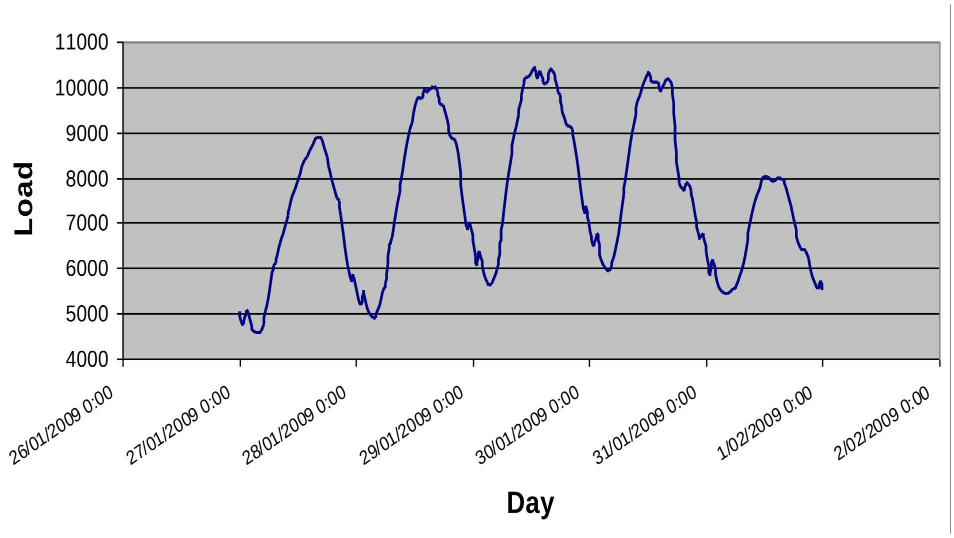


Figure 4.4 Victorian electricity load from 27–31 January 2009 (courtesy of Jemena)

Load shedding was required to protect the security of the electrical system, and therefore supply was restricted on both days. Whilst there was a loss of reserve and power shedding during the daytime on 29 and 30 January, the most significant event occurred on the evening of 30 January 2009. Three 500 kV lines from South Morang supply the interconnector to South Australia and most of the load on the west side of Melbourne and western Victoria. On 30 January, the South Morang to Keilor (No. 1) 500 kV line tripped at 14.12 hours leaving two of these lines in service. At 17.01 hours the South Morang to Sydenham (No. 2) 500 kV line had to be taken out of service as an emergency outage, leaving only one of these lines in service. As a result of this second event, the two 500 kV-line outages 'left the power system insecure' (NEMMCO 2009a, p. 30). Contingency analysis studies indicated that the loss of the third 500 kV transmission line Sydenham to South Morang No.1 would have resulted in system collapse.

As a result of the load shedding, the need to repair the voltage transformers, and bring the two high-voltage lines back into service, it is estimated that over 500 000 residents in Melbourne were without power for the evening of 30 January 2009. The incident resulted in rolling blackouts throughout western and central Melbourne for times that ranged from an hour to two hours. Knock-on effects of up to two days occurred in a number of cases. The system was finally restored just after 10.00pm on 30 January. A timeline of events is outlined in Figure 4.5.

In general, the sector tries to shed load at a distribution level, where the decisions about who and what loses power are more nuanced than at the transmission level. That is, turning off a high voltage transmission line may cut off the power to a whole neighbourhood; whereas turning off a number of lower voltage distribution lines will affect a series of residential streets. At this local level, it is then possible to discriminate between users (e.g. keeping the power flowing to a local hospital). In normal circumstances, the distribution companies aim to turn power off for no more than an hour at a time to any one area, rotating locations that experience shutdown in order to minimise inconvenience and potential problems.

Not all the events were significant in terms of the shedding of load that occurred. Considering all reveals an electrical system that was operating at close to its capacity. Some equipment is old, stressed by the heat, and struggling to meet the demands of this extreme event, particularly in some key southern metropolitan areas. Sufficient generation capacity exists to meet Victoria's demand for electricity in the medium term under non-extreme temperature conditions. However, as already noted, there are shortcomings —'*Additional baseload electricity investment in Victoria is projected to be needed in the 2010–2015 period'* (Government of Victoria 2007, p. 26).

29 January 2009

0142

Hazelwood power station, one of the oldest of the coal-fired generators operating in the Latrobe Valley, experiences an unplanned outage of a 500/220 kV transformer. This is a very large transformer; off-line from *0142–0849*.

0325

Outage of major transmission line (South Morang to Keilor 500 kV). This is one of only three 500 kV lines that link substations in Melbourne's northern suburbs. This was taken out of service due to a faulty line voltage transformer at South Morang. It was returned to service at *1005* with the faulty phase removed.

1237

Basslink, the cable connection running under Bass Strait linking the electrical grids of Tasmania and Victoria, went down at Georgetown, Tasmania. As solid-state pieces of equipment these converters have inbuilt temperature limitations. At this time of rising ambient temperatures, the convertor progressively shut down as it came close to its maximum operating temperature, eventually reducing the flow of electricity to Victoria to nil once full shutdown had been triggered.

1240

NEMMCO declared an actual 'Loss of Reserve' (LOR3) in Victoria from *1240–1520*; as a direct consequence 280 MW of electricity was shed in Victoria.

2347

The Jeeralang Terminal Station Number 1 220 kV busbar tripped, due to the 'explosive failure of a Jeeralang B Station busbar voltage transformer'. The station returned to normal availability after *0830* on 30 Jan.

30 January 2009

1015

Basslink began to progressively shut down due to heat, again at the Georgetown end.

1227

NEMMCO instructed 270 MW of load to be shed in Victoria. Various levels of load were restored and shed at intervals throughout the next few hours as NEMMCO struggled to balance the power supply against high levels of demand.

1241

Complete shutdown of Basslink, which did not resume service until *1456*.

1412

The South Morang to Keilor (No.1) 500 kV line tripped due to the 'explosive failure' of the line voltage transformer. This was the same transformer that had been taken out of service for a short period the day before. This outage didn't affect the power system immediately.

1701

The South Morang to Sydenham (No. 2) 500 kV line had to be taken out of service because of damage sustained in the earlier explosion (*1412*).

1750

Direction given to Newport Power Station to increase power output.

1753

Direction given to Laverton North Power Station to increase power output. The shed load was gradually restored throughout the evening.

2301

South Morang – Sydenham (No. 2) 500 kV line returned to service.

2310

Directions to Laverton North and Newport Power Stations cancelled.

Figure 4.5 Timeline of events

There were similar pressures operating in Adelaide, which was also impacted by the failure of supply from Basslink. This further compounded the difficulty in matching supply with dramatically increased demand for power.

4.1.2 Gas

Context

The majority of Victoria's natural gas is sourced offshore from the Gippsland Basin, east of Melbourne, and is produced at the Longford processing plant. Over 86% of Victoria's gas supply comes from this field. An increasing amount of gas is being supplied by the Otway Basins (including the Casino, Minerva, Geographe and Thylacine Fields) west of Melbourne and from the Bass Coast area (Yolla field) as well as from interstate sources. According to DPI, which has portfolio responsibility for the energy sector for Melbourne and the State of Victoria, natural gas reserves known in Victoria are expected to meet demand for at least the next 15 years. The gas network for Victoria is shown in Figure 4.6.

Figure 4.6 Victorian gas network (AEMO 2010)

Gas is extracted from these naturally occurring gas basins off the coast of Victoria, delivered to a processing plant and prepared for transmission through high-pressure pipelines across Victoria. There are approximately 1900 km of the Victorian Transmission System (VTS — also referred to as the Principal Transmission System, PTS or GasNet system). The transmission system links Victoria's gas fields with other states; the Eastern Gas Pipeline transports natural gas from Longford to Sydney, the SEA Gas pipeline from Western Victoria to Adelaide, and the Tasmanian Gas Pipeline from gas from Longford to Tasmania.

The majority of gas is used for domestic and industry heating in the winter. However, one emerging issue is the increasing use of natural gas to fire quick response electricity generators. This has increased the use of gas in the summer months.

Impacts and adaptation

Climate risks are not considered significant for gas infrastructure. The most obvious of these — drought (and subsequent drying and movement of the ground) — has already been identified as an issue due to pipe breakages. However, the distribution companies now have an ongoing policy of replacing aging pipelines and according to the recent Engineers Australia infrastructure report card; the incidence of gas leakage is decreasing (Engineers Australia 2010).

Gas explosions and upstream fires are extremely rare, but are potentially very dangerous. In 1998 there was an explosion at the Longford gas plant that left Victoria very limited gas availability for two weeks affecting a significant number of businesses and households. However, heat is usually not a factor in these sorts of accidents given that the plant operates between 60 °C to 230 °C.

There were no recorded incidents of any impacts on infrastructure arising from the 2009 heatwave. Whilst there was a failure of a compressor due to smoke intake, this was caused by the bushfire episode. Hence, gas infrastructure appears to have a high level of resilience to the impact of heat.

4.2 Transport infrastructure

Context

Various studies have pointed towards an already changing climate in Melbourne brought about by increasing temperatures and diminishing precipitation. Such changes are projected to continue and further intensify in future climate scenarios (Department of Premier and Cabinet 2009; Climate Change Task Force 2008). In general, much of the literature concentrates on mitigation, with little or no emphasis given to adaptation measures or how to build resilience into different types of transport infrastructure. Some sources, however, are beginning to express concern about climate risks and suggest that future infrastructure will have to be designed to withstand new levels of impact (Department of Transport 2009a). This implies a new approach that isn't based solely on past design criteria and one that is more aware of likely additional maintenance costs (ATSE 2008).

Lessons should have been learnt from the 2009 heatwave, but publicly accessible information on its impact on transport infrastructure is scarce. Information from the various mass media reports cannot always be considered reliable. A Department of Transport (2009a) bulletin, published in spring 2009 after the heatwave, does highlight heat stress as a key aspect of future climate change and the risk it poses for the transport sector, necessitating infrastructure to be 'designed, developed and maintained to meet current and future climate conditions'. As a consequence, risk assessments began to be updated from August 2009, though results are yet to become available in the public domain.

Because of the lack of literature specifically on the impacts of the heatwave on transport infrastructure, analysis is based primarily on primary sources, in particular interviews with key personnel and subsequent access to organisational records. The proceedings of the inquiry of the Select Committee on Train Services (2009) is an important secondary source. It documents the narratives of various stakeholders providing insights into both functional aspects and the institutional frameworks involved.

4.2.1 Rail

There are two modes of rail transport in Melbourne — trams and trains. Together they comprise one of the largest rail systems in the world at 240 km in length (Betts & McKenzie et al. 2009). While both have similar levels of boardings (Department of Infrastructure 2009b), the train network is much more extensive and spatially more widely distributed. According to both the literature and interviews, heat impacts on transport appear to have been most pronounced on rail infrastructure and operations.

Rail transport, both trains and trams, was privatised in 1999 (Stone 2008), with private operators running the franchises within a regulatory and public subsidy framework of the Victorian Government's Department of Transport. At the time of the heatwave, Yarra Trams were responsible for operating the tram network and Connex Melbourne, a wholly owned subsidiary of French company Veolia Environment, had the franchise for the trains. Both franchises are now under new ownership.

Impacts and adaptation

Trams

There were two main heat impacts that affected trams. Firstly, the heatwave caused buckling of the rail tracks. In previous times, tracks were joined by ‘fish plates’; bolted at the side and having the benefit of expansion joints. This practice has now been replaced by the use of continuous welded joints, which have no expansion gap. According to one interview respondent, there is now ‘too much rail’ which has led to increased vulnerability.

When the new tracks expand due to heat exposure, by lacking expansion joints they are susceptible to buckling at weak spots. Weakness can develop for various reasons. The tracks might have been in poor condition due to lack of maintenance, not being pre-stressed or welded adequately; or old wooden sleepers may have moved out of place due to decay or through a weakening of their fastenings to the rail (see for example: Osborne & McKeown 2009). Small stone (granite) chips, known as ballast, are consolidated around and between the rails and sleepers to keep them in place, and these may also become loose due to lack of maintenance. In reality, weakness can arise as a combination of these stresses.

Buckling is most applicable to tracks elevated above the ground (see Figure 4.7). The large majority of tram tracks are embedded into the road, which keeps them in place and helps to prevent buckling. However, even in such cases the metal tracks still experience expansion due to heat, resulting in pressure and cracking in the road paving. There does not seem to be any separate accounting of this phenomenon and repairs to cracks tend to be carried out as part of routine maintenance procedures.

Figure 4.7 Buckled tram tracks due to the heatwave (Tillotson 2009)

In its most basic form, remedial action at times of extreme heat entails cooling down the tracks by pouring water over them. Following this, the ‘extra’ rail formed by expansion is measured and trimmed off. Then the rail is straightened, realigned, and welded back into place. The buckling is usually not a significant amount — in a 300-m section it might have to be pulled up by 25 mm, with about 50 mm trimmed – and it does not weaken the rail. Since the repairs during the heatwave, no additional problems have been reported.

Tracks buckled on the first hot day (28 January) of the heatwave, but the problems fixed at that time through 'de-stressing' suffered no recurrences on the subsequent hot days. Technical personnel at Yarra Trams consider this a common procedure in rail maintenance and not a unique response to the heatwave episode.

Earlier literature that deals with this issue was cited in illustration of this long-standing issue (Kish & Samayedam 1990; Hagaman 1990; Kerr 1978). In maintenance terms, there are regular checks for rail movement at station measuring points. If there is any movement, de-stressing responses are implemented. Despite a sustained hot spell the following summer 2009/2010, albeit not of the same magnitude as 2008/2009, no buckling problems occurred. This perhaps suggests that buckling is more likely to occur above certain temperature thresholds — possibly when temperatures exceed 40 °C.

During the heatwave tram tracks buckled at Port Melbourne, Airport West and Royal Park. Compared to train tracks, impact was minimal as there are only a few places with elevated (or ballast) tram tracks. Therefore, only a few tram services were cancelled. Even on the buckled tracks, trams could continue under a speed restriction of 10 km per hour, mainly resulting in delays rather than cancellations. Drivers are trained to be careful and drive slowly in such circumstances, and workers were sent ahead of trams to pour water on tracks to cool them. In January 2009, Yarra Trams performance results indicate 98.73% of required kilometres were covered. This was above the minimum service level of 95% agreed with the government, below which compensation has to be paid. Punctuality was 82.35% above the minimum service level of 80% (Yarra Trams interviewee 2010). These results do not vary significantly from other months, indicating that service remained within normal limits.

The second impact of concern was on the physical comfort of tram passengers. Except for the ageing tourist W-class trams, the remaining fleet of 485 trams have air conditioning for drivers, though only about half of these actually have passenger air conditioning (Figure 4.8). Despite the operable windows, passengers experienced heat stress. There was no report of air-conditioning failure on trams, possibly because new air-conditioning equipment had only recently been fitted. Since the transfer of the franchise in late 2009, more trams are now being fitted with air conditioners, but this process of upgrading will be a long-term (and expensive) process with no immediate prospect of equipping the whole fleet to cater for all passenger trips. This may prove to be a contentious issue at times of heat stress, particularly when impacting children and the elderly.

As is the case with all transport sub-sectors, Yarra Trams has a heat policy. On hot days drivers and workers are provided with water and thermos flasks for carrying iced water on the job. Tram depots are equipped with ice machines. At times of excess heat, work hours are reduced and outdoor workers are advised to stay under shade. Various upgrading commitments have been made under the new franchise ownership, but there does not appear to be any significant adaptation considered beyond the measures under their general heat policy.

Figure 4.8 Many trams do not have air-conditioning, a cause of human discomfort in heat (courtesy of Ifte Ahmed 2010)

Trams did break down in the heatwave, but these were too few to cause any significant service cancellation or disruption. Indeed, in some cases trams actually served as an alternative to failed train services. As evident from the Department of Transport's situation reports of the heatwave period (Croucamp 2009), and also from the interviews, the impact of the heatwave on the tram sub-sector was minimal. About 97% of the tram services ran during the 29–30 January period. Impact was not considered of a magnitude sufficient to stimulate new resilience-building policy, although evidence from this review does show that risks continue to persist.

Trains

The impacts of the heatwave on trains were similar in nature to trams, but of a much greater severity. On the three days of the initial heatwave peak, train service was on average 76%, with only 64% operating on the third day (Department of Transport 2009c). According to Connex media releases, more than 750 services out of 2400 were cancelled, that is, more than one-third of services.

Rail buckling occurred for the same reasons as elevated tram tracks, however for train lines there were 29 instances of buckling reported (Osborne & McKeown 2009) that either slowed or disrupted service. All train tracks are elevated, making them especially vulnerable to buckling. The reasons given by personnel at the Department of Transport for the transition from tracks with expansion joints to continuous welded tracks are safety and better performance. Although savings are gained from reduced maintenance cost, it is claimed that cost of maintenance is not the 'main driver'. Nonetheless reduction of maintenance costs is significant. Tracks with expansion joints requiring frequent inspection and monitoring of rail connections and fastenings, though it can be seen that the trade-off has been increased vulnerability to buckling on extremely hot days.

Perceived deficiencies are highlighted by one observer's comment that 'franchise operators skimp on maintenance'. When reflecting on the heatwave period it is evident that extra maintenance and repair expenses were incurred. For example, in addition to sending workers to cool down tracks with water, buckled rails had to be repaired at night (at higher labour cost) not only to avoid further service disruption but also to prevent the daytime heat stress of workers.

Whether such unanticipated expenses offset savings made from reduced maintenance of continuous welded tracks is unclear, but the increasing frequency and intensity of such extreme events can only impact on operational budgets, as well as public sector subsidy over the long term. However, Department of Transport personnel reported that none of the train cancellations during the heatwave were attributed to buckling, though some may have been delayed due to speed restriction. Indeed, in their view, the system of continuous welded rails is considered 'international best practice' and privatisation has brought about a system of accountability as well as promoting greater levels of service quality.

One of the structural responses to prevent track buckling is to replace old timber sleepers with concrete sleepers (Metcalfe et al. 2009). All timber sleepers are being replaced for curved tracks, but in straight stretches a concrete sleeper is placed after every four timber sleepers (Figure 4.9). Although this will improve the stability and strength of the tracks, some observers have questioned why all the timber sleepers are not being replaced and whether this is another way to save on costs and maximise profits (Metcalfe et al. 2009; personal interviews). According to Connex representatives however, it is not only an issue of funds. The concrete sleeper manufacturer produces 100 000 sleepers a year, not sufficient for immediate complete replacement. Thus, the approach to track strengthening is being undertaken incrementally and the extent of the replacement program will only become evident over the longer term.

Figure 4.9 Old timber sleepers being replaced by concrete sleepers to resist track buckling (courtesy of Ifte Ahmed 2010)

As with trams, problems with air conditioning were one of the main grievances of train passengers. The failure of air conditioning was an underlying cause of train cancellations. Among a fleet of 331 trains, more than half are Comeng trains dating back to the early 1980s. According to Connex representatives (Metcalfe et al. 2009), the air-conditioning units in Comeng trains are not designed to operate above 34.5 °C (the remaining fleet consists of mainly Siemens and X’Trapolis trains which have units designed for about 42 °C).

Several interviewees suggested that when the temperature rises above these levels, air conditioning tends to fail (being a particular problem in the Comeng trains). The R22 refrigerant used in these units does not operate properly in temperature above 38 °C, as stated in the Connex submission (Metcalfe et al. 2009). However, it should be noted that dissenting voices cast doubt on the reasons for air-conditioning failure and its role in train cancellation. As pointed out by Mees (2009), a Hitachi air-conditioning manual shows units using R22 refrigerant specified to operate at a maximum temperature of 52 °C.

Further factors complicate the picture. To some, air-conditioning ‘failure’ was not a sufficient cause for cancellation; rather it was a pretext for informal industrial action by train drivers who invoked Fault Management Protocol (FMP) clauses during the 2009 heatwave[3] (Department of Transport 2009c; Mees 2009; Metcalfe et al. 2009; Stone 2009). According to Connex and others, nearly 80% of the service cancellations could have been avoided if there had been no industrial action (Metcalfe et al. 2009). Whilst it is beyond the scope of this report to comment on either side of the argument, it is clear from comments that there is a link between heat, air-conditioning failure, and train service cancellation.

The maximum number of cancellations took place on the third day of the heatwave (30 January), which was also the hottest of the initial peak (see Figure 4.10). On that day, the direct impact of heat was complicated by an additional contributing factor — electrical power failure. Just before 7:00pm, electricity supply to overhead powerlines and signals was cut off due to the explosion at the transmission station in South Morang. Train services into the city loop had to be cancelled, stranding large numbers of inner-city commuters (Croucamp 2009; Metcalfe et al. 2009). Signalling equipment was also vulnerable to extreme heat, and various failures were reported during the heatwave.

According to one interviewee, one of the winning arguments in the tender of the new train franchise operator was a commitment to improvement of summertime service; including the upgrading of equipment and infrastructure. Some key new measures being implemented, or under consideration, which address the above heatwave impacts are summarised in Table 4.1 (based on interviews and also Department of Transport 2009c; Lezala et al. 2009; Pakula et al. 2009). Other measures include maintaining a standby train fleet (an extra 10 trains), bus contingency arrangements, interface between operations and infrastructure staff, and an increase in funding for maintenance.

The timing of the heatwave coincided closely with the turnover of the franchise contract, which perhaps catalysed commitment to the measures listed. Some of the measures reportedly achieved positive results in the subsequent 2009–2010 summer (Lezala et al. 2009; Pakula et al. 2009), albeit under lesser heat stress conditions. Revised FMP agreements also appear to have contributed to avoiding cancellations similar to those during the heatwave (Lezala et al. 2009).

[3] It is argued that 2008 revisions to FMP that allow for running services if faults are minor and do not present safety risks were not followed during the heatwave event.

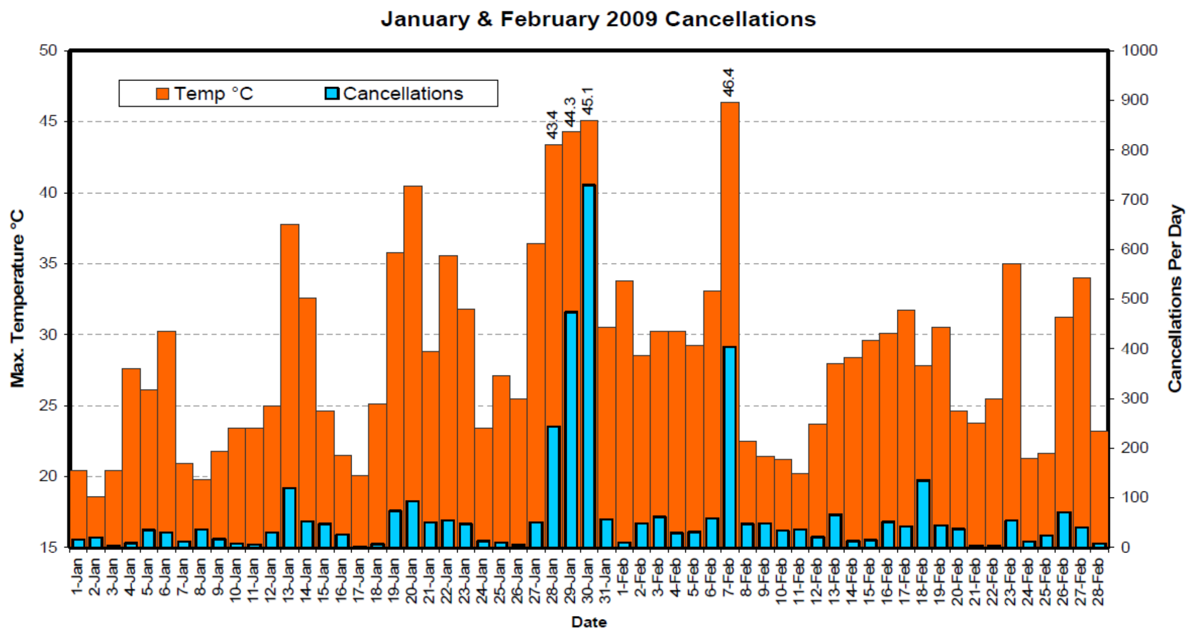


Figure 4.10 Temperature and cancellation record in January–February 2009 (Metcalfe et al. 2009)

Table 4.1 New adaptation measures in response to heat

Impacts	Measures
Track buckling	• Replacement of timber sleepers with concrete sleepers. Increasing from 22 000 sleeper replacements to 64 000 per year. • Provision and compaction of additional ballast and track strengthening at 400 locations. • Field technicians deployed during hot weather for monitoring at high-risk locations. • Mobile track gangs with water to cool tracks during hot weather.
Air-conditioning (A/C) failure	• A/C units in the Comeng fleet have been serviced by cleaning condenser coils and radiators, and changing filters. • Changing filters at 2-week intervals instead of 3-week intervals as before. • New fleet of X'Trapolis trains are being brought in, which have a higher heat tolerance level. • Trial upgrade of some Comeng unit, which indicate positive results. Upgrading began in July 2009 and will continue for 30 months to complete. • Sufficient A/C upgrade by 2010 so that all driving cabs will be fed from a new unit to ensure driver comfort and safety, and compliance with new FMP. • Leaving pantographs up on hot days for continuity of A/C operation and reducing load on A/C system. • Resetting carriage temperature to higher level to reduce A/C load. • Investigation for opportunity for Split Saloon Window operable during hot weather and automatic closing doors.
Electrical faults	• Deployment of field technicians to high risk locations (e.g. Camberwell and Ringwood) during hot weather. • Standby and portable generators deployed around the train network to

	allow restoring power to signalling in case of electricity outage. • Cubicles for electric circuits to be opened up to allow airflow and prevent overheating. • Running Comeng trains on EP brake on hot days to preserve motor alternator. • Discussion with power supplier (Vencorp) about prioritising load shedding. • Avoiding connection of signalling system to local domestic power supply. • Reflective paint and operable doors for signal cabinets.

The Department of Transport (2009c, p. 9) has acknowledged the limitations of current measures, stating:

> '*it is important to note, however, that the network will not be immune from heat and other weather extremes. The initiatives outlined and those in the longer term will incrementally improve resilience and give the network a better chance of withstanding the extremes that are likely to occur'*.

For example, despite the high temperature during the heatwave, there were no reports of overhead wire sagging, yet almost a year later (in January 2010) an overhead wire expanded due to heat, sagged and touched the top of a train, resulting in a short circuit. This caused service cancellations and delays (Lezala et al. 2009). Steps are reportedly underway to address this risk of overhead sagging.

According to press reports (see Table 4.2), Adelaide also had some track buckling and transport cancellations. However, even under the severe temperatures did not experience the 'rail meltdown' that occurred in Melbourne, despite it having similar trains.

Table 4.2 Summary of press reports of transport disruptions in Adelaide from media analysis (see Appendix B.1, p. 138 for full details and sources)

	Transport
28 Jan	Public transport system literally buckled under the strain of 45 °C heat. Dozens of TransAdelaide and hired security staff manned the entrance of the Adelaide Railway Station and tram stops along North Terrace, advising commuters of alternatives; staff on other lines handed out bottled water. In Victoria Square, shuttle buses replaced trams when they stopped running.
29 Jan	Train and tram cancellations with buses used to transport commuters. The heat meant trams engines were taken off the network during the hottest part of the day to allow engines to cool. Train tracks buckled and rail work continued through the night to repair them. TransAdelaide reported delays of up to 15 minutes on several lines. Some buses delayed due to power outages affecting traffic lights. The rail meltdown that occurred in Melbourne did not happen in Adelaide, despite it having similar trains (smaller Comengs built by the same manufacturer shortly after Melbourne's) and experiencing an even worse heatwave. Over 28–30 January, Adelaide cancelled 7% of train services compared with 24% in Melbourne. Adelaide's trains are virtually the same as Melbourne's, but are powered by diesel and did not experience air-conditioning problems.

4.2.2 Road

Context

The users of road infrastructure are much more diverse than rail. After trains and trams, the bus service is the next major form of land-based public transport in Melbourne. It is the main type of public transport using the road system. Therefore this section discusses the impact of the heatwave on buses as well as roads.

In order to discuss the impact of the 2009 heatwave on Melbourne's road system, it is necessary to briefly outline the different types of impact that tend to occur. 'Flushing' or 'bleeding' describes patches of stickiness that occur during hot weather on the surface of roads made of bitumen and stone aggregate (known as sprayed seal roads). This is often a result of excessive bitumen, a design issue, but can also be due to sealing too often or too soon, embedment into underlying materials or inadequate allowance for traffic. In such cases, the bitumen rises to the surface and stones become totally immersed. This leads to removal of bitumen from the 'flushed' surface by sticking to tyres and damaging roads as well as vehicles. On the other hand, if the bitumen is not sufficient then stone aggregate is lost due to friction from vehicle tyres, known as 'stripping'. This often happens in cold weather.

Impacts and adaptation

Flushing of paved seals is a common occurrence during the summer, but can become more of a problem if aggravated by a prolonged period of high temperatures. This is further exaggerated if the road has been newly constructed and is used by heavy vehicles. Faulty work, such as an inappropriate mix, quickly becomes evident in summer, often in the form of flushing (contractors are advised by VicRoads to check the weather forecast following the work and make allowances accordingly). If stones are removed or displaced by stripping in a preceding cold season, it may result in problems of melting and a reduced skid resistance (a property provided by the stone aggregate). If the impaired road is not repaired in time, then channels and potholes may also undermine the quality, and driving safety, of the road. Even if repaired, flushing and stripping can reduce the 'lifetime' of a road.

In an attempt to minimise long-term damage to roads and ensure continuity of use; repairs and re-sealing work had to be carried out as soon as possible during the heatwave in 2009. As reported in the interview process, Mornington Peninsula Shire staff had to be diverted from regular duties to attend to emergency work, due to incidents of flushing in local roads under the Shire. However, at less than 1% of roads affected, it was not considered to be at a large enough scale to engage additional resources.

According to records made available by VicRoads, the main direct impact on roads under its management was flushing at a number of places. From 29 January to 7 February, 15 incidents of flushing were reported from three regions. Some of these occurred on major highways including Princes Highway East, Strzelecki Highway, Bass Highway Stage 5 and the South Gippsland Highway and a number of arterial roads.

Flushing mainly affects bituminous sprayed seal roads, not roads with asphalt surfacing. Sprayed seals (if done properly) last for about 10–15 years, but asphalt is thicker and more durable and lasts for 15–20 years. Roads within the boundary of the City of Melbourne have high-grade asphalt surfacing, and hence did not experience any flushing or other heatwave impacts (Figure 4.11). Because of the importance of the inner city, and associated administrative and commercial status, a greater degree of investment has been made to render its roads durable compared to roads outside its boundary (where they are also considerably less extensive). It would require considerable additional investment to make the extensive road network of greater Melbourne as durable as that constructed with asphalt surfacing. As such, outlying roads will continue to be vulnerable to heat impacts, necessitating a vigilant and efficient maintenance regime as part of a heatwave adaptation strategy.

Figure 4.11 Roads within the City of Melbourne have high grade, heat resistant, asphalt surfacing (courtesy of Ifte Ahmed 2008)

Footpaths for pedestrian and bicycle traffic were also impacted during the heatwave. In the City of Melbourne, the surfaces of footpaths and roads became very hot, to the extent that pedestrians had difficulty using them. The City Council responded by sprinkling footpaths with water to cool them. Also, as reported by maintenance staff at the Mornington Peninsula Shire, in a few places under the Shire's jurisdiction, concrete slab footpaths lifted and cracked during the heatwave. This was put down to a lack of sufficient expansion joints, and these were subsequently introduced as part of the repair process when slabs were replaced. Since the heatwave, the practice of ensuring adequate and frequent expansion joints has been introduced to avoid future heat impacts.

Interviews with VicRoads engineering staff highlighted the sensitivity of electrical traffic to heat. Some of the older equipment, such as controllers (which control traffic flow), CCTV cameras and traffic signals 'misbehaved'. According to the Department of Transport's records (Croucamp 2009) (which includes all road networks: those under VicRoads, city councils, Citylink and the City of Melbourne), in the early morning of 29 January, seven traffic signals in central Melbourne malfunctioned. This was not considered serious and was accepted as a routine hot weather occurrence. However, later that morning many more traffic signal failures were reported throughout Victoria — 16 in metropolitan Melbourne and 2 in regional Victoria. By the afternoon of the next day, 30 January, traffic signals at 124 intersections in metropolitan Melbourne and 3 in regional Victoria were reported to be malfunctioning not only due to excessive heat, but primarily due to failure of electrical supply. LEDs (traffic signals) are sensitive to heat and periods of high temperature can result in a reduction of their service life. Whilst impacts during the heatwave were acknowledged, VicRoads staff explained that that there are many variables and causes relating to road equipment failure, and it is difficult to always pinpoint a specific cause for deterioration of road assets.

Buses

Buses accounted for 20% of public transport usage in Melbourne during 2008–09. As with other road users, buses were also affected by the heatwave. A representative from the Bus Association of Victoria (BAV) reported that the main impact was air-conditioning failure. The air conditioners generally struggle at temperature above 35 °C, and above 40 °C they tend to blow warm air. This created discomfort for bus drivers and passengers. Unlike trains, there is no protocol to discontinue service because of malfunctioning air conditioning, therefore bus services continued to operate. Indeed, buses served as a backup service for cancelled train services. However, a shortage of buses was experienced during the heatwave, highlighting the fact that the existing fleet is incapable of providing a full backup service under such conditions. It is estimated that around 4000 bus trips would be required to replace train services if there was ever a total shutdown of the rail system[4]. It is usual practice for 30–40 buses to be on standby on a regular basis.

As part of an existing heat policy, bus drivers are provided with extra water and care is taken to replenish cool water supply in depots. Since the heatwave, as a pre-emptive measure, two of the main operators (Ventura Bus and Grenda Transit) now place technical staff at strategic points on the network where buses are at risk of breaking down during warm weather. Although this has not yet become a formalised policy, it has become accepted operational practice by managerial staff.

4.2.3 Seaports

Context

The Port of Melbourne is Australia's busiest maritime port for general and container cargo (Minister for Public Transport 2006). Together with three other commercial trading ports (Geelong, Hastings and Portland), exports and imports worth almost $100 billion are channelled through these important trading nodes (Government of Victoria 2009a). In this study, the impact of the 2009 heatwave was examined in the context of two of these ports — the Port of Melbourne and the Port of Hastings — both being within the Melbourne conurbation area and connected by the metropolitan train network. The other two ports are located in regional Victoria and are not reported on here.

Impacts and adaptation

Port of Hastings

Two private-sector companies in the Port of Hastings act as port managers: Patrick Ports Hastings and BlueScope Steel. Patrick Ports Hastings manages an area of the port under an agreement with the Port of Hastings Corporation. BlueScope owns and manages a wharf for mainly loading and unloading its steel products. The port facilities include:

- Stony Point Jetty (see Figure 4.12) and Crib Point Jetty: both are common user jetties used by a variety of traffic including passenger ferries
- Long Island Point Pier: Esso Australia is the sole operator of the facility and uses it to export crude oil and liquid petroleum gas (LPG)
- BlueScope Steel Wharf: as mentioned, for steel products.

[4] 1 train (1,000 persons) = 20 buses @ 50 persons/bus.

Figure 4.12 Stony Point Jetty, Hastings (courtesy of Ifte Ahmed 2009)

In general terms, high temperature poses a potential risk for the loading and unloading of volatile substances such as petroleum and gas products that pass through Esso's Long Island jetty. The loading and unloading of Bluescope's steel products in extreme heat can also present difficulty for stevedores and other outdoor workers. There were though, no reports of jetty materials being affected as most components are designed with appropriate expansion joints. Flaring of excess gas supply in Esso's compound required monitoring during the hot days to avoid risk, particularly to surrounding communities, but again, no problems were reported. Port employees working outside were provided with protective clothing (gloves, hats etc.) and water supply, and allowed more rest breaks on hot days.

The main reason for the lack of impacts on the Port of Hastings is possibly because of its small scale of operation. Compared to the Port of Melbourne which has more than 3500 vessel movements per year, Hasting only has about 400. However, the port is expected to grow in size and importance over future years under a 2035 Expansion Plan, and will need to incorporate climate change considerations into forward planning.

Port of Melbourne

The interview process identified that the private-sector terminal or jetty operators are in a better position to report on the specific impacts of the heatwave, being responsible for the infrastructure assets; whereas the port authorities are involved primarily with management and monitoring of vessel movement. The two key operators of container terminals in the Port of Melbourne are Patrick Terminals and DP World. Personnel at DP World were interviewed and their communication of the impact of the heatwave is discussed below.

DP World has had a heat agreement in place with the Maritime Union under an Enterprise Agreement scheme for more than 15 years. According to the agreement, if the temperature exceeds 35 °C outdoor workers can take a 15-minute break every hour. Above 38 °C, outdoor workers are entitled to stop working altogether until temperature cools (though workers operating air-conditioned machinery such as cranes can continue working). Interviewees reported that there is loss of productivity due to heat every summer. For example, in January 2010 there was a loss of 49.5 crane hours, as compared to the 72 crane hours which were lost in January 2009. Other impacts included vessel delays due to the slowdown in loading/unloading processes and ‘a fairly large’ increase in labour costs because of the need to use labour later in order to complete the shifts. Any delays in receiving and transferring cargo will obviously affect the whole supply chain. This could result in a substantial impact when considering the large number of vessels that could potentially be affected.

Here again, there was a cascading effect from the electricity sector. On 30 January 2009, the electricity outage of about 1 hour (due to the failure at the South Morang transmission station) led to productivity losses for more than 2 hours as it required an additional hour to reset crane machinery and bring them back on line. Although there is a backup diesel generator, this is only for the terminal buildings and not for crane operations. The other main terminal operator, Patrick Terminals, also reported experiencing inconvenience and productivity loss due to the power failure. Since the heatwave, an approach has been made to the Federal Government to ensure future reliable and un-interruptible power supply, arguing the ports value as an important facility for the national economy (as is the case for airports).

Interviewees also cited impacts on other types of machinery. When temperatures reach 40 °C mechanical problems become more commonplace. For instance, straddle carriers were affected, engines boiled, and hydraulic oil overheated. Because of the heat agreement, workers could not go out in the field to repair machinery and because work continues 24/7 at the terminal, repairs tended to be carried out in the evening. There were no reported problems due to expansion of metal components of machinery.

Rail tracks in the terminal yard are set into the paved surface (similar to most tram tracks) so no problems of buckling were experienced. However, whilst there were no heat problems for tracks there were impacts on the extensive ‘yard’ surface — made up of sprayed seal bituminous pavement. Movement of heavy machinery on ‘bleeding’ pavements caused ‘rutting’ and ‘heaving’, with waves forming on the surface. Roughly 5% of the 36-hectare terminal was cited to have been out of action during the heatwave, which contributed to a reduced working capacity. This problem was also experienced on berths and terminal roadways. As with roads, this is considered a regular hot season problem involving repair, and again, extra cost.

The interviews did not identify any significant new measures introduced as a result of the heatwave. As one interviewee commented, ‘we can’t go beyond what we have’. Nonetheless, now when hot days are forecast more labour is shifted to night-time work to minimise impact on workers and to reduce productivity loss. One important measure being implemented after the 2009 summer is the gradual replacement by DP World of bituminous surfaces with concrete paving[5]. This is not only in response to the heatwave (although it was certainly a key contributing factor) but also to address general pavement malfunction during the summer. Replacing the surface of the whole yard in one instalment would incur huge cost. Therefore initially only the berth area has been concreted — roughly 15% of the area of the 36-hectare terminal. The plan is to gradually pave the entire terminal yard.

[5] Because the terminal is built on reclaimed land, a further reason for concreting the yard is to combat settlement.

4.2.4 Airports

Melbourne Airport is next to the north-western Tullamarine suburb and is Australia’s second busiest airport after Sydney. There were nearly 200 000 aircraft movements, the bulk being domestic passenger services (Airservices Australia 2009). Privatisation of Australian airports began in 1994, through which airports and airlines became responsible for terminal operational features depending on the long-term leases, extending to provision and maintenance of terminal infrastructure, with the airport operator providing the land for the terminals under lease (Frost & Sullivan 2006). Melbourne Airport is currently operated by the private-sector Australia Pacific Airports Corporation (APAC).

As reported by infrastructure management staff, the impact of the 2009 heatwave was barely felt at the airport. There was no business interruption and no flights were delayed or cancelled because of the heatwave. Overall the airport facilities coped very well, and as runway surfaces are either asphalt or concrete there were no incidences of tarmac failure (Figure 4.13).

The central air-conditioning plant was fully functional and there was electricity supply throughout all the terminal support precincts during this period. As the airport buildings are designed for a maximum 36 °C temperature, during the heatwave the central air-conditioning plant needed to be adjusted upwards. The terminals needed additional cooling of roughly +2 °C to maintain a comfortable temperature of 22 °C. As a consequence, approximately 1 MW more electricity was used across the whole of the month of January compared to other months, some 10–15% above the normal usage. As the chiller was upgraded in the previous year (2008) for increased cooling capacity to cater for extra terminal space, the new asset had latent built-in capacity, which was of great benefit through the heatwave period. Another impact was increased water usage as a consequence of the cooling tower working harder. This resulted in an increased monthly usage rate roughly comparable to the rate of increased electricity usage[6].

Figure 4.13 Melbourne Airport runway (Nathan Bartlett 2010)

[6] Ongoing building works at that time was also said to have contributed to extra energy and water usage.

Since 2005, the airport assets manager has deliberately fostered a long-term vision extending up to 20 years and which takes explicit account of a changing climate. One tangible outcome is the implementation of extra cooling capacity (which proved so useful during the 2009 heatwave). The air-conditioning system is designed so that it can be adjusted according to passenger volume and flow, a reflection of management plans which plan ahead 10 years when replacing assets and which are based on the best available technology. It is evident that a significant amount of upgrading has taken place in recent years (Table 4.3). Extra care is also taken to treat water used in the cooling tower so that it is ‘crystal clear’. This ensures there are no sediments that can clog machine parts. Furthermore, a 4 MW unit can run at 5 MW if required.

Table 4.3 Recent upgrading of air-conditioning (A/C) assets at Melbourne airport

2007	2008	2009
3 (nos. chillers) x 2.9 (megawatt)	2 x 2.9 (one removed/end of life)	2 x 2.9
1 x 2.7	1 x 2.7	1 x 2.7
	1 x 4.0 (new asset)	1 x 4.0
		1 x 4.0 (new asset, Dec. 2009)

The airport has stand-alone generators capable of operating during prolonged power outage, but there was no electricity failure at the airport during the heatwave. The airport is classed as an essential service, and therefore electricity service providers are required to provide uninterrupted supply. Interestingly, there are also plans to increase usage of natural gas in the future. Whilst the primary driver for this is to reduce the carbon footprint arising from the operation of such a large energy-intensive facility, a secondary consideration relates to concerns about increasing power outages in the future.

Special training was provided to personnel recently in the USA on infrastructure management, where there was emphasis on understanding machinery plants (all plants, not only air conditioning) such that machinery and maintenance regimes allow greater performance in ‘abnormal’ situations. Maintenance work is scheduled during low-use periods so as not to affect services. Critically, airport facilities are considered as a whole precinct including terminals and airfields, all of which are required to function under all circumstances — that is the ‘philosophy’, as stressed by an interviewee. The same standard is expected from service providers, such as electricity and water suppliers. During peak periods, constant contact is maintained with service providers, together with a contingency plan that can be implemented if necessary.

Risk management is obviously a core concern for the airport. Pre-summer maintenance preparation, planning for periods of high passenger volume and contingencies for worst-case scenarios, were all highlighted as normal practice. Staff duties are carried out according to heat conditions. For instance, minimal external work was done during the heatwave, except for emergency or reactive work that was necessary. Routine work, such as line marking, was rescheduled for a more convenient time. Outdoor safety vehicles are air-conditioned so they were operational. Hats, sunscreen, water bottles etc. were supplied to staff, and prolonged outdoor exposure was avoided. The overriding message from airport management personnel is that normal practice is of a high standard and airport infrastructure has the capacity to cope with extreme heat events.

4.3 Water infrastructure

Context

Melbourne central business district sits close to the mouth of the Yarra River and the river entrance to Port Phillip Bay. However, the geographical spread of suburban Melbourne radiates out in an approximate 50-kilometre arc, encompassing grasslands to the west and spreading into the Dandenong Ranges to the east. Melbourne's water system has two natural advantages: firstly, around 90% of Melbourne's water is collected in the Yarra Ranges and is transported to Melbourne through a gravity-fed system (reducing the need for power-driven pumping stations); and secondly, human access to the catchment areas is restricted.

These catchments cover 160 000 hectares of uninhabited bushland north-east of the city, all of which is closed to the general public. Entry into the catchment areas is by permit only, so there is very little disturbance to the natural environment and reservoirs are clean. Melbourne is one of only five cities in the world to have catchments that are protected in this manner. As the bulk of the water Melbournians drink is naturally clean, minimal disinfection is required. A small amount of Melbourne's water comes from the Sugarloaf Reservoir, which collects water from an open catchment downstream from towns and farms— this source of water undergoes full treatment at the Winneke Treatment Plant.

Potable water for the metropolitan area is captured in nine reservoirs which are situated in the Yarra, Thompson and Goulburn river basins; with most water taken from the Thompson, Upper Yarra, Maroondah and O'Shannassy reservoirs (see Figure 4.14). From the major reservoir storages, water flows by gravity (or in some cases is pumped) through large distribution pipes to 55 service reservoirs. From these, water flows by gravity through a smaller pipe system to three retail water businesses. The service reservoirs, which are scattered throughout the metropolitan area, provide short-term storage for one to two days to ensure a constant water supply during peak demand periods. Melbourne Water also operates 63 water treatment plants and 23 pump stations as part of this network (Melbourne Water website, accessed 10-05-10).

The three retail water companies, City West Water, South East Water, and Yarra Valley Water, take the bulk water delivered by Melbourne Water and distribute it to individual homes and businesses. The wastewater is then collected by the retail companies and transferred to the sewage system (which treats both household and trade waste)[7]. Approximately 94% of this waste is processed by Melbourne Water's Eastern Treatment Plant at Bangholme and the Western Treatment Plant at Werribee, both run by Melbourne Water. The remaining waste is treated by retail water companies at smaller local treatment plants. Wastewater is generally returned to the environment via an infrastructure of drains, sewers, pumping stations and wastewater treatment plants that treat the waste to primary, secondary and tertiary levels. The outflows from the Western and Eastern Treatment Plant go into Port Phillip Bay and Bass Strait respectively. Recycled water from the sewage system is mainly used within the wastewater treatment plants, although there is a small amount available for commercial use.

[7] The drainage system operates separately to sewerage, and is managed by different authorities. It has not been considered in this study as impacts were considered negligible.

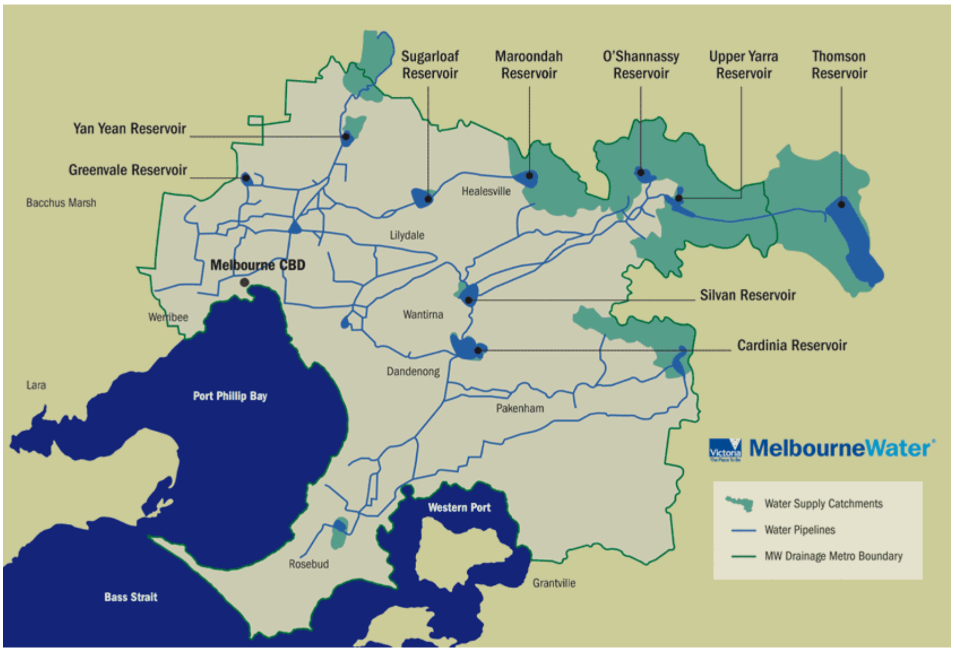


Figure 4.14 The Melbourne water supply system (Department of Sustainability and Environment 2008)

In Victoria, the impact of drought far outweighs stakeholder concerns about heatwaves. Twelve years of drought conditions act as the primary influence on water infrastructure decision making. The most dramatic rainfall deficits over this period have been around metropolitan Melbourne and to its east, including its major water supply catchments. Rainfall totals have been around 20% below the 1961–90 average, and 10–13% below the lowest on record for any 12-year period prior to 1996 (National Climate Centre 2009). For Victoria as a whole, rainfall in the period 1996–2008 was 15.3% below the 1961–90 average, or in other words, Victoria missed out on nearly two years worth of rainfall during this period.

Our Water, Our Future: Securing Our Water Future Together (2007; superseding a 2004 version) was in direct response to the lowest recorded inflows to Victoria's water storage reservoirs in 2006. This new strategy document sets out a $4.9 billion infrastructure plan; including a desalination plant, the Sugarloaf Interconnector pipeline to supply Melbourne with water from the Goulburn River, and an expansion of Victoria's water grid. Construction of the desalinisation plant began in September 2009 in order to deliver water by the end of 2011. The potable water created will be transferred via an 85-kilometre pipe to Melbourne's water supply system near Cardinia Reservoir (Department of Sustainability and Environment 2007).

Impacts and adaptation

Interviews were held with several Melbourne Water personnel with responsibility for bulk water and the reservoir system, as well as the major sewage system.

Although there is obvious concern about longer term trends, particularly associated with the slow onset of drought conditions, interviewees suggested that the one-off impacts of the 2009 heatwave on water infrastructure were minimal, and that there were no serious issues for Melbourne Water. Indeed, much of the infrastructure is considered robust and capable of functioning in high temperatures[8]. Where problems did arise, they tended to be associated with electric motors; either as a direct consequence of heat affecting the performance of motors, or else were indirectly compromised as a result of electricity outages associated with the heatwave.

The most significant information elicited on the direct impact of heat concerned the infrastructure at the Western Treatment Plant. During the heatwave period, aeration blowers overheated and shutdown automatically. These large 750 kW units service one of the lagoon-based activated sludge plants (ASP), providing a source of oxygen — fine bubbles of air through diffusers — for the nitrogen removal process (see Figure 4.15). Normally the system requires three blowers to be in operation to supply sufficient air. During the heatwave Melbourne Water was able to run two at once and recycle the ones in operation. When one blower began to overheat it was shut down and another one started. The blower building doors were also left open to increase airflow. The ultimate impact of this was a reduced treatment capacity in the system for a period of about four or five days which led to a slight reduction in the volume of recycled water available to supply to customers[9]. To resolve this in the longer term, improved ventilation for the blowers is being investigated.

Figure 4.15 ASP aeration basin (courtesy Melbourne Water 2010)

The heatwave also had indirect impacts for the treatment plant (Figure 4.16). As was the case with other infrastructure types, electricity outage was an issue that needed to be carefully managed, though the 2009 event was not of sufficient duration to cause more than minor impacts. The plant itself is fairly robust and the processes were not immediately impacted by the loss of power. When the electricity came back online, it was with reduced load and therefore use had to be prioritised. Paradoxically, managing electricity demand was helped by the fact that the blower system was not running at full capacity due to the heat. Interviews highlighted that onsite power generation, using biogas from the lagoon treatment process, supplements electricity from the grid; therefore provides a valuable alternative source of energy for the treatment plant when energy supply is disrupted. Backup

[8] Pipe breakages are a problem for the industry but these are attributed to drought-related ground movement rather than individual heat episodes.

[9] Some instruments used in the plant were also found to be unsuitable for operation in high temperatures above 40 °C, however, this did not have any impact on operation.

generators are also in place for critical operations such as sewage flow distribution in order to avoid spillage and other system failures.

Figure 4.16 Western treatment plant (courtesy Melbourne Water 2010)

The second indirect impact arising from heatwaves is a sharp increase in the amount of water used. Evidence suggests that once the temperatures top 30 °C, the Victorian Government's campaign to reduce person water usage to no more than 155 L per person per day is commonly exceeded. Interviews with Melbourne Water personnel reinforced this message, noting that on really hot days total consumption for Melbourne can peak at over 1400 ML (roughly, the average usage for Melbourne under current restrictions is around 900–1000 ML). Table 4.4 shows the total Metropolitan consumption for the heatwave period. On the days in January when the temperature went over 40 °C, usage crept up over 1500 ML.

Table 4.4 Water consumption: Melbourne metropolitan area (courtesy Melbourne Water)

Date	**Total metropolitan consumption** (ML)	**Melbourne max. temp.** (°C)
27-Jan-09	1230.0	36.4
28-Jan-09	1437.0	43.4
29-Jan-09	1598.0	44.3
30-Jan-09	1557.0	45.1
31-Jan-09	1571.0	30.5
01-Feb-09	1464.0	33.8
02-Feb-09	1374.0	28.5
03-Feb-09	1204.0	30.2
04-Feb-09	1319.0	30.2
05-Feb-09	1328.0	29.2
06-Feb-09	1212.0	33.1
07-Feb-09	1357.0	46.4
08-Feb-09	1544.0	22.5

Although of less direct relevance to physical infrastructure, other issues are also raised during periods of high temperatures. For instance, evaporation from the reservoirs goes up, particularly in the open shallow reservoirs like Yan Yean. This is considered negligible when looking at the overall system. At the Western Treatment Plant blue-green algae growth was also found to increase during mid January to March 2009 in one of the lagoons. This cannot be attributed solely to the heatwave and may have occurred anyway. That said, evidence indicates that algae numbers in 2008–09 were less than summer 2009–10.

Beyond the minor incidents noted and the need to manage a substantial increase in the demand for water, those interviewed did not consider the heatwave to have had any great direct impact on water infrastructure. However, the greater probability of bushfires during such hot periods is a matter of real concern. Prior to the heatwave, Melbourne Water activated its normal emergency response procedures and held a series of meetings to plan what to do in the event of a serious bushfire in the catchment area. These meetings are now normal practice and part of existing emergency management and disaster planning regimes[10].

One of the responses in 2009 involved transferring water away from possible contamination by bushfires and into reservoirs closer to Melbourne. As the threat of bushfire strengthened, water was moved to Cardinia Reservoir, away from the bushfire zone (at a maximum rate of 10 GL a week), as a precautionary measure. This transfer continued for another two weeks after the fire. However, once the water is stored in Cardinia Reservoir which is one of the reservoirs at lowest altitude, it is not possible to pump the water back 'up' the system. This creates difficulties for those managing the water system, and one consequence is likely to be additional time and effort spent on analysing future climate-related risks. Furthermore, a large volume pump is planned for the Cardinia Dam in the future.

4.4 Telecommunications infrastructure

Context

The telecommunications sector comprises voice telephony (both fixed line and mobile) and Internet services. The Broadband Framework is the Victorian Government's major telecommunications policy which sets out the future direction of the digital economy in the State (Government of Victoria 2005). Physical infrastructure. It consists of:

i) fixed-line Customer Access Networks (CAN) infrastructure and Mobile CAN infrastructure — these networks connect customers to an 'aggregation point' and consist of underground cables or mobile phone towers and networks.
ii) back-haul infrastructure — connect aggregation points to major nodes, as well as providing high-capacity links between cities or regional centres. These links are provided by fibre or microwave technologies.

Telstra

Telstra is Australia's largest telecommunications and information services company, providing integrated telecommunications services across fixed line, mobiles, broadband, information transactions, search-and-pay TV. It manages network facilities, depots and offices as well as individual installations such as roadside equipment cabinets, underground cables and jointing pits and payphones. Telstra also has a large vehicle fleet which includes service, construction and staff vehicles.

[10] Melbourne Water have more than 30 permanent accredited fire fighters based near water catchment areas year round and during the summer, more than 100 extra trained fire fighters are introduced.

Under its Universal Service Obligation, the company is required to respond to customer faults within set time frames. Exemption is provided in the case of extreme events (such as significant service disruptions related to the 7 February bushfires). There is no information regarding any issues on the days of the heatwave. Telstra also has a Global Operations Centre in Melbourne, which includes a major incident control centre for emergencies. This capability not only means that emergency services organisations are better able to protect vital telecommunications infrastructure, but it also acts as a valuable communication resource for the emergency services.

Internal reviews have identified the key risks posed by a changing climate. These include an increased incidence of bushfires (with infrastructure in rural and remote locations identified as particularly vulnerable), drought, and heightened cycles of drought and flooding which will affect both overhead and underground cabling (stretching and contracting). Heat is not highlighted as a problem.

Impacts and adaptation

Communication with Telstra did not signify any major impacts arising from the 2009 heatwave. Perhaps the most obvious issue is the cooling of the exchanges and the need to manage the additional loading required to keep temperatures maintained during periods of extreme heat. It was noted that backup power is available at all exchanges; large exchanges having diesel generators with smaller versions supported by back up batteries. In human terms, management procedures for staff are in place for hot periods, but these were not updated as a result of the 2009 event.

It is recognised that reliable telecommunications are essential during a heatwave (or any other extreme weather event). Telstra have the ability to redirect telecommunications traffic if a facility or transmission line fails or is damaged. This may occur automatically, or can be invoked manually if necessary.

4.5 Overview and reflections

Analysis of the 2009 heatwave has shown that different types of infrastructure in Melbourne were subject to varying levels of impact. For telecommunications, water and airports the impacts appear minimal; for trams and sea ports the impacts were relatively minor, whereas the impacts on roads (moderate) and the train system (moderate-high) more severe. In this latter case, issues were either related to physical impacts such as buckling, or the comfort of travellers (where the lack or failure of air conditioning was a primary concern). From analysis of the accumulated evidence, the electricity sector stands out as being the most vulnerable to heat, with the transmission and distribution systems particularly affected by the extreme event.

A clear message from a review of the literature, and information elicited from the interviews, is that of an electricity system operating with little spare capacity (highlighted by an already tight supply–demand balance), and consequently exhibiting a lack of resilience to unexpected perturbations such as that experienced during the heatwave. A combination of driving forces increased the vulnerability of the system: ageing infrastructure (some components were cited as being 60 years old), rapidly increasing demand[11] (a mix of population growth and a spike in demand for air conditioning during very hot periods), and the predicted increase in frequency and severity of climate-related extreme events. Furthermore, findings suggest that it is not only peak daytime temperatures that are

[11] Electricity demand in 2009 as a result of the heatwave was the highest ever recorded.

problematic for critical infrastructure – cumulative days of heat, and continuing high temperatures at night, are also significant contributing factors.

> *'The electricity sector knows that if the temperature goes over 38 degrees Celsius over three days on a Wednesday or Thursday then the system is under stress'.*

The vexed issue of investment also emerged as a significant influencing factor, with concerns raised about the lack of adequate investment aimed at improving the resilience of the electricity system. This issue had already been identified as an important factor by infrastructure documentation in recent years (Maunsell 2008; CSIRO 2007) but was a key message reinforced by the interview process. The nuances of ensuring a robust supply system against managing the demand for energy (especially on the days of extreme heat), as well as ensuring a balance between investment and profitability of private interests, is clearly a matter of current debate as evidenced by the Australian Energy Regulator's recent rejection (4 June, 2010) of proposed increases in capital and operating expenditure by the distribution companies in Victoria (which would have resulted in price increases for consumers)[12]. Findings from this study will clearly have some resonance with these discussions.

> *'We are not putting the funding into increasing the strength and resilience of the current system. And we are tending to run the system at 100% capacity which has two effects: there is no spare resilience in the system for any difference in operating conditions, and when there is a weather or some other event that puts pressure on the system, it is being asked to run at a level beyond a normal operating baseline'.*

The direct impact of heat affected all parts of the electricity system in the 2009 heatwave – with unplanned events that included the shutdown of Bass Link, faults with transformers leading to outages of major transmission lines, resulting in load shedding, and ultimately power blackouts for some Melbourne residents. However, although these direct impacts were clearly important in their own right there were also additional 'cascading' effects from the electricity outages that affected many other parts of the urban system including other infrastructure sectors. Indeed, many of the impacts of the 2009 heatwave were related to the breakdown in electricity supply, with actual (and potential) knock–on consequences for community wellbeing. These range from simple inconvenience (such as failure of traffic lights or train cancellations) through to economic and even life threatening implications For example, as more ill people are given the opportunity to be treated, and recuperate, outside of the confines of hospital; it becomes more difficult to effectively target load shedding to avoid the loss of human life. In this and other cases where the loss of electricity would have significant repercussions, the argument for back-up generators obviously becomes heightened.

In conclusion, key findings of this research highlight that although heat impact on infrastructure is rarely given the same prominence as high impact events such as bushfires or flooding, heat stress can have significant impacts both on human health and on vulnerable elements of the urban system. These consequences can be either direct or indirect as shown most vividly by the cascading effects of the electricity outages.

Strengthening the resilience of vulnerable infrastructure will be vital if we are to successfully adapt and build in resilience to Australian cities to cope with future conditions. Ultimately, effective adaptation responses will need to take account of a range of different risks, both climate and non-climate, as well as preparing for the potential impact of simultaneously occurring climate-related hazards. To that end, a greater emphasis needs to be placed on the urban system as a whole when considering future risks and appropriate resilience enhancing measures.

[12] http://www.aer.gov.au/content/index.phtml?itemId=736984

4.5.1 Challenges and potential strategies for resolution

Whilst it is necessary to stress that this research was limited in terms of time and scope, and hence does not provide definitive answers, the authors have identified three important issues for more in-depth analysis.

The first of these relates to the cascading effects illustrated above. Although many of those interviewed felt that adequate precautions were being taken, and that risks were being effectively managed by their respective organisations, these assurances tended to apply to their particular area of concern. The overall impression gained was one of individual entities and a degree of sectoral segmentation, and when problems did arise (as they did under the extreme conditions of the heatwave) there was the very real possibility of experiencing 'systems failure'.

The authors argue that the lack of a whole-system approach to thinking about urban infrastructure, both within and across sectors, is a major impediment to ensuring the integrity of critical infrastructure which supports the functioning of major cities such as Melbourne. This limitation is further complicated by the need for greater clarity surrounding roles and responsibilities. There is also a need for improved governance arrangements with regards to emergency management and other adaptation responses. Complex issues of liability also arise when considering issues such as guarantees of supply of power and the potential for public directives to increase power generation.

The second issue relates to traditional management practice and a continued reliance on looking to the past when planning for the future. Indeed, a fairly common response to adaptation to the heatwave has been relatively small adjustments to existing management processes rather than a more fundamental shift in thinking that explicitly acknowledges the new and uncertain risks that a changing climate is likely to bring. This is best illustrated by commentary that cites the heatwave as a one in a hundred year event (implicitly failing to recognise that such extreme events are likely to become increasingly commonplace and potentially even more extreme in the future). Changing mindsets, and behaviour to give greater consideration to the impacts of a changing climate, among multiple stressors, will be necessary. In this regard, new spaces for learning which bring together stakeholders and key decision makers with the scientific community could be enormously beneficial in promoting new forms of dialogue and consensus building.

The last issue that is noteworthy concerns the general lack of attention paid to cumulative impacts arising from the coincidence of multiple climate-related hazards, and their potential combined effect on critical elements of the urban system. For instance, whilst the remit of this particular study was on the impact of heat on infrastructure. there are very clearly important overlaps with bushfire episodes, as well as interaction with human comfort and health. Whilst the naturally occurring linkages between drought, heat and fire have been highlighted by several literature sources, there is much less evidence of real-world planning for the risks associated with simultaneous or compound hazards. In the case of the Victorian electricity supply system for instance, bushfires in 2007 caused disruption to different parts of the transmission system than the 2009 heatwave. It would be reasonable to ask what the repercussions would have been if the worst period of the heatwave from 28–30 January 2009 matched with the bushfire outbreak a week later on 7 February 2009?

Specific areas for further research include:

- examination of the heat-sensitive components of the transport system e.g. susceptibility of rail lines to buckling in high heat

- determining the weak links of interconnected systems.

In addition, the regulator Australian Energy Market Operator (AEMO previously NEMMCO made a number of recommendations post event. These include:

- an investigation of the volatility of 220 kV line ratings
- a review of the strategy for managing Hazelwood 500/220 kV transformer outages at times of high temperature
- a review of processes for load forecasting, particularly for high temperature periods
- an assessment of plant reliability issues during high temperatures, particularly in the case of Capacitor Voltage Transformers, creation of new contingency plans
- the development of processes to increase resources to manage high impact outages in real time.

Table 4.5 Institution, company or authority approached and the number of people who were interviewed or provided relevant information

Institution, company or authority	No. of people	Institution, company or authority	No. of people
AECOM	1	Melbourne Water	4
Ambulance Victoria	1	Metro Trains	1
Aurecon	1	Mornington Peninsula Shire	2
Australian Centre for the Governance and Management of Urban Transport (GAMUT)	1	National Transport Commission	2
Australian Commonwealth Scientific and Research Organization (CSIRO)	1	Patrick Ports Hastings	1
Australian Energy Market Operator (AEMO)	2	Port of Hastings	2
Bus Association of Victoria	1	Port of Melbourne Corporation	2
CitiPower Pty		Powercor Australia Limited	1
City of Melbourne	6	RMIT University	4
DP World	1	SP AusNet	1
Emergency Management Australia	1	Telstra	2
Energy Safe Victoria	1	Tullamarine Airport	1
Engineers Australia		University of Melbourne	1
Government of Victoria, Department of Primary Industries	2	VicRoads	3
Government of Victoria, Department of Transport	3	Western Port Greenhouse Alliance (WPGA)	1
Jemena	1	World Vision	1
LoyYang Power	2	Yarra Trams	1

Section 5 Emergency management response to the 2009 heatwave

Introduction

This section of the case study describes the outcomes of an interview and report-based analysis of the emergency management response to the 2009 southern Australian heatwave in South Australia (5.1) and Victoria (5.2) and outlines the prior planning and resulting policy changes that arose as a consequence of this experience. The overview and reflections (5.3) highlights salient differences between the two states and the ongoing and future challenges they face. Table 5.4 lists the emergency management, health and service organisations that were interviewed. The interviews were digitally recorded and transcribed with the permission of participants. Two focus group discussions were also conducted with a range of community / health workers. Where possible, interviews were supplemented with reports, policy and procedural documentation.

This research was conducted over a brief period in April and May 2010. While the data collected accurately reflects the state of play at the time of collection it is likely that policy and procedures have changed or will change over the months and years to come.

Emergency management practice worldwide is moving from a response focus to more proactive management arrangements that take an all-hazards approach. This comes from recognition that underlying social and economic vulnerabilities contribute significantly to disasters. Measures and policies that can reduce these vulnerabilities ahead of time will minimise disaster impacts and the emergency response needed. Climate change has added further complexity and urgency in that future meteorological disasters may be more extreme and frequent. Identifying the true motivations for the adaptation and implementation of new policy and practice to reduce disaster risks is challenging and often not well documented. In particular, the need for adequate planning to reduce the risks associated with heatwaves is increasingly recognised.

5.1 South Australia

5.1.1 South Australian State Emergency Services

The *South Australia Emergency Management Act 2004* (SA Government 2004) adopts an all-hazards approach. Each hazard type has a designated leader and control agency responsible for ensuring that all key government agencies are working to mitigate the impacts of the hazard. Prior to the 2009 southern Australia heatwave event, severe weather planning had focused on storms and flood. There was no designated hazard leader for heatwaves and no specific heat planning in place.

Experience of the 2009 event

As the existing control agency and hazard leader for extreme weather events, the South Australian State Emergency Services (SASES) became the hazard leader and control agency for the 2009 event. Its main responsibilities are to coordinate and facilitate cooperation between agencies.

The State Emergency Centre (SEC) became aware of heat as an emerging issue on 27 or 28 January and by Sunday 1 February had begun to comprehend the scale of the emergency. SASES was working closely with the Bureau of Meteorology (BoM). The BoM's existing classification for a heatwave event in Adelaide was three days over 40 °C or five days over 35 °C. It began to realise that the January/February event was surpassing its existing classifications.

> *‘We fired up on the Tuesday or Wednesday and, by the Sunday, we understood that this was no normal sort of heat event’* (SASES1).

A decision was made to begin issuing public warnings: however,

> ‘*there was no template, there was nothing for public warnings at that time*’ (SASES1).

On 31 January, the first set of public warnings was issued. Authorities considered the situation serious enough to warrant use of the Standard Emergency Warning Signal (SEWS), with repeat heat-related health warnings issued over the radio. (See Appendix B.2, p. 145: Government of South Australia/SASES media alert issued 31 January, 2009).

A mobile phone text message was used for the first time to issue a warning about the heat. This received a considerable amount of publicity and SASES considered it successful.

SEC and the Department of Health (SA Health) held daily briefings, and South Australian Ambulance Service and other essential services began ramping up their capacities to respond.

The emergency management team realised that misinformation and mixed-messages were circulating. To counteract this, SASES and SA Health worked cooperatively to develop a communication strategy with consistent messages. This strategy focused on sending messages via the radio, television and newspapers promoting community self-reliance.

SASES realised that its communications were targeted at people who listened to radio and read newspapers and were unlikely to reach certain disadvantaged groups such as the homeless. To counteract this they started opening ‘bush shelters’ and advised people to take shelter in the shade. SASES recognised that its response was largely reactive rather than proactive.

Although the primary impact of extreme heat was on human health, SASES was confronted with the full range of issues and hazards that developed during the heatwave. This reinforced the view that SASES is the most appropriate hazard leader. An extreme heat event is now viewed and treated like any other emergency situation.

> ‘*When you take this back to its purest form, it’s just another emergency. It doesn’t matter if I’m facing five metres of water or storms, there are some common elements… You just work out who is doing what and how*’ (SASES1).

Lessons and policy changes due to the 2009 event

SASES attributed the effective management of the heat event to daily briefings at the SEC, which enabled agencies to work together to identify key issues, plan their response and produce consistent messages. The 2009 heatwave created an opportunity to learn and, together with other key agencies, develop an evidence-based heatwave policy.

In April 2009, the key stakeholders (Extreme Heat Stakeholder Group) met to review their response to the extreme heat event and prepare a plan for future events. They developed an ‘Extreme Heat

Arrangements Plan' (SASES 2009) as Annex A to the 'South Australian Extreme Weather Hazard Plan'.

> *'I am clear in my mind, very clear, that we wouldn't have written this plan prior to 2009. It would have been quite a different document but, because we had the learning of 2009, we all sat around the table with a common goal and we actually generated something which was quite beneficial. That's what happens: you write a plan, you test it, you change it. Well, in essence, that is what we did'* (SASES1*).*

The Plan was implemented in October 2009 with the aim of:

- clarifying extreme heat events within South Australia
- defining triggers for action for government agencies
- outlining the associated communication and management strategies.

The Plan provided coverage for the 2009–2010 summer and will be monitored by SASES and amended as required.

The foundation for the 'Extreme Heat Arrangements Plan' is a set of temperature triggers developed collaboratively by the BoM and the heat stakeholder group. These triggers are based on average daily temperatures calculated from the day-time maximum and the night-time minimum temperatures.

Temperature triggers were used to determine three levels of alert which initiate specific communications and actions. For full details see Appendix B.3, p. 146: Heatwave alert levels and agency actions as detailed in SASES 'Extreme Heat Arrangements Plan'.

Table 5.1 Communication actions (adapted from SASES 'Extreme Heat Arrangements Plan', p. 3)

Level	Trigger (threshold)	Communication
Moderate (Advice)	Adelaide forecast temperatures next 5 days Max. >30 °C on each day and Min. >20 °C on each night (ADT* 25 °C)	Heat advice to agencies Issued 3–5 days in advance of an event if practicable
High (Watch)	Adelaide forecast temperatures next 5 days Max. >35 °C for 3+ consecutive days and Min. >21 °C for 3+ consecutive nights (ADT 28 °C)	Heat watch to communities and/or agencies SEC briefing (as appropriate) Issued 2–3 days in advance of event if practicable
Extreme (Warning)	Adelaide forecast temperatures next 5 days Max. >40 °C for 3+ consecutive days and Min. >24 °C for 3+ consecutive nights (ADT 32 °C)	Heat warning to community and/or agencies SEC briefing or teleconference Issued 0–48 hours in advance of event if practicable

* ADT – average daily temperature

When average daily temperatures (ADT) are forecast to be 32 °C or higher for three or more consecutive days, the event is considered an 'Extreme Heat Event'. At 48 hours SASES let key stakeholders know that an extreme heat event is predicted. This alert is also important for the Red Cross 'TeleCross REDi' service so it can get its volunteers into place and ready to activate. At 24 to 12 hours SASES go public with the 'Warning'. At this stage, SASES will consider a partial or full activation of the SEC and a debrief at the SEC as appropriate. There are two lesser alert levels: 'Advice' and 'Watch' (Table 5.1).

> *'"Watch" is the first time we go public and it says some hot weather is coming and, if you need to get your air-con serviced or change appointments or put plans in place to check on your elderly, now is the time to start planning. Then "warning" is the end stage: we say "It's hot, go inside, check on your neighbours, make some proactive changes".* (SASES1).

'Watch' and 'Warning' alerts are scrolled across the bottom of the television and broadcast over the radio. SASES is very mindful that public messaging around heat has to be cognisant of fire risk. They will liaise with the Country Fire Service (CFS) and Metropolitan Fire Service of South Australia (MFS) in relation to issuing heat alerts and bushfire messages will always take precedence. The overall objective is to ensure that messages are consistent and do not contradict each other.

Following the heatwave, DH produced heat-related health advice and, under the 'Extreme Heat Arrangements Plan', SASES developed a communication template to enable each agency to release information pertaining to their specific area of responsibility. This reduced the potential for duplication and conflicting messages and also ensured that the tone was consistent with the level of threat at that time.

SASES considered that the use of the Standard Emergency Warning Signal (SEWS) with the first series of warnings they issued in 2009 had been a mistake. The SEWS is reserved for situations where there is an immediate threat to life. During the January/February 2009 event the extreme heat was interpreted as an immediate threat, as the SEC was suddenly faced with an emergency situation and escalating deaths. SASES has since dealt with two extreme heat events (November 2009 and January 2010) and considered that, by following its heatwave plan, the risks have been minimised through thorough planning and proactive preparedness.

Other changes anticipated by SASES:

- plans for a heat advice line where people can get information or be referred to a more appropriate agency
- no more text-messaging templates are being developed due to its better state of preparedness
- a reduction in the number of messages in its alert system prior to the 2010–11 season
- altering the trigger temperatures in consultation with the BoM and other health researchers to better understand extreme heat, its impacts and the degree of acclimatisation.

Overall, SASES now considers its heatwave planning and preparedness to be effective.

> '*We have a lot of fine tuning to do but I do think we have one of the most robust plans I have ever seen*' (SASES 1).

Most agencies within its plan now have a good understanding of their responsibilities and actions. The significant number of heat-related deaths recorded in South Australia and Victoria during the January/February 2009 event was considered the main driver for policy development.

SASES believes that the all-hazards approach is fundamental to the success of its extreme heat strategy. It enables a greater range of messages to be communicated and promotes greater awareness of the many dangers of extreme heat. The 'Extreme Heat Arrangements Plan' (the Plan) engages all key government agencies under one overarching plan, making extreme heat an 'all-of-government' concern. The event is centrally managed, with leadership from state government agencies. The Plan enables communication with local government to offer solutions and suggestions without the burden of responsibility.

As detailed in the draft 'Extreme Heat Guide for Local Government' (SA Government 2010), local governments are advised to promote community awareness through reinforcement of the messages developed by SASES and SA Health. They are directed to align activities with the trigger temperatures and alert levels in the Plan: however, they are not to duplicate any activities already being carried out, such as the Red Cross TeleCross REDi service.

The primary benefit of the 'Extreme Heat Arrangements Plan' is that each agency aligns their actions to complement each other. The Plan does not dictate roles and responsibilities, but requires agencies to document their planned actions and risk messages. SASES reiterated the importance of robust communication between key government agencies during extreme heat events through daily or twice-daily briefings. It also noted the fundamental importance of having all agencies work to the same heat triggers.

> *'Health acts on our triggers, our triggers drive Engineering and Functional Services, and they drive SAPOL* [South Australian Police]*, Ambulance and everyone else. All their plans have been written to correspond with our plan. So that has been the big win – we all talk and we all do our own job'* (SASES1).

Future challenges

SASES identified a range of challenges in relation to the temperature triggers. These include:

- informing government ministers about the heat plan and temperature triggers
- translating temperature triggers into response actions
- temperatures oscillating around important trigger temperatures, not quite reaching the daily average target temperatures for long enough to make an 'alert' level call. (Using rolling averages over a period of days rather than a daily average may be the solution.)
- tailoring heat messages and warnings to the areas at risk (districts) rather than to the whole state
- communicating with the visually and hearing impaired and to culturally and linguistically diverse groups.

5.1.2 South Australian Police

Experience of the 2009 event

SAPOL responded to the heatwave event within its normal operations. This is probably because it had ramped up its response capacity in anticipation of a bushfire.

The only noticeable increase in workload came from collecting extra information for the coroner on the circumstances of the deceased. Prior to more information being requested from the coroner, there was no protocol for collecting it unless the investigation officer thought it worthy of note.

Lessons and policy changes due to the 2009 event

Since the January/February 2009 event, there has been a significant amount of work done to increase the response capacity, the communications given and the coordination of all the agencies.

SAPOL stated that they already had a good Occupational Health and Safety (OHS) policy in place relating to staff and the heat, and therefore there had been no change after the 2009 event.

Future challenges

Challenges identified include:

- preventing disparity in messages to the public
- the increased workload from collecting detailed information for the coroner on the circumstances surrounding heat-related deaths
- potential resourcing issues in the event of a heat event and a bushfire coinciding.

5.1.3 South Australian Metropolitan Fire Service

Experience of the 2009 event

False fire alarms triggered during the heatwave lead to a rise in callouts for the South Australia Metropolitan Fire Service (MFS), increasing the heat stress on staff.

During periods of extreme heat such as the 2009 heatwave, the MFS also experience a steady increase in calls for fires from cooling equipment. These fires are often only detected when already well developed and when they break through the ceiling, as there is no economic and effective early warning system for roof space fires. Other fire risks that increased were from candles, and when power returned after a period of disconnection. The MFS also received more calls to support ambulance crews and the SES.

Lessons and policy changes due to the 2009 event

During periods of extreme heat, the emphasis for the MFS has always been on ramping up its capacity to support the Country Fire Service (CFS). Planning for the other heat-related hazards produced by extreme heat presented a new challenge.

The MFS recounted how the state coordinator raised the issue of too many public communications early during the January/February 2009 event, particularly the use of the SEWS on the radio for heat health warnings. Although the MFS will advise the public on getting their air-conditioning units serviced or fixed, it is now very conscious about circulating too many messages.

During the January/February 2009 event, the MFS was very mindful not to tell people to switch off air-conditioning units but to be aware of how they were using the units and how well the units were functioning. Previously it would have recommended not leaving them unattended or running overnight; however, its Chief Fire Investigator now says that units can run constantly if the unit is the correct size for the premises and is in a proper operating condition.

The MFS hope to have a fact sheet on its website before the next fire season detailing safety guidelines for cooling equipment.

Future challenges

The MFS noted that one of the main barriers to adaptation was the organisational mindset at senior level which remained very response focused.

5.1.4 South Australian Department of Health

Experience of the 2009 event

The Department of Health (SA Health) confirmed that although it knew anecdotally that more people attended hospital during hot weather, it had no formal plans in place. It had never previously had to respond to extreme heat as an emergency event.

> '*At that stage there was no hazard leader for heat. We had never actually had to think about it in these terms before. That's happened consequently, but at the time we were all flying by the seat of our pants*' (SA DH1).

The control centre at SA Health remained open from Thursday 29 January due to the increased activity experienced by the hospitals and the Ambulance Service.

On 1 February, the South Australian Premier asked SA Health/Department of Families and Communities (DFC) to start telephoning vulnerable people across the state. As the government-funded service Metro Home Link proved too expensive, the South Australian Red Cross expanded its TeleCross service for the purpose.

SA Health also put a number of advertisements in the newspapers and its Chief Medical Officer appeared on television and radio, warning people about the heat and how they could minimise its effects.

Lessons and policy changes due to the 2009 event

> *'It was a huge intervention. In the wash up of it all, it was clear that we needed something more long-term and strategic'* (SA DH1).

SA Health has developed the 'Extreme Heat Action Plan' (SA DH 2010a), an internal document that details health actions to be implemented at each of the Extreme Heat Alerts within SASES's 'Extreme Heat Arrangements Plan'. They aim to develop a full health heatwave plan for the 2010–11 summer.

Within the current health heat action plan, the 'Warning' level alert activates the Red Cross TeleCross REDI. A protocol now exists for putting advertisements in the newspapers when certain alert levels are reached, rather than the ad hoc response undertaken during the January/February 2009 event.

SA Health now has a brochure (70 000 copies distributed) and a number of specific factsheets available on its website (SA DH 2010b; SA DH 2010c). SA Health plans to review and refine these for the 2010–2011 summer season. The communication strategy is based on building community resilience with messages about preparing for hot weather and when the heat arrives, looking after oneself and others in the community. This represents a shift in emphasis from response to risk reduction.

SA Health learned from other agencies that people can become too focused on actual temperatures so, in its 'Extreme Heat Action Plan', they are using the particular level that has been reached (Moderate, High, Extreme). SA Health also plan to communicate more effectively that 'Moderate' and 'High' alert levels may not feel particularly hot, but they represent an opportunity to prepare for hotter days to come. It has also compiled a short directive for staff working with mental health clients.

Health Direct (a 24-hour government-funded telephone health advice line staffed by registered nurses) is kept aware of the extreme heat alert to prepare them for any increase in calls.

SA Health would no longer fully activate its emergency control room in an extreme heat event, but instead has its operational response team meet and ensure that all processes are in place.

Under the 'Extreme Heat Arrangements Plan', SASES informs the Director of Emergency Management at SA Health of a heat alert and that plans for that level should be activated. SA Health then passes this on to its key health agencies, who have a responsibility to begin activating plans and alerting others.

At the 'Extreme' heat level, all key health agencies send information about hospital bed/patient numbers for cases that are related to heat, as well as any impacts that the heat may be having on their service to SA Health. This is reported to the SEC, and SA Health states how it will respond.

> '*When we hit the top level of 'Extreme' they* [key health agencies] *are expected by 10am each day to report back whether the heat has had any impact on their business, then we have to say what our strategy is to overcome it. That is reported back centrally and kept as whole-of-government information every day*' (SA DH1).

Although telephoning vulnerable people is a costly service, it has prevented some hospital admissions and potentially some heat-related deaths. SA Health is working with researchers at Flinders University to examine heat-related mortality and morbidity and how chronic medication needs change under conditions of heat stress.

Future challenges

Challenges identified by SA Health include:

- managing the coordination of and communication with TeleCross REDI clients, the Red Cross and Royal District Nursing Service when evacuations of the vulnerable are needed on catastrophic bushfire days
- accurately determining which excess deaths are heat-related — there is the potential for heat-related mortality to be attributed to other causes, particularly where heat is one of a number of causal factors
- significant social and economic barriers to adaptation and the ability of people to reduce their risks from extreme heat.

5.1.5 Department of Families and Communities

Experience of the 2009 event

The Department of Families and Community (DFC) first became aware of the risks posed by extreme heat at daily meetings held at the State Emergency Centre due to the high level of bushfire risk.

> ‘*We were meeting daily because of the high risk of bushfire, and part way through the week someone said “Gosh, it’s hot. I think this is a heatwave”. Like, it was just this moment. People hadn’t considered it at all. And so they were all talking about “What should we do?” And we had no plans*…’ (DFC1).

The DFC considered establishing ‘cooling’ or relief centres. However, sufficient power to run air conditioners could not be guaranteed and the centres would require nursing staff to provide people with food and water. Ultimately it was agreed that the people most vulnerable to extreme heat would be those unable to leave their homes. Consequently, the Premier made a public statement encouraging people to check on the safety of their neighbours:

> ‘*He just said, “Look everybody, this is the time: if you don’t know your neighbour, go and knock on their door now and see how they are and see what you can do…”. And I think that was actually a really valuable thing, because he was putting it back on the community...“You’re the people who know that you’ve got an old lady living next door to you. See how she is”*’ (DFC1).

The DFC activated the Red Cross to call vulnerable people and check on their wellbeing, and used the media to invite people to register themselves or others for the service.

Lessons and policy changes due to the 2009 event

Since the 2009 heatwave, the DFC has developed policies and plans for responding to extreme heat in cooperation with SASES. It recognises that each agency working for the DFC should have a plan for responding to extreme heat events. The DFC developed a template to assist agencies develop their plans and to ensure that they were consistent.

The DFC recognised that the agencies who work with homeless people were under enormous stress during the heatwave and were continuing to deliver bottles of water to the homeless after hours. In response to this, the DFC will now provide these agencies with assistance during extreme heat events.

The DFC is now more aware of the impacts that extreme heat can have on infrastructure and how this may affect delivery of services. The potential for technological and system breakdowns reinforces the need for greater preventative and preparedness measures to reduce the impacts of extreme heat.

> *‘A lot of what we were talking about has no relevance at all if these things are going to break down. So you have to find solutions for people in their own homes, and we can’t rely on electricity. So buying fans and that is not necessarily the way to go’* (DFC1).

Future challenges

The DFC has encountered a range of challenges in responding to the three extreme heat events they have now experienced (January/February 2009, November 2009 and February 2010). These relate to its joint operations with agencies (such as the Red Cross):

- running out of volunteers to make TeleCross REDi phone calls
- improving awareness of the limitations of a phone call service and the need for highly skilled interviewers.

5.1.6 South Australian Red Cross

Policy prior to the event

Prior to the January/February 2009 event, the Red Cross had no specific program for heatwave events other than OHS policy around working in the heat, although it would ring clients listed on its TeleCross service more often during hot weather.

The National Red Cross has a general emergency preparedness campaign entitled Red Cross REDiPlan. This has been in operation since late 2008 and aims to better prepare Australian communities for disaster events. It includes tailored information for a range of vulnerable groups.

Experience of the 2009 event

Three or four days into the event, the Red Cross received a request from the Department of Health/Department of Families and Communities (SA Health/DFC) to assist them in supporting and monitoring vulnerable people. Although the Red Cross is used to dealing with disaster responses, the 2009 heat event presented it with new challenges.

> '*as a community, as a State really, we didn't have our heads around what we need to do and how we need to be prepared. ... We talk about preparedness all the time but we hadn't talked about preparedness for heatwaves — we certainly weren't in that frame of mind*' (RCSA2).

Typically, its emergency services recovery teams work face-to-face with emergency clients. During the heat event, it adapted the TeleCross service and responded to a broader, state-wide crisis from a central phoning point.

The DFC supplied the Red Cross with a list of the most vulnerable. Operations expanded beyond its TeleCross call centre as the client list grew with the severity of the heatwave.

Prior to the January/February 2009 heat event, there were 600 clients on the TeleCross program. This has since doubled to 1200, as a number of those who were called during the heatwave event decided to remain on the daily system.

During the extreme heat event of January/February 2009 the Red Cross cancelled any non-urgent activities and transport of clients. In many cases, volunteers who would normally visit clients telephoned them from head office instead.

Lessons and policy changes due to the 2009 event

Since the 2009 heatwave, the Red Cross has developed TeleCross REDi, a dedicated extreme heat calling service that is now part of the SA Health/DFC heatwave plan.

Physical capacity has increased with more phones at the Adelaide headquarters and a new dedicated call centre at the training centre in Marleston. The Red Cross is also setting up smaller centres at its regional bases and training regional volunteers. These centres can be used for local calls or as a backup for the Adelaide centres if they get overloaded.

New processes to improve the registration of clients, training for volunteers and protocols for escalation procedures were implemented, including the development and application of a vulnerability assessment tool to help partner agencies better target the most vulnerable in their communities.

Mental illness is often exacerbated by heat if clients are on certain medication. Therefore, after the January/February 2009 event, mental health services looked after the critical clients who needed regular checking.

One of the many lessons learnt, now incorporated into the procedures, is not to duplicate the activities of other organisations. To avoid this they have set up a stakeholder advisory working group. The health messages developed by SA Health are being used by all agencies and the TeleCross REDi callers as their general key messages, thereby also reducing miscommunication.

To avoid the confusion surrounding phones not being answered, clients have been requested to notify Red Cross (or the relevant service) if they intend to evacuate their premises. Related to this is the problem of where to evacuate vulnerable individuals.

> '*Where do you relocate them to, shopping centres shut at five, councils are reluctant to run cooling centres as they don't know how to manage the risk around that. ... they have to be fed, have water, have their medications, ... where do they sleep, when do they go home*?' (RCSA1).

For the Red Cross, the best way forward is to educate people to have a firm plan in place if a serious fire danger area is also subject to a heatwave.

Since the January/February 2009 heat event, the Red Cross has produced emergency heatwave REDiPlan factsheets for the general public and specifically for senior citizens.

In order to reach the homeless and those in transitional accommodation, the Red Cross has partnered with the major homelessness provider in South Australia. These partnerships and other collaborations, such as that with ETSA Utilities, are regarded by the Red Cross as a positive outcome of the heatwave.

> '*We tried to work with these other agencies prior to this, there are some synergies and we were trying to forge some partnerships, but this has really given us the opportunity to talk a lot more*' (RCSA2).

If the heat event runs for a considerable length of time or the regular volunteers are difficult to access, the Red Cross has planned to access corporate groups to source volunteers. This ability to quickly expand makes the TeleCross REDi program adaptable and flexible to a range of situations.

In anticipation of the likely event that the Red Cross will need to activate its bushfire emergency response in addition to a heatwave response, it has set up an extra emergency call centre for emergency services.

The Red Cross have a formal review process after every activation in order to fully debrief and build lessons or recommendations into its plans. This process includes an internal Red Cross-only debrief followed by a general debrief with all stakeholders.

Future challenges

Red Cross identified a number of areas that could prove a challenge during future heatwave events. These included:

- keeping the TeleCross REDi client list up-to-date and registering clients
- keeping the daily TeleCross program running when they activate TeleCross REDi
- maintaining day-to-day Red Cross activities while activating the TeleCross REDi emergency service, and ensuring staff are rostered appropriately and do not become overworked
- recruiting sufficient volunteer callers for advertising, interviewing, police checking, training, support etc. The Red Cross has trained up 220 volunteers since October 2009 as part of the heatwave program
- the need for bilingual volunteers
- providing relief for TeleCross REDi volunteers and staff if the heat event continues for a significant length of time
- ensuring enough volunteers are available if an event extends over weekends and holiday periods
- providing timely services for clients in regional areas — DFC's heatwave plan is Adelaide-centric, so Red Cross cannot officially activate its TeleCross service until the temperature triggers are reached in Adelaide city
- South Australia's aging population and the aging volunteers.

5.1.7 South Australia: discussion and summary

In South Australia, there were no extant plans or arrangements in place to reduce the risks associated with extreme heat or to respond to a heatwave emergency. It took rapidly escalating deaths, ambulance calls and hospital admissions — in addition to mass utility and infrastructure issues — before key agencies realised there was a problem. However, once the emergency situation was acknowledged, all responsible organisations recognised the seriousness of the heat event and responded with urgency. Since the January/February 2009 event, there has been much greater awareness among government, the media and the wider community.

> '*It was this realisation that a heatwave is an emergency event. We have to do the preparedness, the planning; the response has to be critical, urgent. It has to be exactly the same as we do for anything else we are involved in. And I think clearly that is being heard now. It's just you can't see the flames, you can't see the water; it's not visual: it just creeps up on everybody, but the impacts are just as dangerous, if not more*' (RCSA1).

The 2009 event was viewed as an emergency with multiple impacts on health; transport, utilities and infrastructure; trees; house fires etc. For this reason SASES emerged as the appropriate hazard leader. SASES has produced an 'Extreme Heat Arrangements Plan' (SASES 2009) that includes a full communication plan. This is based on its experiences of the January/February 2009 event. Significant cooperation and collaboration between all agencies has produced management actions and communication aligned under the overarching heat plan. The heat plans are considered effective as they encompass an all-hazard, whole-of-government approach managed from the top down.

The Extreme Heat Stakeholder Group continues to adapt its plan as it learns from ongoing heat events and through collaboration with researchers at the BoM, DH and local universities.

The response to the January/February event was considered urgent because the SEC was suddenly faced with escalating deaths. However, the stakeholders now realise that the impacts from extreme heat events can be considerably reduced with appropriate cooperation, planning and education.

There was some discussion as to why the January/February 2009 extreme heat emergency occurred. Although there was agreement that the climate may be changing and that prolonged periods of high temperatures are to be expected, it was also acknowledged that Adelaide had experienced extreme heat events in the past. It appears that in addition to the extreme temperatures experienced, people's vulnerability and expectations of emergency services had increased.

> '*Heat has been a part of the landscape here forever and I don't know if we have become a soft society or too reliant on air conditioners. People are now de-climatised. … Heat [has] always been here but all of a sudden it has become an issue'* (SASES1).
>
> '*I think the interesting thing now is to take a step back and say "What is this we are doing that we never have done before? Is something different happening or is it just that people's expectations are different?" I think it's a little bit of both. … If this is going to be a "more normal" business as usual, clearly we need to respond to it, there is no doubt about that. But we also need to build the resilience of the community*' (SA DH1).

Therefore, in addition to improved planning and response to extreme heat events, community expectations must be addressed and capacities for self-reliance and resilience developed. This problem was thought to be particularly acute for those under the age of 40–50, who are more reliant on technology and air conditioning. This overdependence needs to be reduced.

5.2 Victoria

5.2.1 Victoria Police

The 'State Emergency Response Plan' (SERP) is prepared under section 10 (1) of the *Emergency Management Act 1986* (VIC Government 1986). The Chief Commissioner of Police is the State Coordinator of the SERP and is responsible for the coordination of the activities of agencies with responsibilities in relation to the response to an emergency. The 'Emergency Management Manual Victoria' (VIC Government 1997) details the control and support agencies for specific emergencies — extreme heat events are not listed. However, the Chief Commissioner of Police has the authority to nominate one of the response agencies to be the control agency during or in anticipation of an emergency (s16a *Emergency Management Act 1986*).

Victoria Police (VICPOL) noted that, under the current SERP, one week prior to a weather-related event the BoM distributes weather reports to VICPOL via email and these are updated daily. Although temperatures dominate the report, in Victoria they are largely provided for bushfire planning. The Department of Health (DH) also distribute heat triggers to various stakeholders (see associated report on DH).

Experience of the 2009 event

According to VICPOL, during the 2009 heat event DH adequately covered the health aspects of the emergency and put out sufficient warnings. For VICPOL, the emphasis was very much on bushfire risk, particularly as there were fires burning prior to 30 January, 2009.

During this period, The State Emergency Response Coordination Centre (SERCC) was activated for most of the heatwave in order to deal with the bushfire risk and the impacts from heat. The focus was always on bushfire except on 30 January, when heat became an issue.

In the dynamic environment created by the heatwave and bushfire risk, VICPOL didn't necessarily follow the emergency management plans outlined in the SERP. However, the VICPOL representative interviewed felt that what they did ad hoc was better than the designated plans.

The Department of Primary Industries coordinates communication with the various power companies but, during such emergencies, VICPOL deals directly with the power companies in order to maintain direct and timely lines of communication. At 6pm on 30 January, the power was lost at VICPOL and its generators kicked in. It became apparent that an important substation was down and power was lost to a large section of the city.

As the power supply for Victoria was now insecure, VICPOL brought operations police into the SERCC.

VICPOL admitted that there had been an embargo on the numbers and details of excess deaths being publicly released. This embargo was believed to have come from DH — possibly because it was hard to determine if the deaths were actually heat-related and also to reduce public outcry.

Although types and numbers of calls and police cases could not be given, VICPOL stated that there was a significant increase in the police workload during the heatwave event.

> *'It is safe to say there is an increase in police cases during heatwaves'* (VICPOL).

Lessons and policy changes due to the 2009 event

Actions carried out by VICPOL during the bushfires and heatwave on an ad hoc basis were seen to work better than procedures within the SERP. The state arrangements have now been refined and adjusted accordingly to reflect this experience. VICPOL has also refined its roles and strategy. It has developed an improved structure so as to better deal with social issues and issues arising from power cuts, such as traffic light malfunction or boom gates going down. However, it was believed that VICPOL already had solid networks with the power companies and had responded to the outages effectively.

New command and control arrangements have been agreed upon by CFA, Department of Sustainability and Environment (DSE), Metropolitan Fire Brigade (MFB), Ambulance Victoria (AV) and VICPOL. Although they are in response to the 7 February 'Black Saturday' bushfires, the new management arrangements will still have an impact on the response to all future incidents and emergencies. The new command and control arrangements include:

- the establishment of three tiers of emergency management
- a single person identifiable and responsible as the controller
- a person higher up in the control agency to monitor the control agency response
- VICPOL as emergency response coordinators to ensure that proper, single line of control for an emergency is in place.

VICPOL will also use WebEOC, a web-based information management system that provides a single access point for the collection and dissemination of emergency or event-related information. It allows real-time information sharing and any police officer will be able to log in.

By 1 October each year, every police management unit has to report on its state of readiness for emergency and its emergency plans. This is largely in relation to bushfire but also includes heat. Questions to be answered include: Where are the generators? Have they been tested? What facilities are in place? While some regions may develop detailed heatwave response plans, others may just respond to power outages.

VICPOL considered that, prior to the 2009 event, *‘the Department of Health have been doing their bit for heatwave but no one else was doing the rest of it’* (VICPOL). They stated that no organisation was covering transport or the social issues. The VICPOL representative also stated that other agencies were not aware of the ‘State Health Emergency Response Plans’ (SHERP) (VIC Government 2009) developed by DHS and what the role of DHS’s Victorian Health Emergency Coordination (VHEC) was in relation to extreme heat prior to the 2009 event.

Subsequent to the 2009 heatwave, the Chief Commissioner of Police has become involved in the heatwave response. During the heatwave, VICPOL dealt mainly with the knock-on effect of the extreme heat, such as fatalities and blackouts, and therefore considered that, despite being the lead agency for a heat emergency, it was not a strong player in terms of heatwave management: *‘it’s very much health dominated’* (VICPOL). VICPOL therefore felt it might be more appropriate for DH/DHS to lead a heatwave emergency.

A heatwave plan will be developed by VICPOL prior to next summer and it will complement that developed by DH. However, it was acknowledged that it would likely be one component of an overarching bushfire plan. VICPOL believe that the public messaging around looking out for your neighbours is a good idea and should be retained.

Fire dominated during the 2009 heatwave event and would likely become an even more dominant factor with the findings of the Royal Commission. There is concern that the heatwave component may be ‘lost’ as a result.

When it became evident that many deaths during the heatwave period might have been attributable to heat, VICPOL asked its officers to take more notes about the circumstances in which bodies were found. As a consequence of this, Form 83 has been adjusted according to feedback from the Coroner’s Office (see associated report on Coroner’s Office).

The policy surrounding the fire kits issued to all members of VICPOL has grown since the 2009 event. It recommends that members of VICPOL drink six litres of water per day. They have to supply their own fluids, but the department supplies a fridge and electrolytes sachets. This protocol mirrors MFB strategies, which includes educating staff to check the colour of their urine.

As policing issues are mostly related to infrastructure and transport, the transport division within VICPOL will also mobilise additional staff during a heatwave.

A VICPOL representative noted that in New York City during times of extreme heat, personal fans were distributed with health information in different languages. This is an option that local governments could adopt in Victoria.

Future challenges

Challenges identified by VICPOL include:

- heatwave plans comprise one component of an overarching bushfire plan and there is no dedicated stand-alone plan

- the agency is very response focused — planning and risk reduction in advance of a heatwave emergency is not part of its strategy
- much emergency management planning occurs at the municipal level, where local governments identify risks within their communities and develop plans based on these risks: however, there is no overarching plan
- the many layers of bureaucracy
- the potential for information overload where many good ideas get lost (e.g. a call for a heatwave control group has not yet been finalised)
- a lack of sharing and assistance across the states in general in terms of emergency management arrangements.

5.2.2 Department of Health and Department of Human Services

The Department of Human Services was split in August 2009 to create two new departments: the Department of Health (DH) and the Department of Human Services (DHS). During the January/ February 2009 heat event they were still the one department and will therefore be reported on as such.

The document 'Our Environment, Our Future – Sustainability Action Statement' (DSE 2006) identifies heatwave planning as a priority for local governments. Local governments were considered best placed to carry out heatwave planning due to their proximity to the community.

In 2007, a system came into operation for surveillance of heat-related morbidity and mortality in order to provide the Chief Health Office with timely information on the impacts of heat. Data sources for the local medical deputising service were available after a 24-hour period following diagnosis. However, the ambulance service had a two-week lag which '*wasn't terribly useful in the end*' (DH1).

Concurrently, DH was investigating strategic directions for establishing climate change and health relationships. This identified that a focus on heat would be the most straightforward approach.

DH contacted Monash University to see if they could define a heatwave with regard to mortality (heat health thresholds). '*Essentially, we wanted a heatwave trigger that we could actually keep under surveillance through the Bureau's* [BoM] *forecast*' (DH1). If these 'trigger' characteristics were known, they could then identify particular heat alert days and, as such, DH could issue public messaging on preventative measures for heat.

In 2008, DH funded 13 pilot projects involving 22 (DH 2008) of the 79 Victorian local government councils to develop heatwave plans (e.g. see Greater Shepparton City Council 2009). The results from these projects were intended to form the basis of a 'heatwave toolkit' that would aid Victorian local governments in their heatwave planning for the 2009–2010 summer. However, no minimum standards for the plans were set and funding was not ongoing. However, DH did inform local councils that they needed a communication and consultation strategy for heatwave events.

Experience of the 2009 event

DH had a basic alert system in trial operation during the 2009 event. It was sent out to the 22 councils in the pilot heatwave project as well as to other stakeholders, such as the Red Cross. The fully developed alert system was produced after the 2009 event and is detailed in the following section.

Although DHS was aware of the impending heatwave, it wasn't until Thursday 29 January 2009 that they became heavily involved in mitigating its impacts. Many hospitals were switching to bypass (not admitting new patients) and, as a consequence, the ambulances were pushed on to other hospitals. That evening, the DHS emergency management arm — VHEC — stepped in by taking all hospitals off bypass. This unprecedented intervention allowed the ambulances to deliver patients where needed, placing tremendous pressure on the hospitals.

Those within DH were very much taken by surprise by the rapidly escalating demand on the health services. This was despite its pre-heatwave work with local councils and the development of heat health thresholds and its heat alert system.

> '*We monitored the BoM site, but for us then the first inkling was that it was just bloody hot… The ambulance is probably the first thing that suffers but you learn that in hindsight. I suspect for us, like anybody else it's transport failures, then we started to hear about power outages… We know in hindsight that calls to Nurse-on-Call follow the temperature. As it gets hotter and hotter, people call Nurse-on-Call. But these are all things you learn in hindsight'* (DH2).

During the heatwave event, DH had an agreement with AV to send out the same messages. The Chief Health Officer appeared in the media, briefings were sent to newspapers and DH also asked that an emergency alert appear on the BoM's website. Despite this increased communication and media strategy, one DH representative suggested that very little was done proactively within the organisation in terms of response and actual risk reduction.

Despite efforts since 2006 to develop the surveillance system, there was a scramble for indicator information in order to measure the impact of the 2009 event.

> '*Getting death information in a timely way is extremely difficult… Determining the cause of death as heat-related; how we collect that data and how we look at it, is one of the challenges to moving forward*' (DHS).

Lessons and policy changes due to the 2009 event

In July 2009, DH published its 'Heatwave Planning Guide' (DHS 2009) from the experiences of the local governments involved in the heatwave pilot project, national and international documents on heatwave planning and the experiences of the January 2009 heatwave. However, one DH representative felt that, despite the level of funding that had gone into the guide, it was not a helpful document for local governments. In order to take best advantage of the experiences of the 2009 event, DH fast tracked funding for the remaining 57 councils to develop heatwave plans for addressing preparedness. DH stated that the heatwave plans differed from council to council depending on which section was involved and the level of consultation completed. The majority of local governments across Victoria now appear to have some form of a heatwave response plan although the quality of these varies significantly.

In order to assist local governments DH has developed a comprehensive suite of fact sheets and brochures. These resources are available in various languages both in print and on its website. There is an easy-to-read version and a vision-impaired version is in development.

DH are encouraging local councils to help people stay cool and safe in their homes, rather than plan open relief centres and relocate people. Local councils would get no extra funds to help cover the costs from opening a relief centre during a heat event: also, such actions carry significant levels of planning and liability. However, for those who are mobile, the advice is to visit public places that may be cooler, such as shopping centres and swimming pools. Other responses include programs to maintain public drinking fountains, and lighting parks in the evenings so people can cool off there but also be safe. It was stated that a policy focus and risk assessment procedure around some of the planning for heatwave response would be useful.

In December, DH published the ‘Heatwave Plan for Victoria 2009–2010’ (DH 2009), that aims to:

- provide a framework of support for heatwave preparedness and response across Victoria
- build the capacity of communities and individuals to manage their response to heatwaves
- identify and carry out additional research to support the above objectives.

The plan outlines that DH is specifically responsible for:

- funding, guidance and resources to assist Victorian councils develop heatwave response plans
- working with Personal Alert Victoria to provide additional support during a heat event to over 22 000 vulnerable clients
- providing bushfire and heat advice for Home and Community Care organisations
- public health messages and communications delivered through a range of community-based organisations including ‘various paraphernalia produced by some councils’ (DH 2009, p.14)
- establishing a system of consultation with health and community service providers.

The responsibilities of other departments within DH and DHS are detailed on page 15 of the Plan (DH 2009). Of note are the plans for the:

- Housing and Community Building Branch of DHS to expand its ‘Keeping in Touch’ weekly telephone program to include all 7000 public housing tenants aged 75 years or over
- Office of Senior Victorians (OSV) (Department of Planning and Community Development) with support from VICPOL, to implement 23 new and seven enhanced community registers in local communities around Victoria. DH will provide funding. Page 16 of the Plan gives a full list of existing and new registers. DH is working with organisations that provide a phone-communication service in order to develop consistent health messages and scripts.

Two heatwave definitions are given in the Plan (DH 2009, p. 3):

- *general definition* — a period of abnormally and uncomfortably hot weather that could impact on human health, community infrastructure and services
- *technical definition* — a minimum temperature ‘threshold’ that is likely to impact on the health of a community.

The mean temperature is calculated from the forecast daily maximum and the forecast overnight minimum temperatures. The thresholds vary by region, but for Melbourne the threshold mean temperature is 30 °C.

DH staff monitor the BoM’s forecast temperatures for Victoria daily. They inform the Health Protection Branch if a trigger temperature is forecast or if threshold temperatures are predicted. DH would prefer the BoM to have an automated system and provide it with alerts.

> ‘*It’s not a sophisticated system. One of my staff actually sits down and looks at the BoM website, morning and night and looks at the 7-day forecast’* (DH2).

The current alert system is based on one day of heat over a certain level, although DH understands that the greater impact occurs during multiple heatwave days.

> *'Our definition is one day… it's a one day of heat over a certain level… But practically, when you only have one day, we don't see the huge service response like we did on multiple days… We're not quite sure what we will do. We are really waiting to see what we will do after the last summer. We've got a lot of work ahead of us to try and refine that'* (DH2).

Table 5.2 DH's heat health alert system developed for the 2009–10 summer (adapted DH 2009, p. 19)

Alert level	Trigger temperature	Action
Heat Watch	Maximum temperature of 36 °C or above forecast for Victorian regions (not including Mildura district). Maximum temperature of 40 °C forecast for the Mildura district.	DH release public health messages via information sheets, through the media, community registers and the health and community sector.
Heat Health Alert (6 days to 1 day prior to a forecast heatwave)	Mean temperature threshold of 30 °C or above is forecast for Victorian regions (not including Mildura district). Mean temperature threshold of 32 °C or above is forecast for the Mildura district.	Health Protection Branch of DH will monitor the BoM forecasts and issue heat health alerts (via email and followed by an SMS when the BoM forecasters provide confidence) to advise local governments, departments and health and community service providers to prepare to activate their heatwave response plans. In some cases the alerts will aim to raise awareness or inform of potential service disruption.
During a heatwave (day 0)	Same as above	The Chief Health Officer, in cooperation with the Health and Human Services Emergency Coordination Centre, will coordinate the action of the health and community sector and provide advice in relation to public health messaging. DH may issue a further heat health alert to notify local governments, departments and health and community service providers to activate their heatwave plans.

During the heatwave, DH positioned the Chief Health Officer in the media but considered that the heatwave wasn't getting enough media focus because of the attention on bushfires. In October 2009, DHS appointed a communication person to facilitate better interaction with media agencies.

DH has continued its agreement with AV to send consistent messages to the public for the forthcoming summer period. If extreme heat is forecast, DH has material prepared for a paid advertisement in the state-wide *Herald Sun* or *Age* and a senior citizens' publication.

DH targets large bodies working with the community that sit outside the responsibility of local councils and assists them to increase their capacity in response to a heat event. Their expected roles and responsibilities prior to and during a heat event are detailed within the Plan. Local councils are expected to target and work with small home and community care services.

DH recently put out a tender to look at a strategy for educating health professionals around heat issues, with an emphasis on dealing with the homeless and mental health issues.

Under the Plan (DH 2009, p. 21), the circumstances under which a heat event will be declared an emergency and require management by municipal and state emergency management plans are:

- record breaking or extreme heat events
- code red fire danger days
- power and public transport failures
- extreme demand on essential medical services.

Once an emergency is declared, Victoria’s State Emergency Management Arrangements will be activated. By default, VICPOL remains the coordinating body for extreme heat emergencies in the absence of a defined or designated heatwave control agency. Heatwaves/extreme heat events remain unlisted within Victoria’s emergency arrangements.

After the 2009 event, DH further developed its Heat Health Intelligence Surveillance System in order to track and report on the health impact of heatwaves. It is also conducting a full review of its heatwave planning through an external consultant.

Although DH had been planning for heatwaves, it was the experience of the 2009 heat event which provided the opportunity and momentum for them to drive the policy through.

> *‘But things like 2009 heatwave and the bushfires will always bring about big steps in responses. Things have been going on forever, they will take a quantum leap and that’s always been the way that you can make quite significant policy shifts in the wake of those things. And I guess that’s what we’ve been doing with local government is taking an opportunity for that sort of big event to make some policy shifts’ (DH2).*

Ongoing and future challenges

Challenges identified include:

- continuing to develop effective communication and emergency management for vulnerable, underrepresented community groups (e.g. public housing)
- developing an effective strategy for connecting with vulnerable groups by phone without causing offence
- shifting from the conceptual to the practical level when encouraging people to take personal responsibility during extreme events to help build resilient communities
- establishing the right balance between alerting the community about fire and heatwave hazards as they tend to occur simultaneously
- determining the amount of DH/DHS versus local government input into heatwave plans given the varying capacities of municipalities to develop them, especially as there is no formal process for DH to assess the plans
- overcoming the fragmented planning approach by different local governments — a collaborative heatwave response plan for the entire city region may be more effective.

However, this is additionally challenging given that there is little coordination from a designated hazard leader

- addressing concerns around the ‘Heatwave Plan for Victoria 2009–2010’ (DH 2009) — some view it as essentially a public relations exercise rather than a useful planning tool and consider that little actual preparedness to reduce future heatwave risks is taking place on the ground. Others regard it as DH’s role to clearly outline responsibilities and roles and not to tell people what to do
- finding the right people within councils to receive heat alerts and getting the heat alerts through to all health services such as aged care services, hospitals and emergency services
- using reliable heat threshold triggers (a preference for the BoM’s automated and consistent system rather than DH manual calculations)
- acquiring timely, relatively accurate and regular information not just related to mortality but also to morbidity — the information that DH receives within its Heat Health Intelligence Surveillance System is not yet effective at identifying timely surges in capacity within agencies such as AV and Nurse-on-Call
- identifying who is the most appropriate lead agency for heat events, particularly as heatwaves remain unrecognised within Victoria’s emergency management arrangements. At this point the police retain de-facto control, although some consider DH should lead as impacts on health are most significant.

‘Heatwave is not a designated emergency. There is still no formal protocol. It is not part of the emergency management arrangements. ... There is no sort of protocol for what you do in those sorts of things. Or there wasn’t. We’ve certainly made it our business to develop standard operating procedures for how we work, particularly since then. But it still remains to this day not an identified emergency’ (DH2)

- improving collaborative preparation to stop the heat event becoming a disaster in the first place, rather than being response based.

‘Police are the lead; DH/DHS are helping out. The arrangements are basically that when a heatwave occurs they’ll get together and decide what to do. Which is disappointing, since heatwaves are definitely going to occur in future; they’re predictable… So everything about heatwaves screams preparation, preparation, preparation! And none of the preparation taking place includes any of that, unfortunately. It’s like we’ll get together on the day and decide what we’ll do about it’ (DH1).

‘When you have a heatwave and an extreme heatwave it will turn into an emergency when power failures happen, transport failures happen, hospitals can’t cope and services are totally overwhelmed by the call on them… even though there are health impacts, it’s not actually a health issue. It’s a little different. People mostly manage when they have power, when they have transport. They manage… Health has an interest in making sure that that works right and will continue to do so but it’s about planning. It’s highly unlikely that Health will be that agency… and you need a whole range of agencies coordinated’ (DH2).

5.2.3 Ambulance Victoria Report

Prior to 2006, AV overhauled the concepts, strategies and responsibilities of its internal Disaster Plan document. This led to the development of its 'Emergency Response Plan' (ERP), which adopted a whole-organisation approach — recognising that every division within AV is either directly or indirectly involved in the response to an incident.

A challenge for the emergency management staff was to get AV to adopt this new proactive policy.

In the lead-up to the Commonwealth Games 2006, AV developed emergency management strategies to prepare for major incidents, including heatwaves. A new strategy built into the ERP is the dispatch of an incident manager with the responding ambulances.

The ERP was implemented state-wide but AV realised that incidents such as heatwaves were not events that personnel could be dispatched to because they were not discrete events. '*It's not something you can respond to, you have to monitor. You have to monitor calls coming in and look for trends*' (AV1).

In the lead-up to the 2009 heatwave, a State Emergency Management Committee (SEMC) meeting of stakeholders invited AV to discuss the upcoming event. During this meeting the BoM announced a forecast for significant extreme heat days over 40 °C. According to AV, bushfire issues dominated proceedings and heat risk alone was not really considered.

AV already knew anecdotally that they were busier during extreme heat events. '*Not so much during the day, but during the night it used to get busy in hot weather*' (AV1). Following the SEMC meeting, AV approached its executives and highlighted that it was essential to prepare.

AV recognised the need to provide in-field support (water, sustenance and rest) for its paramedics and extra resources for the communication centre, the focal point for 000 calls. An emergency operations centre had to be established to coordinate the whole strategy, monitor the trends and communicate with other emergency services and internal departments within AV. Also, AV highlighted the need to prepare the community by distributing heatwave information.

These preparations were implemented following approval from AV executives.

Experience of the 2009 event

For AV the heatwave constituted multiple days working at or above surge capacity. It was not just a single point event; it was across the whole state of Victoria and, especially for AV, the whole of metropolitan Melbourne.

> *'The bushfires were a significant event for this organisation for that period of time. … In comparison to the heatwave, it was a breeze. We barely coped, if at all, with the heatwave' (AV1).*
>
> *'Our 000 calls went through the roof and one of the things we learnt was it's because people generally look for relief overnight. They weren't getting it here because the temperature was still high at night. We think that the pensioners and the elderly in this*

> *community culturally are probably economically conservative. They don't want to run their air conditioners because they cost money, if they have them at all'* (AV1).

Despite AV's recognised success at resuscitation, it had a significant morbidity rise in terms of resuscitation during the heatwave because most patients were already deceased.

> '*People would find them the next day. There was nothing for us to work with. These people died overnight'* (AV1).

As a consequence, emergency response activity increased significantly for AV during the mornings.

> '*We were completely overwhelmed in terms of the response*' (AV2).

> *'Most of those patients were elderly and in the poor socioeconomic groups. They were mostly in metropolitan regions and also consequently they were unable to access the same sorts of resources e.g. air conditioning. People were going around saying keep cool, but you tell the poor lady in the housing commission flats living in a dog box to keep cool'* (AV2).

Considering that the elderly are often isolated, AV was encouraging people to check on their elderly family and neighbours.

> *'They forget to drink water or they drink too much alcohol. Their coping mechanisms have disappeared, or are forgotten about... during that heatwave we had power blackouts for a period of time as well and people don't know how to cope when that occurs'* (AV1).

Despite these messages, AV found that people weren't changing their behaviour.

> '*We were still treating people running around in 44 °C. People don't change their behaviour patterns because of heatwave because we're a hot country. … People were complacent. They didn't take it seriously*' (AV2).

AV wanted to release information about the health impact of the event to get the public to take it seriously. However, this was not possible.

> '*South Australia did very well. They approached it differently. In South Australia they were on the radio on a daily basis saying "We've had 40 deaths today, you need to do something". They took a very different approach'* (AV2).

AV not only experienced a significant increase in emergency work but also an increase in non-emergency work. The increase in activity occurred a few days into the heatwave and this increase lasted well after the heat subsided.

Lessons and policy changes due to the 2009 event

Although AV planned for the 2009 heatwave, it believes that it wasn't enough. AV had learnt that preparation was extremely important, especially for the welfare of the paramedics. Following the event, AV held a debriefing and, as a consequence, developed a heatwave sub-plan. During this time, AV worked closely with all the emergency services but mainly DH because '*it's very much a health impact*' (AV1).

A single hot day in Victoria does not create much of an issue for AV. The problem is when there are consecutive hot days, especially if the temperature stays above 25 °C overnight. The heatwave sub-plan is triggered when two or more consecutive days reach a certain mean temperature. These triggers link with DH triggers.

> '*We know in terms of pre-hospital it is that second day that's an issue for us'* (AV1).

Since initiating the heatwave sub-plan during the 2009–10 summer, amendments have been made. These include AV adjusting its triggers to make them more relevant to the situation to avoid over notifying or over preparing. Conversely, call monitoring and activation and coordination of the emergency management centre had improved as a result of new strategies within the heatwave sub-plan.

Future challenges

Challenges identified include:

- getting people to change their behaviour in the heat. AV felt that people are generally dismissive of messages about heat as they already live in a hot country
- getting heatwaves recognised within the SERP. A meeting is scheduled for May 2010 to further consider the inclusion of heatwaves in the manual. AV is 'fighting to keep it at the forefront of people's psyche' (AV1).
- changing the mindset of paramedics to accept the new protocol to dispatch a manager with the responding ambulances. Their role is to oversee the operation where public and media scrutiny on the emergency services is significant.

5.2.4 Metropolitan Fire Brigade

As stated in Section 32 of the *Metropolitan Fire Brigades Act 1958* (VIC Government 1958), the MFB is responsible and accountable for alarms, incidents, exchange calls for fire, explosion and other emergencies. The MFB adopts an all-hazards approach and considers that its systems and policies are flexible enough to adapt to any event.

The representatives interviewed stated that the SERP arrangements are '*a living thing'* and are often updated after a big event. They consider that MFB would only ever be a support agency during a heat event.

About two and a half years ago, MFB established the Environmental Action committee to construct policy and provide advice in relation to climate change. A project group within the committee was formed to look at how MFB could cope with surge capacity in the face of extreme weather impacts.

In dealing with surge capacity, MFB protocol is to form an emergency coordination centre. It then minimises all non-essential activities, and stays on at the station on higher alert, ready to respond. There is an essential focus on core activity.

MFB has internal staff policies for heat that limit the amount of physical work to ensure provision of shaded areas and hydration. On an extreme heat day, a logistics officer is present at all jobs in order to monitor exposure to heat.

Experience of the 2009 event

On particularly hot days, calls can increase due to systems having been tripped into an alarm phase — it does not necessarily mean there has been an increase in emergencies. Nevertheless, for the period 26 January to 3 February 2009, MFB identified that it had received an excessive number of calls.

MFB staff protocols, which were already in place, were enacted during this period. All staff were recalled from non-essential duty so that they were ready and available for any emergency calls that came in.

Lessons and policy changes due to the 2009 event

No policy changes for MFB evolved from the 2009 heatwave event. It considered that its protocols were adaptive and flexible and they had coped well with the heat event.

MFB recognised that after the Black Saturday bushfires there were a lot of changes to the SERP arrangements in Victoria.

> '*Because in that review process we realised that no one had actually put their hand up* [for heatwave]. *But in the arrangements for all of those ambiguous areas there's a default to VICPOL*' (MFB3).

Following this review, VICPOL took on the responsibility for heatwave events.

Future challenges

Challenges identified include:

- quantifying MFB's ability to work during surge capacity
- determining whether changes to the SERP in response to the 2009 bushfires will impact on the MFB's all-hazards capability.

In conclusion, an MFB representative offered his opinion about how to overcome inherent issues in coping with surge capacity.

> '*I wonder whether a single emergency service might come out of the whole issue… I would love to see that happen myself, what a great opportunity, to work in Victoria and not just Melbourne. One board, one set of procedures, one set of arrangements, one type of communication system. The surge capability would be better understood*' (MFB1).

5.2.5 Coroner's Office

The Coroner's Office has a duty to protect public health and safety by investigating the preventative context of deaths. Working in collaboration with stakeholders, the Coroner's Office aims to develop potential recommendations that are acceptable, implementable and effective at addressing particular causes of death, including heat.

When a case is reported to the Coroner's Office by the police, Form 83 is attached. The police are required by law to complete this form for every case submitted to the coroner. Form 83 includes a summary of circumstances in which the body was found, but there was no predetermined protocol for completing it.

Experience of the 2009 event

The Coroner’s Office provided a comprehensive analysis of reported cases during the 2009 heatwave for the Chief Health Officer’s Report. This dataset also highlighted existing weaknesses for identifying heat cases during the coronial process.

The Coroner’s Office compared age groups of the deceased during the heatwave with baseline fatality data from 2006 to 2008 and, as expected, there was a shift in composition to the older population, and a dramatic increase in cardiovascular cases.

Over the course of the heatwave, police officers were recording more heat-related information in Form 83 such as, ‘*person found in stuffy room, windows closed, air conditioning present but not operating*’. Although information regarding air conditioning wasn’t reliably reported, it did become a recurring theme and the Coroner’s Office started using it as a specific variable.

Based on Form 83, pathologists became increasingly willing to include heat as a potential contributor to the cause of death.

Almost all cases during the heatwave were found indoors and most were living alone or with others in private residences.

> ‘*The sense that we had of most of our cases was that these were quite independent individuals who were quite functioning at the time of their death*’ (CO).

Lessons and policy changes due to the 2009

A number of stakeholders came together to develop a protocol to assist police in collecting basic standardised circumstances surrounding the discovery of a death, including such risk factors as air conditioning, room ventilation etc. Pathologists can use these characteristics to assess the possibility that heat contributed to a death.

The police were advised during the 2009–10 summer to record information on Form 83 if they found someone during an extreme heat event, or in the context of an extreme heat event, and this led to the recording of a lot of heat-related information.

Since 1 January 2010, the Coroner’s Office has instituted a daily surveillance system for coronial cases that includes heat as one of the variables.

Future challenges

As heatwaves are mass casualty events, the State Coroner’s Office is extremely keen to deal with heat as a coronial issue.

One of the challenges is to educate each judicial officer so that they will include heat in their findings. The Coroner’s Office is working with judicial officers to help demonstrate that, although a heat-related death could be seen as natural, it is a potentially preventable death as well.

Successfully identifying which cases are heat-related is another challenge, especially as Australia lacks the risk factor information. To address this, the Coroner’s Office would like to see the development of an indicator or test that enables a pathologist to run through a standard set of procedures and determine if the case is heat related.

A further challenge for the Coroner’s Office is the availability of facilities to store bodies during mass casualty events.

The Coroner’s Officer representative also expressed concern about local governments proactively reducing the impacts of heatwaves within their local communities.

> ‘*Most heatwave plans that we’re aware... don’t actually activate anything... don’t actually do anything preventative. From a coronial perspective, we would be very interested in seeing systems that had direct intervention with people and had an evaluation process attached to them so they could demonstrate effectiveness. They’re the things that would be examined if a heatwave went to inquest*’ (CO).

5.2.6 Red Cross (Victoria)

The Red Cross is engaged in emergency management activities at all levels across the state with other agencies. In relation to its preparedness work, the Red Cross partners with one of the hazard agencies wherever possible.

Experience of the 2009 event

Most activity for the Red Cross was in relation to bushfires, not heatwaves. Following the power outages on 30 January, the Premier of Victoria announced the commencement of outreach programs involving door-to-door visits by the Red Cross on behalf of DH. These were for people without power for more than 48 hours. The initial notification meant that potentially 20 000 could be involved, but ultimately only around 40 required visits.

Lessons and policy changes due to the 2009 event

In relation to local government heatwave plans, the Red Cross offered to assist and extend the capacities of local governments by conducting basic preparedness work with vulnerable community groups. During the 2009–10 summer, this involved talking with local governments’ health and community care workers about the REDiPlan program, which promotes household preparedness.

Prior to the development of the internal policy in late 2009, staff during the 2009 heatwave were required to make judgement calls about safe work practices. Despite the policy, there were still gaps in relation to the appropriate frequency and length of breaks for volunteers, given that the majority of its 4000 strong workforce in Victoria is over 60 years of age and, as such, vulnerable to extreme weather.

The Red Cross developed fact sheets entitled ‘Coping with hot weather — Advice for seniors’ which it also sent out to its volunteers.

It also set up a protocol around an internal early warning system for heatwaves, whereby heat health alerts broadcast by DH would trigger a series of events and initiate communication strategies.

Following the 2009 heatwave, the Red Cross partnered with other organisations to augment its capacity during emergencies. Working in collaboration not only expands community response during emergencies, but also allows the Red Cross to tap into a slightly different demographic of volunteers.

Future challenges

Challenges identified include:

- improving the capacity of local governments to plan for heatwaves
- increasing its preparedness for implementing door-to-door visits during prolonged blackouts.

5.2.7 Focus group discussions: Victorian community organisations

Participants

Sixteen participants took part in two focus group discussions (8 participants in each) following an information session ‘Working in the heat: Information session on planning for heatwaves for community organisations’ organised by the Victorian Council of Social Services.

Key points

Key points that emerged from the talks presented at the information session and focus group discussions include:

- on the whole, community organisations did not have prior planning in place before the 2009 heatwaves and simply responded as best they could with ad hoc arrangements. It wasn’t until afterwards, particularly after the peak temperature on 7 February, that people reflected on the difficulties they had encountered
- community organisations expressed concern regarding their ability to follow DH recommendations to suspend all work or, in some instances, to evacuate special needs patients on catastrophic bushfire days. These organisations lacked the facilities to accommodate these people elsewhere. Evacuations also placed tremendous strain on clients
- since the 2009 events, DH has requested heatwave plans from some community organisations. These organisations have found it difficult to produce these plans because there is no template or framework from which to start
- community organisations expressed concern regarding the lack of DH funding to support initiatives such as community call registers and the evacuation of special needs clients during heatwave events
- most organisations still haven’t developed individual heatwave plans. Following the focus group, one organisation felt that its plan wasn’t *‘good enough’*.

Suggestions

The following suggestions arose from the focus group discussions:

- the Royal District Nursing Service has undertaken impressive measures to reduce the impacts of heatwave events on its staff and clients (e.g. see RDNS 2010). It appears to be a leader among the community organisations that participated. Perhaps this strategy could be used as a template for other large organisations
- it was felt that the most vulnerable and isolated need to be identified and a clear plan developed for each individual in each circumstance. It was suggested that DH should have responsibility for such a register. However, DH was working to the premise that the duty should lie with neighbours and friends. Although there was agreement on this, it was noted that when the community system failed, responsibility would fall to community organisations that do not receive funding from DH

- the Red Cross heatwave policy includes statements to the effect that no non-critical work can be carried out in temperatures over 40 °C and that a risk assessment must be completed for all critical work. Other community organisations could use this checklist as a template
- DH should develop a framework to assist community organisations to develop heatwave policies and plans
- there is a need for inter-agency support and coordination, in particular for organisations to know the planned activities of other organisations on days of extreme heat. Most importantly, service providers need to know if other organisations are going to halt service provision. Participants also wanted better sharing of knowledge and tools between community organisations. They wanted to know what changes other organisations had made in order to reduce the risks and respond more effectively.

5.3 Overview and reflections

Recognising the need for adequate planning to reduce the risks associated with heatwaves is a new but emergent area. This research was conducted over a brief period in April and May 2010. While the data collected accurately reflected the state of play at the time of collection, it is likely that policy and procedures may have changed or will certainly do so over the months and years to come.

Given Australia's history of bushfires, it is understandable that, in both states, the initial and bigger focus was on bushfire risk. Although DH in Victoria had begun some planning and provisions for heat events, both states were taken by surprise by the rapidly escalating impacts from heat.

In South Australia, SASES emerged as the hazard leader. SASES has facilitated a collaborative effort between all agencies to produce management actions and communications aligned under one overarching 'Extreme Heat Arrangements Plan' (SASES 2009, Annex A to the 'South Australian Extreme Weather Hazard Plan'). The heat plans encompass an all-hazard, whole-of-government approach managed from the top down. They now believe that, with appropriate risk reduction, they can avoid a rapidly escalating emergency situation such as the one they faced in January/February 2009.

In Victoria, after a pilot program was delivered (before and during the 2009 event) to 22 of the local governments to help them create heatwave plans, DH funded the remaining 57 local governments to develop heat response plans. They provided a 'Heatwave Planning Guide' (DHS 2009) and communications material and produced a 'Heatwave Plan for Victoria 2009–2010', (DH 2009). The Victorian Police (VICPOL) emerged as the coordinating agency and aim to develop a heat plan in line with that developed by DH.

A number of interviewees in South Australia observed that the 7 February 2009 bushfires in Victoria had overshadowed the impacts of the extreme heat in Melbourne in the two weeks before the fires. It was also felt that opportunities to publicise the impacts of the heat event had not been taken and that opportunities for learning and policy change had not been fully applied in Victoria. It was noted that extreme heat events in Victoria were still largely regarded as a health issue, with responsibility resting primarily with local governments. This was not considered to be the most effective approach for managing and reducing the risks from extreme heat in South Australia.

The salient differences between the two states in terms of their prior planning, the approach taken and changes since the January/February 2009 event are detailed in Table 5.3.

Table 5.3 Salient differences between South Australia and Victoria

South Australia	Victoria
Prior planning	
Had not been planning for heat events	Had been beginning to undertaking planning for heat events since 2006
No defined hazard leader for heatwave events	No defined hazard leader for heatwave events
Experience of the event	
Estimated 50 to 150 excess deaths	Estimated 374 excess deaths
Considerable infrastructure, utility and transport failure	Considerable infrastructure, utility and transport failure
Recognition that the 2009 heat event was an emergency situation by all	Black Saturday bushfires overshadowed the heatwave emergency
SEC activated, SASES in charge	SEC activated, VICPOL in charge
SASES provided strong leadership and coordinated a multi agency response	Health organisations coordinated a response
Communications issued to the public from multiple agencies and daily excess death counts issued	Communications issued to the public from DH/AV. Daily excess death counts not publicised in the media.
Use of the SEWS and text message alerts	SEWS and text message alerts not used
No bushfires although considerable alertness to the possibility and awareness of the VIC bushfires	Extreme bushfire fatalities and devastation
Policy/procedural changes and lessons learnt	
SASES official extreme heat hazard leaders. Roles of all key stakeholders clearly outlined	No overall leadership through a defined hazard leader. VICPOL extreme heat hazard leaders when event declared an emergency. Until then DH are the control agency. Unclear at what point a heat event is declared an emergency and what the response actions and responsibilities will be.
Heatwaves listed under the state’s disaster legislation	Heatwaves not listed under the state’s disaster legislation
All-of- government heat and communications plan developed. Significant coordination and collaboration between all agencies to produce management actions and communications aligned under the overarching heat plan. Top down approach with consultation.	Heatwave planning guide, to assist local governments, and a Victorian heatwave plan developed by the DH. AV has developed a heatwave sub-plan in-line with DH. Police aim to develop a heatwave response plan. Local governments develop individual heat plans. Bottom-up approach.
Forecasts monitored and alerts provided by the BoM to SASES and the extreme heat stakeholder group	Forecasts monitored and alerts provided by DH to agencies and government departments
Three levels of alert developed based on forecast ADT. Watch and Warning levels based on forecast ADT over three or more consecutive days. Detailed response actions for all agencies and departments outlined.	Three levels of alert developed based on forecast ADT. Levels based on one day of forecast ADT. Response actions outlined include the issuing of alerts and the coordination of the health and community sector.
Same temperature triggers used by all agencies to develop a coordinated response.	Unclear. Appears that different agencies have differing temperature triggers at which they will respond.

5.3.1 Challenges and potential strategies for resolution

Table 5.3 demonstrates that a number of significant challenges remain for Victoria. Suggested actions to address these are:

- add extreme heat events as a hazard within the SERP arrangements for Victoria in order that it is included within the all hazard approach
- designate a lead agency responsible for overall leadership and coordination to fully implement heatwave risk reduction across all agencies and levels of government. It is worth noting that one of the major findings from the Victorian Bushfires Royal Commission was the need for greater leadership and the appointment of a fire services commissioner. Police take a highly response-focused, command-and-control approach. It is questionable whether or not they are an appropriate agency to conduct the pre-planning, preparedness and coordination necessary to reduce the risks of extreme heat events.
- have coordinated response actions and communication aligned between <u>all</u> agencies (not just health specific organisations) and tied to defined temperature triggers.

South Australia, ironically, may have had a head start in developing an effective extreme heat plan due to their lack of prior planning. Unlike Victoria, South Australia was not already in a process of developing plans for heatwaves prior to the 2009 event. South Australia was therefore able to develop an appropriate response as the heat event occurred and have since based their plans on this experience.

Moreover, it appears that lessons learnt from the 2009 event have not been applied in Victoria. This is partially because of the Black Saturday bushfires, which eclipsed the heatwave event and thus reduced opportunities for reflection and learning. Successful adaptation to climate change impacts requires organisations to recognise that current policy and practice may be inadequate for future events. This is particularly the case given that, of all the projections from climate change models, we can have most confidence in those of temperature. Processes must be established where governments and other organisations can make changes without blame or recrimination.

Salient challenges faced by both states include:

- an accurate heat related mortality count — a number of organisations believed the actual number of heat-related fatalities for Adelaide was higher than the official count. Within Melbourne the greater problem was stated to be gathering timely mortality and morbidity data. Improvements in police reporting procedures, a greater awareness of the impacts of extreme heat and improved reporting systems for monitoring mortality and morbidity should improve the accuracy of the statistics collected at future events

- national funding for heatwave disasters — under the Federal 'Natural Disaster Response and Recovery Arrangements' (NDRRA), heatwaves are not a recognised emergency. Under these arrangements, state governments are able to claim reimbursement for 50% of certain response and recovery costs for recognised disasters. It was suggested in both South Australia and Victoria that, should this grant become available for heatwaves, it would help governments respond more effectively, and greatly assist the most vulnerable.

> '*If we were going to give money to people so that they could afford to turn their air-conditioners on, that sort of thing, then we would be able to get 50% back from the Commonwealth. However, heatwave is not accepted at the moment.*

> *That was one of the things we suggested to the Premier, as we had heard that people were frightened to turn their air-con on because of the cost. We said ‘If you offered $50 it might be cheaper, as people would use their air-conditioners’, but that didn’t happen*’ (DFC1).
>
> *‘In terms of reimbursement, once local government sets up whatever systems to deal with bushfires and floods, if it’s been declared an emergency someone will provide them with the funds to cover that because they simply don’t have the funds to pay for it. There’s a number of discussions being led out of the Attorney General’s at national level about whether heatwave can come in under that category and what will happen’* (DH2).

It was noted that one of the barriers to the inclusion of extreme heat within the Federal NDRRA was that heat can have a significant impact on the agricultural sector and could be very expensive for the state government. It was stated that discussions have been ongoing concerning a category of reimbursement for personal hardship and distress that does not cover primary producers.

- the likelihood of bushfires and extreme heat events coinciding — the greater emphasis given to evacuation during high fire danger days may conflict with the need for vulnerable individuals to remain cool. Services are also likely to be withdrawn to vulnerable groups in high fire risk areas, increasing their potential risk to heat impacts. Bushfire management policy must take potential heat impacts on vulnerable groups into account with combined bushfire and heatwave risk reduction

- surge capacity — emergency and community services will require an excess or surge capacity to cope with future events of uncertain magnitude and duration. It must be acknowledged that some events may exceed an organisation’s current capacity to respond

- health and welfare of emergency and community service providers — all the emergency services personnel interviewed had rigorous working-in-the-heat guidelines and protective equipment (MFS had new lightweight protective clothing designed as a result of their involvement in the post Victoria Black Saturday bushfire work). However, guidelines for community service providers remain less rigorous. Although a standard temperature policy is required, there was also a consensus that any guidelines relating to reduced operations during extreme heat would need to remain flexible and related to the vulnerability of the client and the type of work required. Furthermore, many volunteers of both types of organisations (Meals on Wheels, Country Fire Authority etc.) are within the age groups (65+) considered vulnerable to extreme heat

- the need to build resilience to extreme heat events — community service providers and emergency services can certainly assist to reduce deaths and morbidity. In particular, they have a capacity to promote increased preparedness and greater self-reliance to reduce people’s exposure to heat. Education and information provision may help promote desired behavioural changes. However, such an approach is unlikely to address the problems faced by those who are most vulnerable to extreme heat, as their vulnerability is a result of underlying social and economic factors. Community resilience for extreme heat certainly requires an informed and aware community. However, it also requires a rethink of the design of our built environment. Most importantly, people require greater access to affordable, appropriately designed and constructed housing, including public housing.

Table 5.4 Emergency management and health organisations interviewed

Melbourne	Codes used in report	Date interviewed	Adelaide	Codes used in report	Date interviewed
Metropolitan Fire Brigade	MFB 1,2	13 April	Red Cross	RCSA 1,2	19 April
Ambulance Victoria	AV 1,2	13 April	Dept. of Health	SA DH 1,2	19 April
Focus group of key community / health workers	Service provider 1a, 1b, 4b, 7b, 2b, 2a, 6b	15 April	South Australian State Emergency Service	SASES 1,2	20 April
Coroner’s Court of Victoria	CO	28 of April	South Australia Police	SAPOL	22 April
Red Cross	RCVIC	29 April	Dept. of Families and Community	DFC1	21 April
Dept. of Human Services	DHS	3 May	Metropolitan Fire Service	MFS 1,2,3	21 April
Dept. of Health	VIC DH 1,2,3	4 May	SA Ambulance Service		*Not available at this time*
Victoria Police	VICPOL	6 May			
Office of the Emergency Services Commissioner		*Not available at this time*			
Victorian State Emergency Service		*Not available at this time*			

References

Executive summary

CSIRO 2010, National Research Flagships, Climate Adaptation, *Change: Adapt Now for the Future*, June, 2010.

Section 1 Context and overview

CSIRO 2010, National Research Flagships, Climate Adaptation, *Change: Adapt Now for the Future*, June, 2010.

IPCC 2001, *Climate change 2001* – Third Assessment Report. Impacts, adaptations and vulnerability, contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC 2007a, Fourth Assessment Report (AR4) 2007: Working Group I: The Physical Science Basis 2007.

IPCC, 2007b Climate Change 2007: Synthesis Report.

Wilhelmi, OV, Hayden, MH 2010, ‘Connecting people and place: a new framework for reducing urban vulnerability to extreme heat’, Environ. Res. Lett. 5 014021.

Section 2 The meteorological and climate characteristics of the 2009 southern Australia heatwave

AEMO 2009, Victorian Annual Energy Planning Report: Public Forum, July 2009.

Alexander, LV & Arblaster, JM 2009, ‘Assessing trends in observed and modelled climate extremes over Australia in relation to future projections’, Int. J. Climatol, 29, pp. 417–435.

Bannister, T 2009, Modelling challenges from the Black Saturday event. <http://www.cawcr.gov.au/events/modelling_workshops/workshop_2009/papers/BANNISTER.pdf>.

Berger, A, Brown, C, Kousky, C, & Zeckhauser, R 2010, ‘The five neglects: Risks gone amiss’ in H Kunreuther and M Useem (eds), Learning from catastrophes – strategies for reaction and response, Wharton School Publishing.

Best PR, Stone R, & Allan R 2009, ‘Insuring for resilience in extreme conditions using climate modes and reanalysis products’, Paper presented to 9th International Conference on Southern Hemisphere Meteorology, Melbourne, February 2009, <http://www.bom.gov.au/events/9icshmo>.

Bureau of Meteorology (BoM) 2009, Special Climate Statement 17 ‘The exceptional January-February 2009 heatwave in south-eastern Australia’ <http://www.bom.gov.au/climate/current/statements/scs17c.pdf>.

Capital Hill Consulting 2010, pers. comm.

Charpentier, A 2010, ‘On the return period of the 2003 heat wave’, <http://halshs.archives-ouvertes.fr/hal-00463492/>.

Compo, GP, Whitaker, JS, & Sardeshmukh, PD 2006, ‘Feasibility of a 100 year reanalysis using only surface pressure data’, *Bull. Amer. Met. Soc.*, 87, pp. 175–190.

Cope, M 2009, ‘Climate change air quality and health’, <www.health.vic.gov.au/environment/.../19_cc&hh_mcope.pdf>.

Coutts, AM, Beringer, J & Tapper, NJ 2008, ‘Investigating the climatic impact of urban planning strategies through the use of regional climate modelling: a case study for Melbourne, Australia’. Int. J. Climatol, 28, pp. 1943–1957.

CSIRO 2007, Climate change in Australia, ISBN 978191232930.

Diamond, HJ, Plummer, N & Walsh, K 2010, 'Southern hemisphere meteorology and oceanography', Bulletin of American Meteorological Society, February 2010, pp. 245–249.

Diffenbaugh, NS, Pal, JS, Giorgi, F & Gao, X 2007, 'Heat stress intensification in the Mediterranean climate hotspot', Geophysical Research Letters 34, L11706 doi: 10.1029/2007GL030000.

Diffenbaugh, NS & Ashfaq, M 2010, 'Intensification of hot extremes in the United States', Geophysical Research Letters 37, L15701 doi: 10.1029/2010GL043888.

Fawcett, R & Hume, T 2010, 'The GOCF/AWAP system – forecasting temperature extremes" *Australian Meteorological and Oceanographic Society's 17 Annual Meeting*, Australian National University, Canberra, 27–29 January 2010.

Fischer, EM & Schar, C 2010, 'Consistent geographical patterns of changes in high-impact European heatwaves', Nature Geoscience 3, pp. 398–403.

Garcia-Herrera, R, Diaz, J, Trigo, RM, Luterbacher, J & Fischer, EM 2010, 'A review of the European summer heat wave of 2003', Critical Reviews in Environmental Science and Technology 40, pp. 267–306.

Gaughan, JB, Mader, TL, Holt, SM, & Lisle, A 2008, 'A new heat load index for feedlot cattle', J. Anim Sci, 2008, 86: pp.226–234, DOI:10.2527/jas.2007–0305.

Gaughan, JB, Lacetera, N, Valtorta, SE, Khalifa, HH, Hahn, GL & Mader, TL 2009, 'Adaptive responses of domestic (farm animals) to climate challenges' in GR McGregor, R de Dear, KL Ebi, D Scott, S Sheridan and MD Schwartz (eds), Biometeorology for Adaptation to Climate Variability and Change, (1st ed), pp. 131–170 Germany: Springer.

Intergovernmental Panel on Climate Change 2007,(IPCC) Climate Change 2007 - Impacts, Adaptation and Vulnerability, Cambridge University Press, Cambridge.

Kalkstein, L, Koppe, C, Orlandine, S, Sheridan, S & Smoyer-Tomic, S 2009, 'Health impacts of heat: present realities and potential impacts of climate change' in M Roth and M Obarraran (eds), Distributional impacts of climate change and disasters: Concepts and Cases, Universidad Iberoamericana Publica.

Karoly, D 2009, Heat waves and bushfires in SE Australia: are they related to climate change? <http://www.nccarf.edu.au/node/102>.

Kininmonth, W 2009, Southeast Australian heatwave and Victorian firestorm, January–February 2009.

Kousky, C & Cooke, RM 2009, 'The unholy trinity: Fat tails, tail dependence and micro-correlations', Resources for the Future 09-36-REV, November 2009.

Kousky, C & Cooke, RM 2010, 'Adapting to extreme events: managing fat tails and micro-correlations', Resources for the Future, Issue Brief 10–12, May 2010.

Loughnan, ME, Nicholls, N & Tapper, NJ 2010, 'The effects of summer temperature, age and socioeconomic circumstance on acute myocardial infarction admissions in Melbourne, Australia', International Journal of Health Geographics 9:41.

Lunney, KE 2001, Load Forecasting and Demand Management for the Privatised Electricity Market, Residential School in Electrical Power Engineering, Monash University.

McBride, JL, Mills, G & Wain, AG 2009, The meteorology of Australian heatwaves. <http://www.cawcr.gov.au/events/modelling_workshops/workshop_2009/papers/McBRIDE.pdf>

Met Office 2009, Landfalling hurricanes and other hazards – Climate services for the re-insurance industry.

Nairn, J 2009, Defining and predicting Excessive Heat events, a National system, <www.health.vic.gov.au/environment/downloads/pres_john_nairn.pdf>.

Nairn, J, Fawcett, R & Ray, D 2009, Defining and predicting Excessive Heat events, a National system, <www.cawcr.gov.au/events/modelling_workshops/.../NAIRN_1Dec.pdf>.

Nairn, J 2010, pers. comm.

National Health Service (NHS) 2009, Heat wave plan 2009, <http://www.climatesoutheast.org.uk/images/uploads/heatwave_plan_09.pdf>.

Nicholls, N, Skinner, C, Loughnan M.E. and Tapper N, 2008 A simple heat alert for Melbourne, Australia. Int J Biometeorol., 52(5): pp. 375–84.

Rakich, CS, Holbrook, NJ & Timbal, B 2008, 'A pressure gradient metric capturing planetary-scale influences on eastern Australian rainfall', Geophysical Research Letters, 35, L08713, pp. 1–6.

Risbey, JS, Pook, MJ, McIntosh, PC, Wheeler, MC & Hendon, HH 2009, 'On the remote drivers of rainfall variability in Australia', Mon.Weath. Rev., 137, pp. 3233–53.

Schar, C & Fischer E 2010, 'Extreme events in a changing climate", in <http://wcrp.ipsl.jussieu.fr/Workshops/RegionalClimate/Documents/3_5_Schaer.pdf>.

Sornette, D 2009, Dragon-kings, black swans and the prediction of crises, Swiss Finance Institute Research Paper Series No 09–36.

Steffen, W 2009, Climate change – Faster change and more serious risks ISBN 9781921298585

Tebaldi, C & Meehl, GA 2008, 'Beyond mean climate change: what climate models tell us about future climate extremes' in Diaz and Murname (eds), Climate Extremes and Society, CUP.

Trewin, B 2009, Australian daily temperature and rainfall extremes. ISBN 9780642706072.

Tryhorn, L & Risbey, J 2006, On the distribution of heat waves over the Australian region, Aust. Met. Mag. 55, pp. 169–182.

Van Rensch, P 2008, Hons. 'Heat Waves in Southern Australia: Synoptic Climatology and Large Scale Connections'.

Van Rensch, P, Pezza, AB & Cai, W 2009, A tracking climatology for heat waves in southern Australia. Joint publication of Bureau of Meteorology and CSIRO.

Wikipedia 2009, 'Early 2009 southeastern Australia heatwave', <en.wikipedia.org/.../Early_2009_southeastern_Australia_heat_wave>.

Williams, AAJ & Stone, RC, 2008, 'An assessment of relationships between the Australian sub-tropical ridge, rainfall variability and high latitude circulation patterns', Int. J. Climatol. DOI 10.1002/joc.1792.

WMO Meteoworld 2009, Southeast Australian heatwaves: the hottest in 100 years.

Section 3 Human health impacts of the 2009 heatwave

Adcock, M, Bines, W, et al. 2000, Heat-Related Illnesses, Deaths, and Risk Factors, Cincinnati and Dayton, Ohio 1999, and United States 1979–1997.

Basu, R, 2009, 'High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008', Environ Health, 16(8), p. 40.

Basu, R, & Samet JM, 2002, 'Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence', Epidemiologic Reviews 24(2), pp. 190–202.

Bouchama, A, Dehbi, M, et al. 2007, 'Prognostic Factors in Heat Wave Related Deaths: A Meta-analysis 10.1001/archinte.167.20.ira70009', Arch Intern Med, 167(20), pp. 2170–2176.

Cutter, Sl, Boruff, B, et al. 2003, 'Social Vulnerability to Environmental Hazards', Social Science Quarterly, 84(2) pp. 242–261.

Danks, DM, Webb DW, et al. 2004, 'Heat Illness in Infants and Young Children: a study of 47 cases', Wilderness and Environmental Medicine, 15, pp. 293–300.

Davis, RE, Knappenberger, PC, et al. 2003a, 'Changing heat-related mortality in the United States', Environmental Health Perspectives, 111(14), pp. 1712–1717.

Davis, RE, Knappenberger, PC, et al. 2003b, 'Climate Change Adaptations: Trends in Human Mortality Responses to Summer Heat in the United States', 15th Conference of Biometeorology and Aerobiology. 16th International Congress of Biometeorology.

Dermatte, J, O'Mara, MD, et al. 1998, 'Near-Fatal Heat Stroke during the 1995 Heat Wave in Chicago', Annuls of Internal Medicine 129(3), pp. 173–181.

Faunt, JD, Wilkinson, TJ, et al. 1995, 'The effete in the heat: heat-related hospital presentations during a ten day heat wave', Aust NZ J Med 25, pp. 117–125.

Golden, JS, Hartz, D, et al. 2008, 'A biometeorology study of climate and heat-related morbidity in Phoenix from 2001 to 2006', Int J Biometeorol 52, pp. 471–480.

Green, D 2006, 'Climate Change and Health: Impacts on Remote Indigenous Communities in Northern Australia', Climate Change Impacts and Risk, CSIRO Marine and Atmospheric Research Paper 012.

Green, D, King, U, et al. 2009, 'Disproportionate burdens: the multidimensional impacts of climate change on the health of Indigenous Australians' MJA, 190(1), pp. 4–5.

Hajat, S, Armstrong B, et al. 2006, 'Impact of high temperatures on Mortality. Is there an added heat wave effect?' Epidemiology 17, pp. 632–638.

Hansen, A, Bi, P, et al. 2008, 'The Effect of Heat Waves on Mental Health in a Temperate Australian City', EHP 116(10), pp. 1369–1375.

Hémon, D & Jougla, E 2003, 'Surmortalité liée à la canicule d'août 2003–Rapport d'étape. Estimation de la surmortalité et principales caractéristiques épidémiologiques, Paris', Institut national de la santé et de la recherche médicale, (INSERM).

<http://www.bom.gov.au/climate/current/statements/scs17d.pdf> 2009, 'Special Climate Statement 17 The exceptional January-February 2009 heatwave in south-eastern Australia', viewed 17 April 2010.

<http://www.cawcr.gov.au/events/modelling_workshops/workshop_2009/presentations/NAIRN_1Dec.pdf> 2009, 'Defining and predicting Excessive Heat events, a National system', viewed 5 May 2010.

<http://www.epa.gov/hiri/strategies/index.html> 2008, 'U.S. Environmental Protection Agency. Heat Island Effect. What can be done?' viewed 13 October 2008.

<http://www.health.vic.gov.au/chiefhealthofficer/downloads/heat_impact_rpt.pdf> 2009, 'January 2009 Heatwave in Victoria: an Assessment of Health Impacts' viewed 22 April 2010.

<http://health.vic.gov.au/environment/downloads/heatwave_plan_vic.pdf> 2010, 'Heatwave Plan for Victoria 2009–2010 Protecting health and reducing harm from heatwaves', viewed 22 April 2010.

<http://www.health.vic.gov.au/environment/heatwave> 2009, 'Heatwave Plan for Victoria 2009-2010 Protecting health and reducing harm from heatwaves', viewed 15 June.

Kalkstein, LS & Davis, RE 1989, 'Weather and Human Mortality: An Evaluation of Demographic and Interregional Responses in the United States', Annals of the Association of American Geographers 79(1), pp. 44–64

Kinney, PL, O'Neill, MS, et al. 2008, 'Approaches for estimating effects of climate change on heat-related deaths: challenges and opportunities', Environmental Science & Policy 11(1), pp. 87–96.

Kosatsky, T, King, N, et al. 2004, 'How Toronto and Montreal (Canada) respond to heat', 4th Ministerial Conference on Environment and Health, Budapest, Hungary.

Kovats, RS & Hajat, S 2008, 'Heat stress and public health: A critical review', Annual Review of Public Health 29, pp. 41–54.

Kwok, JS, & Chan, TY 2005, 'Recurrent Heat-Related Illnesses During Antipsychotic Treatment', Ann Pharmacotherapy 39(11), pp. 1940–1942.

Lam, LT 2007, 'The association between climatic factors and childhood illnesses presented to hospital emergency among young children', International Journal of Environmental Health Research 17(1): pp. 1–8.

Le Tertre, A, & Lefranc A, et al. 2006, 'Impact of the 2003 heatwave on all-cause mortality in 9 French cities', Epidemiology, 17(1), pp. 75–9.

Loughnan, M & Nicholls, N et al. 2008, 'Demographic, seasonal, and spatial differences in acute myocardial infarction admissions to hospital in Melbourne Australia', International Journal of Health Geographics, 7(1), p. 42.

Loughnan, M & Nicholls, N et al. 2010, 'The effects of summer temperature, age and socioeconomic circumstance on Acute Myocardial Infarction admissions in Melbourne, Australia', International Journal of Health Geographics, 9(1), p. 41.

Loughnan, ME & Nicholls, N et al. 2010, 'When the heat is on: Threshold temperatures for AMI admissions to hospital in Melbourne Australia', Applied Geography, 30(1), pp. 63-69.

Loughnan, ME & Nicholls, N et al. 2010, 'Mortality-temperature thresholds for ten major population centres in rural Victoria, Australia', Journal of Health and Place, 16(6), pp. 1287–1290

MMWR, City of Cincinnati, MS, Montgomery County, Ohio Dept of Health, 49, pp. 470–473.

Maantay, J, & Maroko, A 2009, 'Mapping urban risk: Flood hazards, race, & environmental justice in New York', Applied Geography, 29 (1), pp. 111–24.

Marzuk, PM, Tardiff, K et al. 1998, 'Ambient Temperature and Mortality from Unintentional Cocaine Overdose', JAMA 279(22), pp. 1795–1800.

McMichael, AJ, Woodruff, R et al. 2006, 'Climate Change and Human Health: present and future risks', Lancet 367, pp. 859–869.

Menne, B & Matthies, F 2009, 'Improving Public Health Responses to Extreme Weather - Heat waves Euroheat', Copenhagen, WHO.

Nicholls, N, Skinner, C et al. 2008 'A simple heat alert for Melbourne, Australia', Int J Biometeorol 52(5), pp. 375–84.

Nitschke, M, Tucker, G, et al. 2007, 'Morbidity and mortality during heatwaves in metropolitan Adelaide' Med J Aust., 187, pp. 662–5.

O'Neill, MS, Zanobetti, A, et al. 2003, 'Modifiers of the Temperature and Mortality Association in Seven US Cities', Am. J. Epidemiol, 157(12), pp. 1074–1082.

Schwartz, J 2005, 'Who is sensitive to Extremes of Temperature? A case-only Analysis', Epidemiology, 16(1), pp. 67–72.

Smoyer-Tomic, KE 1998, 'Putting Risk in its Place: methodological considerations for investigating extreme event health risk', Social Science Medicine, 47(11), pp. 1809–1824.

Smoyer-Tomic, KE, Kuhn, R, et al. 2003, 'Heat-wave Hazards: An overview of heat-waves impacts on Canada', Natural hazards, 28(2-3), pp. 465–486.

Vandentorren, S, Suzan, F, et al. 2004, 'Mortality in 13 French Cities During the August 2003 Heat Wave', Am J Public Health, 94(9), pp. 1518–1520.

Wright, N, Oldham, N, et al. 2005, 'Exploring the relationship between homelessness and risk factors for heroin-related death - a qualitative study', Drug and Alcohol Review, 24(3) pp. 245–251.

Section 4 The impact of the 2009 heatwave on critical infrastructure

Key background literature sources reviewed in this section fall into three broad categories.

1. Documentation targeting specific sectors. For example: *Port Futures: New Priorities and Directions for Victoria's Ports System* (Government of Victoria 2009a), *State of the Energy Market* (Australian Energy Regulator 2009), *Freight Futures: Victorian Freight Network Strategy* (Government of Victoria 2008a), *Victorian Transport Plan* (Government of Victoria 2008b), *Planning for Water Infrastructure in Victoria* (Government of Victoria 2008c), and *Our Water, Our Future – the next stage* (Government of Victoria 2008d).

2. Documentation on resilience issues across all infrastructure assets, though pre-dates the 2009 heatwave event. These include: *National Infrastructure Audit: Victoria* (Government of Victoria 2008e), *Responding with Resilience, City of Melbourne* (AECOM 2008), *Victoria's Infrastructure: Status and Prospects* (Government of Victoria 2007), *Impacts of Climate Change on Infrastructure in Australia and CGE Model Inputs for the Garnaut Climate Change Review* (Maunsell 2008), *Assessment of impacts of climate change on Australia's Physical Infrastructure* (ATSE 2008), and *Infrastructure and Climate Change Risk*

Assessment for Victoria (CSIRO 2007). Of these, the latter three examples place the greatest explicit emphasis on the risks associated with a changing climate.

3. Infrastructure reports published since the heatwave. Two major reports have been produced by the Commonwealth which provide good up-to-date data on the current state of urban infrastructure assets. However, neither the *Infrastructure Report Card 2010: Victoria* (Engineers Australia 2010) nor the *State of Australian Cities 2010* (Infrastructure Australia 2010) reflects on the lessons from the heatwave in any great detail.

AECOM 2008, Toward a City of Melbourne Climate Change Adaptation Strategy. A Risk Assessment and Action Plan Discussion Paper. Responding with Resilience, Maunsell AECOM, Melbourne.

AEMO 2010, Technical Guide to the Victorian Gas Wholesale Market, Australian Energy Market Operator (AEMO), Melbourne

Airservices Australia 2009, Movements at Australian airports, Aviation and Business Systems, Canberra.

ATSE 2008, Assessment of impacts of climate change on Australia’s physical infrastructure, Australian Academy of Technological Sciences and Engineering (ATSE), Parkville, Victoria.

Australian Energy Regulator 2009, State of the energy market, Australian Energy Regulator, Melbourne.

Betts, J, McKenzie, H & Sargant, T 2009, Inquiry into the factors leading to and causes of failure in the provision of metropolitan and V/Line train services, Select Committee on Train Services, Melbourne.

Croucamp, D 2009, Situation Reports (28–30 January 2009), Department of Transport.

CSIRO 2007, Infrastructure and climate change risk assessment for Victoria: Report to the Victorian Government, Commonwealth Scientific and Industrial Research Organization (CSIRO), Collingwood, Victoria and Australian Greenhouse Office, Parkes, ACT.

CSIRO 2008, Impact of climate change on infrastructure in Australia and CGE model inputs for the Garnaut climate change review, Commonwealth Scientific and Industrial Research Organization (CSIRO), Collingwood, Victoria.

Department of Premier and Cabinet 2009, Victorian climate change green paper, Victorian Government Department of Premier and Cabinet, Melbourne.

Department of Sustainability and Environment 2007, Our water, our future: the next stage in the government's plan, Victorian Government Department of Sustainability and Environment.

Department of Transport 2009a, ‘Climate change risks to infrastructure’, Transport Research and Policy Analysis Bulletin, issue 7, p. 2.

Department of Transport 2009b, ‘Annual metropolitan patronage’, Track record: Victorian Transport Services Quarterly Performance Bulletin, issue 40, pp. 16–17.

Department of Transport 2009c, The Department of Transport (DoT) response to the Rail Advisory Services (RAS) review of the resilience and performance of Victoria’s passenger rail system when operating under extreme weather conditions, Victorian Government Department of Transport, Melbourne.

Engineers Australia 2010, Infrastructure report card 2010: Victoria, Engineers Australia, Melbourne.

Frost & Sullivan 2006, Airport privatisation, viewed 3 June 2010, <http://www.marketresearch.com/redirect.asp?progid=1009&productid=1286859>.

Government of Victoria 2005, Broadband Framework: Pathway to the future, Department of Infrastructure, Melbourne

Government of Victoria 2007, Victoria's infrastructure: status and prospects, Final Report to the Council of Australian Governments, Melbourne.

Government of Victoria 2008a, Freight futures: Victorian freight network strategy, Department of Transport, Melbourne.

Government of Victoria 2008b, Victorian transport plan, Department of Transport, Melbourne.

Government of Victoria 2008c, Planning for water infrastructure in Victoria, Department of Sustainability and Environment, Melbourne.

Government of Victoria 2008d, Our water, our future – the next stage, Department of Sustainability and Environment, Melbourne.

Government of Victoria 2008e, National infrastructure audit: Victoria, Final Report to the Australian Governments Infrastructure Working Group & Infrastructure Australia, Melbourne.

Government of Victoria 2009a, Port futures: new priorities and directions for Victoria's ports system, Department of Transport, Melbourne.

Government of Victoria 2009b, January 2009 heatwave in Victoria: an assessment of health impacts, Department of Health, Melbourne.

Hagaman, BR 1990, 'The railways of Australia track buckle projects', Conference on Lateral Track Stability, Transportation Research Board, St Louis, USA.

Infrastructure Australia 2008, A report to the Council of Australian Governments, Infrastructure Australia, Canberra.

Infrastructure Australia 2010, State of Australian Cities 2010, Infrastructure Australia, Canberra.

Kerr, AD 1978, 'Thermal buckling of straight tracks: fundamentals, analyses and preventive measures', Bulletin of the American Railway Engineering Association, bulletin 669, vol. 80.

Kish, A & Samayedam, G 1990, 'Dynamic buckling of CWR tracks: theory, tests and safety concepts', Conference on Lateral Track Stability, Transportation Research Board, St Louis, USA.

Lezala, A, et al. 2009, Inquiry into the factors leading to and causes of failure in the provision of metropolitan and V/Line train services, Select Committee on Train Services, Melbourne.

Maunsell 2008, Impacts of Climate Change on Infrastructure in Australia and CGE model inputs for the Garnaut Climate Change Review, Maunsell Australia Pty Ltd, South Yarra, Victoria.

Mees, P 2009, Inquiry into the factors leading to and causes of failure in the provision of metropolitan and V/Line train services, Select Committee on Train Services, Melbourne.

Metcalfe, J, et al. 2009, Inquiry into the factors leading to and causes of failure in the provision of metropolitan and V/Line train services, Select Committee on Train Services, Melbourne.

Minister for Public Transport 2006, Government outlines vision for Port of Melbourne freight hub, Victorian Government media release, 14 August 2006.

National Climate Centre 2009, 'The exceptional January-February 2009 heatwave in south-eastern Australia', Special Climate Statement 17, Bureau of Meteorology, Melbourne.

NEMMCO 2009a, 'Actual lack of reserve (LOR3) in Victoria and South Australia regions on 29–30 January 2009', Power System Incident Report, National Electricity Market Management Company (NEMMCO) Limited, Melbourne.

Osborne, A & McKeown, C 2009, Inquiry into the factors leading to and causes of failure in the provision of metropolitan and V/Line train services, Select Committee on Train Services, Melbourne.

Pakula, M et al. 2009, Inquiry into the factors leading to and causes of failure in the provision of metropolitan and V/Line train services, Select Committee on Train Services, Melbourne.

Stevens, L 2008, Assessment of impacts of climate change on Australia's infrastructure, Australian Academy of Technological Sciences and Engineering (ATSE), Parkville, Victoria.

Stone, J 2008, Waning or just gone underground? Union power in public transport in Melbourne, Australian Academy of Technological Sciences and Engineering (ATSE), Parkville, Victoria.

Stone, J 2009, Submission to the Victorian Legislative Council Select Committee on Train Services, Australasian Centre for the Governance and Management of Urban Transport (GAMUT), Parkville, Victoria.

Wikipedia 2010, Connex Melbourne, viewed 3 June 2010, <http://en.wikipedia.org/wiki/Connex_Melbourne>.

Section 5 Emergency management response to the 2009 heatwave

DH 2008, Victorian Government, Department of Health, 'Environmental Health Unit Newsletter', December 2008.

DH 2009, Victorian Government, Department of Health, 'Heatwave Plan for Victoria 2009–2010: Protecting health and reducing harm from heatwaves', Melbourne, Victoria, December 2009, viewed May 2010, <http://www.health.vic.gov.au/environment/downloads/heatwave_plan_vic.pdf>.

DHS 2009, Victorian Government, Department of Human Services, 'Heatwave planning guide: development of heatwave plans in local council's in Victoria, July 2009', Environmental Health Unit, viewed May 2010, <https://www.health.vic.gov.au/environment/downloads/planning-guide.pdf>.

DSE 2006, Victorian Government, Department of Sustainability and Environment , 'Our Environment, Our Future – Sustainability Action Statement', July 2006, viewed May 2010, <http://www.dse.vic.gov.au/ourenvironment-ourfuture/documents/DSE%20ESAS%20(low%20res).pdf>.

Greater Shepparton City Council 2009, Greater Shepparton Heatwave Plan 2009, p. 55.

RDNS 2010, Royal District Nursing Service Working in Adverse Weather Conditions policy document, February 2010.

SA DH 2010a, South Australia Department of Health, Extreme Heat Action Plan, Internal document (unpublished).

SA DH 2010b, South Australian Government, Department of Health Extreme Heat Guide viewed May 2010, <http://www.health.sa.gov.au/Portals/0/ExtremeHeatGuide-PEH-100108.pdf>.

SA DH 2010c, South Australian Government, Department of Health Extreme Heat webpage viewed May 2010, <http://www.health.sa.gov.au/Default.aspx?tabid=679>.

SA Government 2004, 'South Australia Emergency Management Act 2004', viewed May 2010, <http://www.legislation.sa.gov.au/lz/c/a/emergency%20management%20act%202004/current/2004.30.un.pdf>.

SA Government 2010, 'Extreme Heat Guide for Local Government', viewed May 2010, <http://www.lga.sa.gov.au/webdata/resources/files/Extreme_Heat_Guide_for_Local_Government_-_Draft_for_Comment.pdf>.

SASES 2009, South Australian State Emergency Service 'Extreme Heat Arrangements Plan' – Annex A to the South Australian Extreme Weather Hazard Plan, November 2009.

VIC Government 1958, 'Metropolitan Fire Brigades Act 1958', Version No. 6315 of 1958, incorporating amendments as at 1 January 2010, viewed May 2010, <http://www.austlii.edu.au/au/legis/vic/consol_act/mfba1958258/>.

VIC Government 1986, 'Emergency Management Act 1986', viewed May 2010, Version No. 041, No. 30 of 1986. Version incorporating amendments as at 2 December 2009, viewed May 2010, <http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubLawToday.nsf/2184e627479f8392ca256da50082bf3e/4D2086EB3C0B411ECA25767F00196DED/$FILE/86-30a041.pdf>.

VIC Government 1997, 'Emergency Management Manual Victoria', Law Press for the Department of Justice, Brunswick, Victoria, viewed May 2010, <http://www.oesc.vic.gov.au/wps/wcm/connect/OESC/Home/Policy+and+Standards/OESC+-+Emergency+Management+Manual+Victoria+(PDF)>.

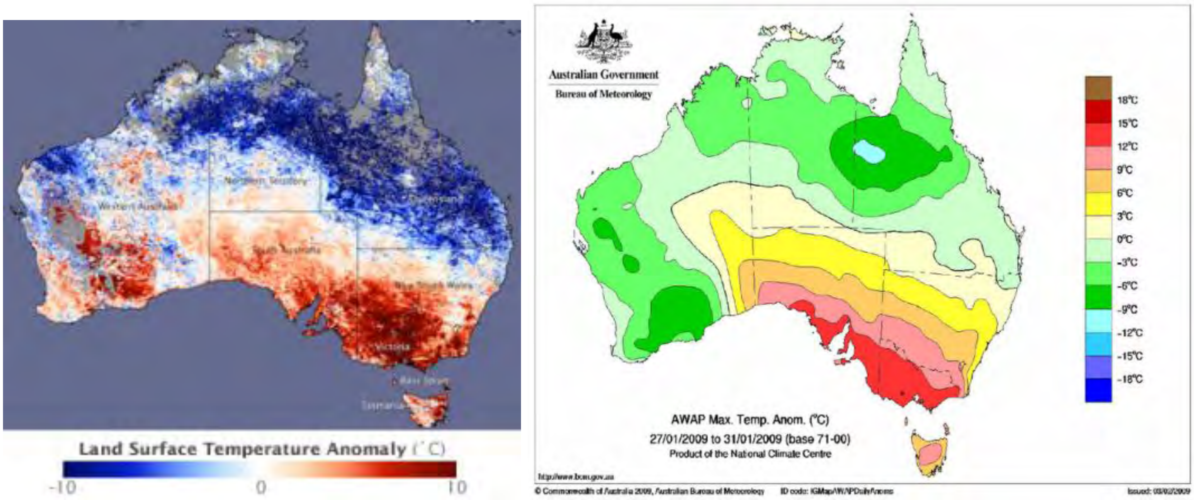
VIC Government 2009, (2nd ed), 'State health emergency response plan', Director Emergency Management, Department of Health, Ambulance Victoria, Melbourne, Victoria, viewed May 2010, <http://www.dhs.vic.gov.au/__data/assets/pdf_file/0005/400883/SHERP_2nd_edition_web.pdf>

Appendices

Appendix A Spatial and historical variability of extreme heatwaves

National distribution of surface temperature

Satellite images of the land surface temperature anomaly across Australia for the Phase 1 heatwave (Figure A2.1a) show significant increases over most of South Australia, Victoria and some parts of Tasmania. The Bureau of Meteorology observations of near-surface temperature throughout Australia have been compared to the historical records for that time of year to give the anomaly map shown in Figure A2.1b. Widespread very hot conditions began to develop in the southeast from 27 January onwards. The maximum temperatures during the last week of January 2009 were 12–15 °C above normal over much of Victoria and southern South Australia.



(a) **(b)**

Figure A2.1 Maximum land-surface (a) and air (b) temperature anomalies for the period 27–31 January 2009 (Bureau of Meteorology 2009)

For 30 January 2009 (Figure A2.2), the northern part of Tasmania was particularly affected, causing continuing and major problems with the temperature-deactivation of the Basslink transmission link.

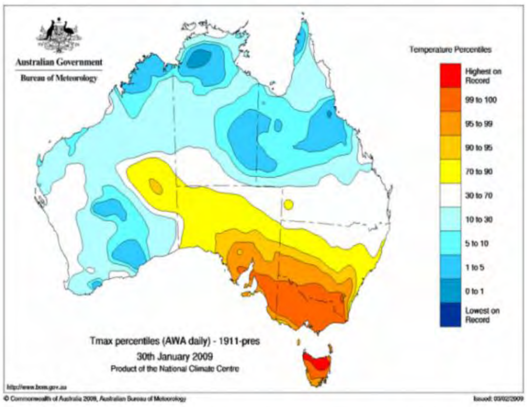


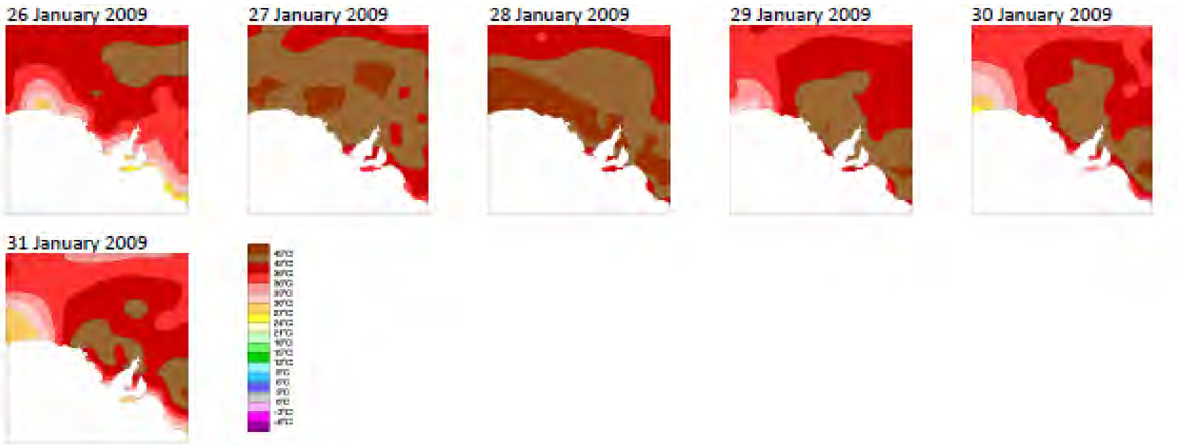
Figure 1. Australian temperature deciles for 30 January 2009, showing the large area in Tasmania which experienced its hottest day on record

Figure A2.2 Temperature deciles for 30 January 2009 (Bureau of Meteorology 2009)

State-wide and metropolitan temperature distributions

Detailed interpolations of near-surface temperatures (Bureau of Meteorology 2009) show that for the Phase 1 heatwave, maximum temperatures for most of the metropolitan regions were over 40 °C for Adelaide and 38 °C for Melbourne (dark red and brown areas in Figure A2.3). During this period, the metropolitan minimum temperatures were 18 °C for Melbourne and 24 °C for Adelaide. Figure A2.4a shows the excess heat factor (EHF) for the relevant Adelaide observations of temperature, with A2.4b showing the aggregated values from 7 January until 18 February 2009 for Australia. The high exposures in Victoria, South Australia and parts of Tasmania are quite pronounced.

(a)



(b)

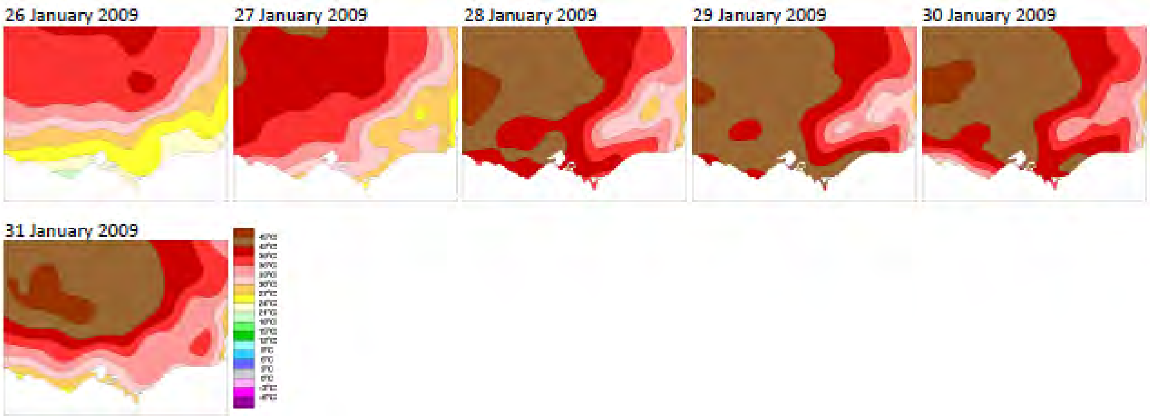
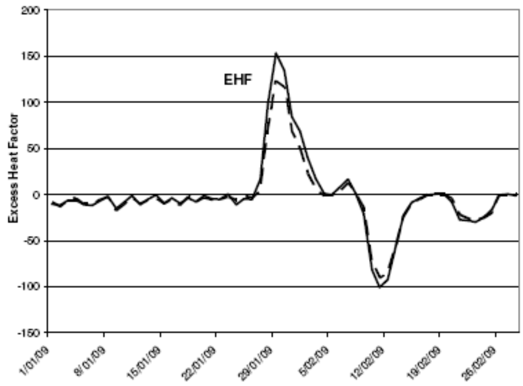
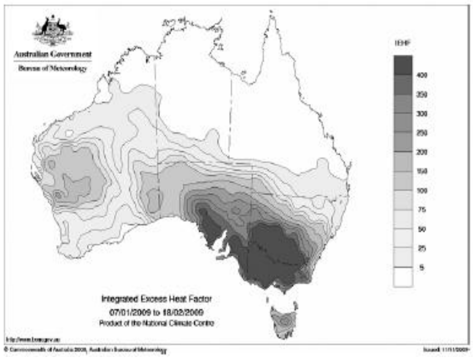


Figure A2.3 Interpolation maps of maximum temperatures for South Australia (a) and Victoria (b) regions, as given in Bureau of Meteorology monthly weather reviews



(a)

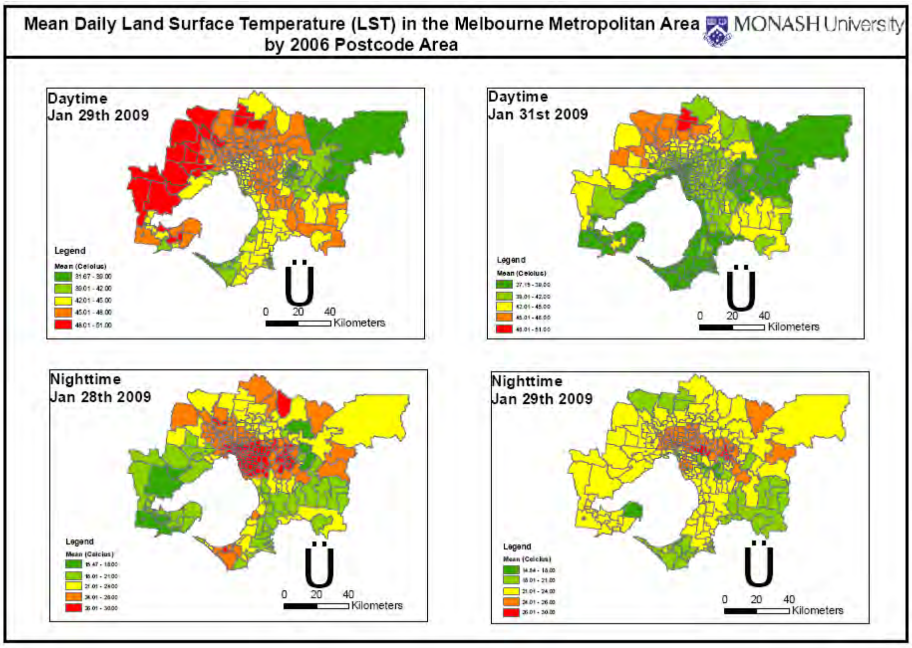


(b)

Figure A2.4 Variation of the excess heat factor for (a) Adelaide for January and February 2009 and (b) in time-integrated form for Australia for 7 Jan–18 Feb 2009 (Nairn 2009)

The spatial variations in surface land ('skin') temperature for the Melbourne and Adelaide metropolitan areas (from MODIS satellite observations as provided in high resolution by Monash University) show surprisingly high gradients, for both daytime and night-time overpasses (Figure A2.5). Investigations are proceeding to see whether these gradients (and the 'skin urban heat island') are reflected in near-surface air temperatures and actual population exposures. This is vital if population and equipment heat impacts are to be estimated from vulnerability and heat comfort mapping. The published schematic (Figure A2.6) shows the heat island for Melbourne during less extreme conditions at 1am on 23 March 2006. There was a spatial range of 3–4 °C, but it is not yet confirmed whether a heat island is as significant as this in extreme conditions.

(a)



(b)

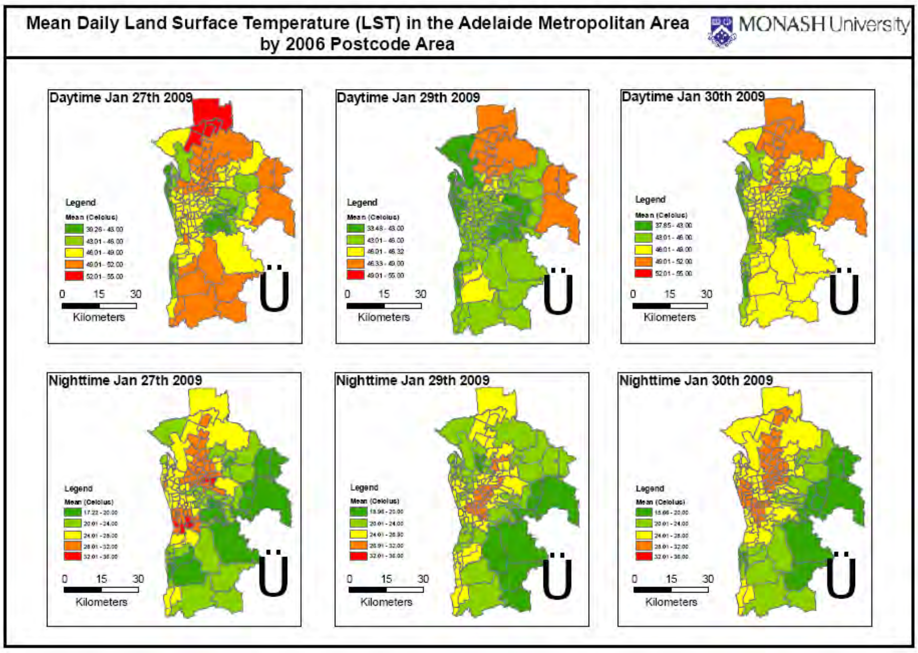


Figure A2.5 Mean daily land surface temperature for Melbourne (a) and Adelaide (b) for various days of the Phase 1 of the 2009 heatwave event, derived from MODIS satellite measurements (M. Loughnan & T. Phan Geography and Environmental Science Monash University).

On 7 February of the heatwave, daily maximum and night-time minimum temperatures at Laverton, only 30 km from inner Melbourne, were 1 °C higher than in the central business district, an inversion of the usual 'urban heat island' (UHI) effect and possibly due to the shielding from hot winds provided by tall buildings.

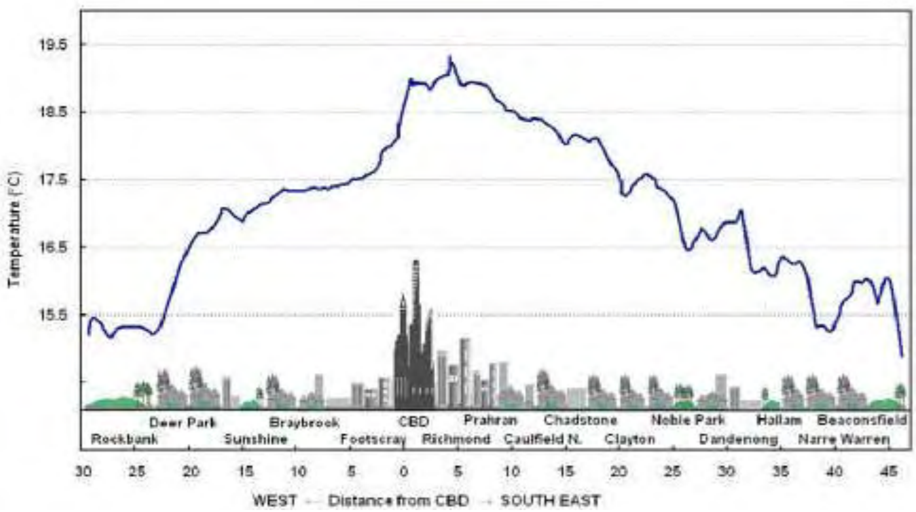


Figure A2.6 Depiction of urban heat island effects based on air temperature measurements made under more normal night-time conditions on 1 am, 23 March 2006 (Adapted from Coutts et al. 2008, 2010)

The behaviour of urban heat islands (UHI) during extreme heatwaves has recently been addressed for Oklahoma City during a 2008 heatwave with five consecutive days with 9 m air temperatures above 36 °C (Basara et al. 2010). A consistent UHI signal was found, with the urban core warmer than rural areas by 0.5 °C during the day and over 2 °C at night. When humidity conditions were included by using an apparent temperature, the urban core (suburban region) was 1–2 °C (0.5–1.5 °C) warmer than rural areas during the day and over 3 °C (2 °C) at night.

More work on Australian cities using similarly dense measurement networks would be required to recommend values of UHI for heatwave conditions, especially during the day (the night-time values of Figure A2.6 seem reasonable); the likely values may be the equivalent of the gains from a single adaptation measure.

Conditions within the built environment

For adaptation measures, it is important to go down one more level from suburban to street and building scale. Generic results from Monash University (Loughnan 2009) and specific estimates of cooling requirements for energy-efficient buildings in Australian cities for various climate scenarios (Wang et al. 2010) have shown the quite different thermal response of buildings, various designs and construction materials, and the influence of orientation and shielding. Specific applications of this research to the 2009 heatwaves and different housing stock would be very worthwhile.

Such detailed modelling for Phase 1 using the verified spatial maps of land surface temperature as a starting point would aid the estimation of actual human thermal comfort at typical locations in vulnerable areas.

Severe heatwaves of similar hue

There are several ways of investigating extreme weather events and providing some ‘historical’ context (Gershunov et al. 2010). Surface and upper-level observations typically extend 120 and 55 years respectively into the recent past. Proxy data such as from tree rings and other biological relics provide indirect vistas into the past centuries (Gergis et al. 2010). Heatwaves though present a challenge. Weather reconstructions (reanalysis) aim to overcome the sparseness of information over time and space for the observational period and may provide reasonable estimates of unobserved but important quantities such as heat fluxes. Global climate models (now with land-ocean and biosphere interactions being taken into account) can recreate general features of the past so that some confidence may be given to their indications of potential futures. The degree to which each of these methods can give information on extreme heat stress conditions and the resulting complex behaviour of adaptive systems has yet to be agreed upon, and is at the forefront of much interdisciplinary research. In the following, most reliance is given to observational results.

For comparison of the 2009 events with well-documented and spatially extended heatwaves, the events of 1939 and 1908 have been selected (Figure A2.7). The heatwave in January 1939 was notable for its longevity (8–14 January), extremely high temperatures (up to 47.8 °C in west Sydney on 14 January) and for affecting three states with maximum temperatures over 44 °C. On 9 January the temperature at Kyancutta reached 49.3 °C, the highest recorded in South Australia at that time. Adelaide's all time record of 46.1 °C was reached on the 12th; Melbourne’s maximum temperature reached 45.6 °C on the 13th (after 44.7 °C on the 10th); and Sydney’s (45.3 °C) on the 14th (with Manly reaching 47.2 °C and Richmond 47.8 °C).

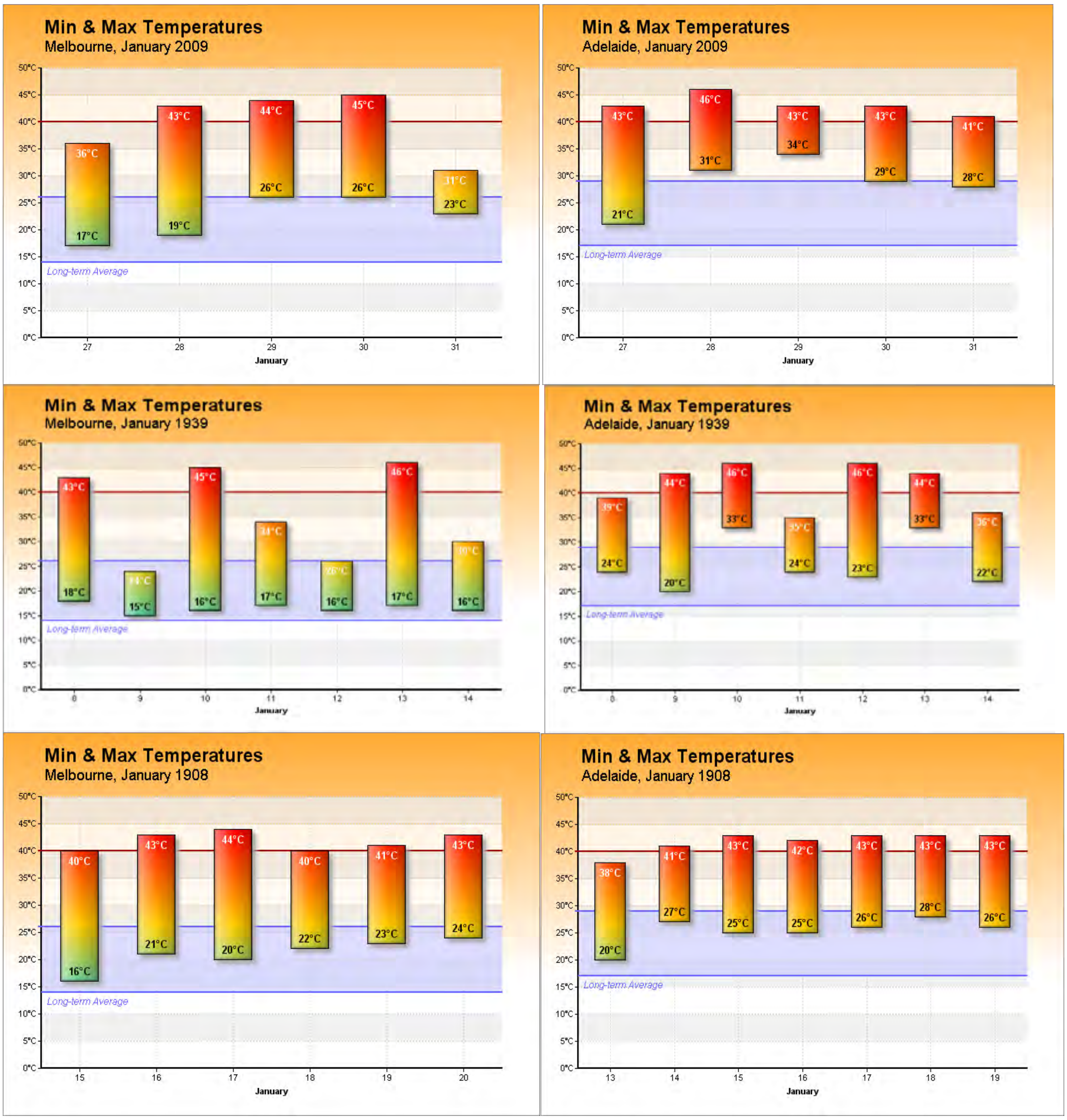


Figure A2.7 Minimum and maximum temperatures for Melbourne and Adelaide during the peak of 2009, 1939 and 1908 heatwaves (based on Bureau of Meteorology information).

For the 2009 event, the maximum temperatures widely reached their highest levels in southern South Australia, and, for much of central, southern and western Victoria, the highest since at least 1939. Melbourne and Adelaide both narrowly missed all-time records during this initial heatwave period. Melbourne’s 45.1 °C on 30 January 2009 was the second-highest on record behind the 45.6 °C recorded on 13 January 1939, while Adelaide’s 45.7 °C on the 28th ranks third behind two 1939 readings of 46.1 °C and 45.9 °C.

In addition to its peak intensity, the 2009 heatwave was also notable for its duration. The 1939 heatwave was similarly prolonged in many inland areas, but sea breezes and weak changes brought temporary relief to coastal areas — a feature absent in 2009 during the heatwave’s first week. In 1939, Melbourne had three days above 43 °C between 8–13 January, but these were interspersed with days in the 20s and low 30s, and there was no night in the period warmer than 18 °C. Adelaide experienced one day of slight relief (11 January) during this period. The maximum and integrated values of the EHF for Adelaide during the 1939 heatwave were very high compared to most in recorded history, but were exceeded by 60 to 100% during the 2009 event (Table 2.3).

The 1908 heatwave occurred between 12–26 January. In Melbourne it was more consistent than during the 1939 heatwave, for which weak, cool changes brought temporary relief. However, the heat inland in 1939 was more intense and longer lasting. In Mildura the temperature exceeded 37.8 °C on each of the first 14 days of January, and at the peak of the heatwave averaged 45.6 °C from 7–14 January. Unlike 1908, the hot spells in 1939 were accompanied by strong northerly winds, and followed a very dry six months.

These considerations and Table 2.3 suggest that the event most directly comparable with the 2009 heatwave was that of January 1908, which had lower peak temperatures but set records in both locations for consecutive days above 40 °C (and had similar very high values of integrated EHF).

Observational statistics and return period estimates

The first question usually asked of extreme weather events is how rare they are in that neighbourhood, based on observations. Answers such as a ‘once in N years’ for Melbourne and Adelaide events include:

- N = 50 for the considerations of the Phase 1 heatwave, as regards the reliability of power supply (AEMO 2009)
- N = 3000 for the Adelaide heatwave of March 2008 (Love & Jarraud 2010) where there was a run of 15 days over 35 °C, N = 40 for the runs of 9 such days and the 14 days with over 30 °C maxima in Phase 1 of the 2009 event
- N = 1000 as cited in the media for the record day of 7 February.

These estimates assume stationarity in climate and urban structure and do not take account of the drivers of extreme events or the sensitivity of the estimated probabilities to the chosen heatwave threshold and attribute. Heatwaves as complex extremes depend on a set and sequencing of conditions, making the estimation of likelihood less straightforward. The far tail of a temperature-type distribution is much ‘heavier’ or ‘fatter’ than a normal (Gaussian) probability distribution, but can often be quite well represented by a sum of normal distributions.

The location and spreads of the component distributions may be parameterised by the values of the pertaining climate mode (e.g. the ENSO or SAM indices as is used in seasonal forecasting by several groups) or by the characteristics of the pertaining high pressure system (Grace et al. 2009). The latter work shows considerable success in describing heatwaves in Victoria and South Australia. The tail of the probability distribution of the number of days in the heat spell is a power law (i.e. going from 9 to 15 day runs should decrease the probability by $(9/15)^M$). The parameters of the distribution (such as M that describes some memory and intermittency) have a realistic spatial variation with altitude and distance from the coast, typically M~0.3. Such work has been used in viticulture applications (Webb et al. 2009) to date; similar semi-empirical approaches may be useful for other heatwave dependencies.

Variability, drivers and trends in heatwave characteristics

With 120 years of observations of near-surface temperatures, there may be sufficient information to look for ENSO and SAM influences and trends in heatwave characteristics to illustrate the role of natural variability and determine which measures are showing signs of climate change. There have been various studies of the climatology of heatwaves for Southern Australia (Van Rensch 2008, Deo et al. 2007, Nairn et al. 2009).

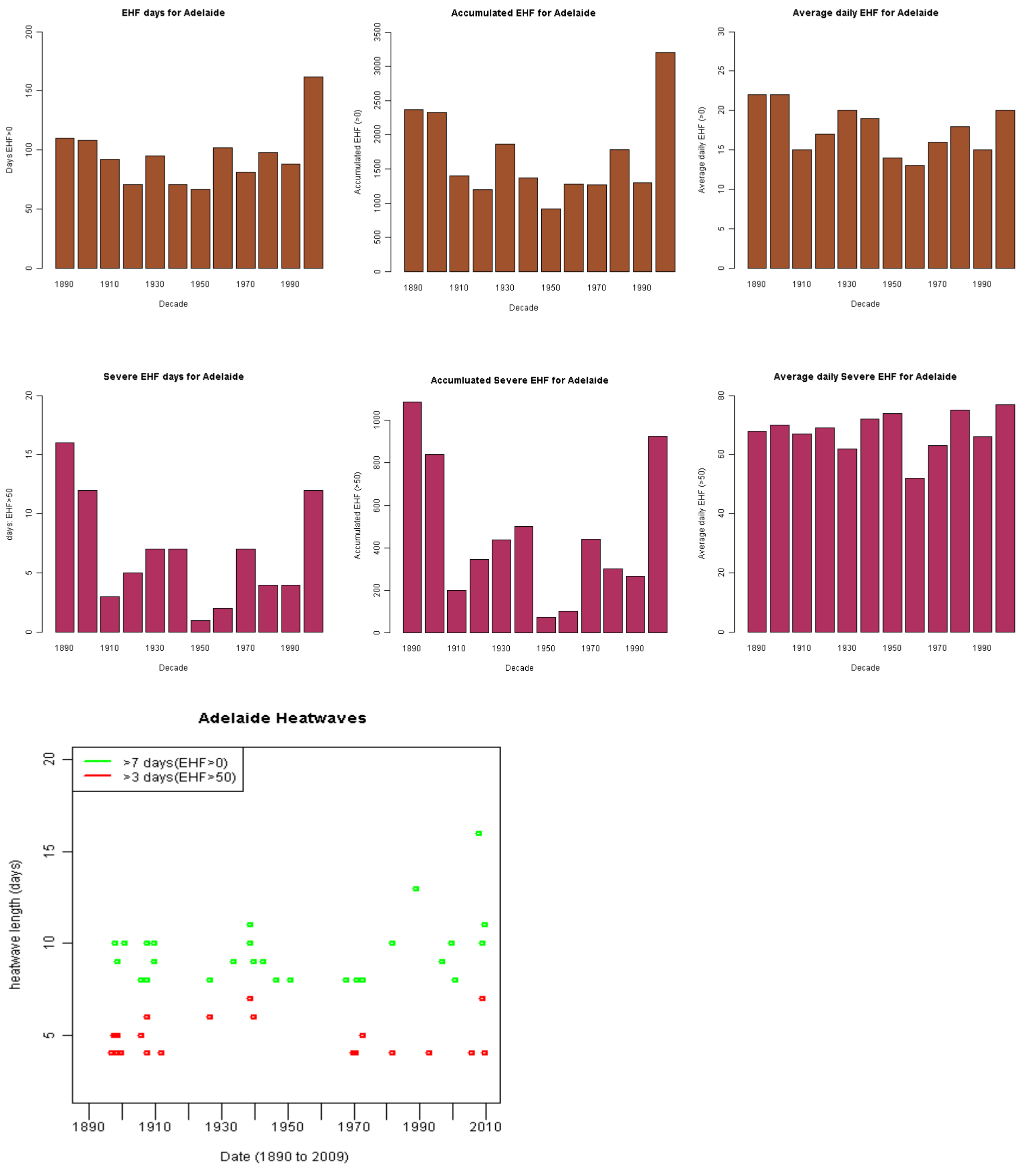


Figure A2.8 Extended Adelaide heatwaves as defined by the EHF index are becoming more frequent apart from two outlier events in more recent decades. Trends in extreme heatwaves are less evident (Nairn in preparation).

The EHF factor has been used with Adelaide City observations of temperature to produce some summary measures of severity and duration by year and decade (Nairn 2010). Integrated positive EHF varies considerably by year and decade. There were many events of note in the 1890–1900s, 1940s and in the first decade of the 21st century (Figure A2.8). Similar considerations show that the long-duration events (e.g. EHF events lasting more than 8 days) have become more frequent in the last 20 years (Nairn in preparation).

Trend analysis of Australian heatwaves during the period 1950–2005 (Deo et al. 2007) has used the worst three-day moving averages of apparent temperature as a heatwave index. There are significant increases (typically 1–2 °C per decade) for most South Australian sites and most Victorian sites (although the relationships for the two Melbourne sites are not as statistically significant).

There is considerable interest in identifying the climate drivers for extreme heatwaves, as any associations may be useful in warning systems (especially seasonal). The primary driver of rainfall and temperature in much of Australia is ENSO. An index for extended hot spells (defined by Trewin 2009 by the highest temperature 'T' in a year, such that there are at least five consecutive days with a temperature equal or greater than T) shows a significant negative correlation with annual-average Nino 3.4 index. For many near-coastal stations in southern Australia, including Adelaide and Melbourne, extended heatwaves are essentially unknown in El Niño years when the greater mobility of synoptic systems may make five days of northerly winds very unlikely.

The interplay between the influences from different oceans and the blocking of circulations has been investigated for rainfall (and heatwaves to a lesser extent) by correlation studies using ENSO, the Indian Ocean dipole index, the Southern Annular Mode index and various blocking indices. The identity and strength of the dominant driver vary with season and location, with southern Australia experiencing influences from all four main drivers (Risbey et al. 2009).

References

AEMO 2009, Victorian Annual Energy Planning Report: Public Forum, July 2009.

Basara, JB, Basara, HG, Illston, BG & Crawford, KC 2010, 'The impact of the urban heat island during an intense heat wave in Oklahoma City', Advances in Meteorology, DOI: 10.1155/2010/230365.

Bureau of Meteorology (BoM) 2009, Special Climate Statement 17 'The exceptional January-February 2009 heatwave in south-eastern Australia', <http://www.bom.gov.au/climate/current/statements/scs17c.pdf>.

Coutts, AM, Beringer, J & Tapper, NJ 2008, 'Investigating the climatic impact of urban planning strategies through the use of regional climate modelling: a case study for Melbourne, Australia'. Int. J. Climatol, 28, pp. 1943–1957.

Coutts, A, Beringer, J & Tapper N 2010, 'Changing Urban Climate and CO_2 Emissions: Implications for the Development of Policies for Sustainable Cities', Urban Policy and Research 28 (1), pp. 27–47.

Deo, RC, McAlpine, CA, Syktus, J, McGowan, HA & Phinn, S 2007, 'On Australian heatwaves: Time series analysis of extreme temperature events in Australia, 1950–2005'.

Gergis, J, Karoly, DJ, Gallant, A, & Braganza, K 2010, 'Reconstructing pre-20th century temperature, rainfall and pressure for the Australian region using palaeo', documentary and early instrumental data, *Australian Meteorological and Oceanographic Society's 17 Annual Meeting*, Australian National University, Canberra, UK, 27–29 January 2010.

Gershunov, A, Cayan, DR & Iacobellis, SF 2010, The Great 2006 heat wave over California and Nevada: Signal of an increasing trend, *J Climate* in press.

Grace, WJ, Sadras, VO & Hayman, PT 2009, 'Modelling heatwaves in viticultural regions of southeastern Australia'. *Australian Meteorological and Oceanographic Journal*, pp. 249–262.

Loughnan, M 2009, *The importance of "Place"*, Victorian Climate Change Adaptation Program, Monash University presentation.

Love, G & Jarraud, M 2010, 'Forecasting and communicating the risk of extreme weather events', in H Kunreuther and M Useem (eds), *Learning from catastrophes – strategies for reaction and response,* Wharton School Publishing.

Nairn, J 2009, *Defining and predicting Excessive Heat events, a National system,* <www.health.vic.gov.au/environment/downloads/pres_john_nairn.pdf>.

Nairn, J, Fawcett, R & Ray, D 2009, *Defining and predicting Excessive Heat events, a National system*, <www.cawcr.gov.au/events/modelling_workshops/.../NAIRN_1Dec.pdf>.

Nairn, J 2010, pers. comm.

Nairn in preparation

Risbey, JS, Pook, MJ, McIntosh, PC, Wheeler, MC & Hendon, HH 2009, 'On the remote drivers of rainfall variability in Australia', Mon.Weath. Rev., 137, pp. 3233–53.

Trewin, B 2009, *A new index for monitoring changes in heatwaves and extended cold spells*.

Van Rensch, P 2008, Hons. 'Heat Waves in Southern Australia: Synoptic Climatology and Large Scale Connections'.

Wang, X, Chen, D, & Ren, Z 2010, 'Assessment of climate change impact on residential building heating and cooling energy requirement in Australia', *Building and Environment* 45 pp. 1663–1682.

Webb, L, Watt, A, Hill, T, Whiting, J, Wigg, F, Dunn, G, Needs, S, & Barlow, EWR 2009, *Extreme heat: Managing grapevine response. Documenting regional and inter–regional variation of viticultural impact and management input relating to the 2009 heatwave in SE Australia*, report to Grape and Wine Research Development Corporation, <www.landfood.unimelb.edu.au/vitum/Heatwave.pdf>.

Appendix B.1 Media analysis of the 2009 event, focussing on health and infrastructure

Submitted by Katharine Haynes, Deanne Bird, Lucinda Coates and Megan Ling Risk Frontiers, Macquarie University

Media analysis of the 2009 event, focussing on health and infrastructure

Introduction

A media analysis of the 2009 heatwave event was undertaken in order to detail impacts and response with respect to health and infrastructure. In view of the time constraints this was limited to the major print media. The search used the Factiva database and covered all articles mentioning heatwave and related terms from 26 January to 11 February 2009, in order to properly cover the two heatwave events of 27-31 January and 6-8 February 2009.

Sources

The primary newspapers for each state and territory of Australia were searched: of those, seven titles held reports pertinent to the heatwave events in Victoria and South Australia. The majority of information was contained in *The Advertiser* (Adelaide, SA), followed by *The Age* (Melbourne, Victoria), and *The Australian* (the national newspaper). As expected, both *The Advertiser* and *The Age* held reports primarily concerning their own state while *The* Australian took a broader view. Interestingly, a small number of reports containing information not found in these major newspapers were found in *The Courier-Mail* (Brisbane, Qld), *The Sydney Morning Herald* (NSW), *The Hobart Mercury* (Tasmania) and the *Canberra Times* (ACT).

Method

A list of information from all relevant newspaper reports is included at the end of Appendix B.1. Data are given for Victoria and South Australia under the headings Infrastructure – Power, Infrastructure – Water, Transport, Human health, Other impacts and General facts. The headings are, in the main part, self explanatory, but Other impacts includes such data as behavioural response, impact on structures and impact on agriculture. The General facts heading captures most reports on the severity of the event – for example, a one in 100-year event, or any records set, keeping in mind the fact that the focus of this report was on any impacts to human health and infrastructure. The reference for each newspaper article used in this analysis is tied to each fact listed in the analysis. A brief section on metadata estimates the relative amounts of reporting done on the various impacts using line counts from the media analysis.

Metadata

The main focus of reports of heatwave impacts in Victoria by the major newspapers (mainly *The Age*) was on infrastructure: namely, power supply. In addition, *The Australian* wrote a large piece on responses (by government and the public) to the load-shedding in both Victoria and South Australia but focused on Victoria. Including this piece under the Victorian heading gives the result of about one and a half times the amount of reporting on power for Victoria as opposed to South Australia; ignoring the piece means the amount of reporting on power was about equal in both states. There were only a few lines of reporting on water infrastructure for both states (as opposed to a page or more on power infrastructure).

There was approximately the same amount of reporting on transport in both states: it represented the second most reported impact in Victoria and the third in South Australia. The main focus of reports of heatwave impacts in South Australia (mainly by *The Advertiser*) was on human health aspects, followed by power supply. There were hardly any references to human health impacts in Victoria and of these, not one was from Melbourne's paper, *The Age*. In fact, there was about six times the amount of reporting on health for South Australia as for Victoria.

Also interesting was the fact that there was no delineation in the major newspapers between the two heatwave events. There was also a dearth of reports after the second, 6-8 February event, whereas the first, 27-31 January event, was reported quite well. Daily updates of figures were given from 27 or 28 January (depending upon the category of impact) but, after 30 January or soon thereafter, any figures given were accumulated tallies from day one of the first heatwave event or generalised summaries. A good example of this is the South Australian health statistics, where fairly good updates were given from 27 January to 2 February but, after that, any new information was in the form of total numbers of sudden deaths since the onset of the heatwave (for example), as opposed to the daily number of sudden deaths.

Victoria

Infrastructure – Power

January

- 28th – United Energy Distribution had to deal with near-record demand. Up to 5000 customers lost power, including in the Rosebud-Frankston area and Braeside. 1200 homes and businesses lost power in South Melbourne in the afternoon. Power was cut to 943 Powercor customers in Hamilton at ~9:10 am and 172 homes in Sunshine and 77 in Kyneton were without power. Demand had risen sharply: the National Electricity Market Management Company, NEMMCO (the nation's power wholesaler), said Victoria's electricity usage record was likely to be broken 29th or 30th, but that there were "more than sufficient" reserves in place to meet it [Jackson, A 2009]

- 29th – electricity supplies cut to >80 000 of homes. NEMMCO announced at 3:30 pm it had started load-shedding (cutting power to homes) because the heat was pushing up electricity demands in Victoria (10 949 MW: smashing the previous highest level of 9818 MW) and SA and following the tripping (failure due to heat) of the Basslink interconnector (the electricity connector supplying power from Tasmania to Victoria). Distributor Jemena, which supplies power to homes in Melbourne's inner west, north and the south-east, cut supply to 42 000 homes for an hour, in addition to 10 000 homes that were already without power because of problems with the network. Supplier SP AusNet was instructed to cut power to 22 000 customers around Eltham, Pakenham, Ferntree Gully, Clyde North, Warragul, Lang Lang and Boronia for ~1 hour. The collapse in the system followed assurances earlier in the week by the Premier and the NEMMCO spokesperson that Victoria had sufficient reserve power to cope with the anticipated surge in demand [Dowling J & Rood D 2009]

- 30th – a massive power outage ~6:30 pm affected at least 235 000 of CitiPower's customers when the system shed 1000 MW of power [La Canna X 2009]

- 30th – massive faults cut two high-voltage (500 kW) transmission lines that service Melbourne's west, near South Morang: power was cut to areas from Southbank to as far west as Geelong from ~6:25 pm. Almost 350 000 households and buildings were still without electricity at 8:30 pm after NEMMCO instructed distributors Powercor and Citipower to cut 1000 MW of power from the market: traffic lights, train lines (signals on the rail network) and elevators were stilled in the city and western suburbs. Some city buildings were evacuated, with firemen called in to rescue office workers trapped in stalled lifts. NEMMCO said the fault happened somewhere between Morang and Sydenham, causing Victoria to lose nearly 10% of its total power supply. Citipower said hospitals and transport were its priority: it had redirected its remaining power to supply them. Also contributing to the problem was the Basslink cable, which was shut down at 1:40 pm due to 'system supply issues'. Basslink chief executive Malcolm Eccles said the interconnector did not trip or fail but had worked according to its present parameters. NEMMCO directed power be cut to Jemena, United Energy Distribution and SP Ausnet customers for one-hour rotations from 3:15 pm, resulting in further power cuts for >47 000 houses. Demand for electricity on 30th was similar to that of 29th, which reached 10 400 MW [Dobbin M et al, 2009]. City buildings were evacuated; fire officers were called to rescue workers trapped in lifts; traffic lights stopped [Lucas C 2009]

- 30th – heat forced Basslink to shut down its underwater power cable, leaving Hydro Tasmania unable to sell power interstate, contributing to hundreds of thousands of homes in Victoria and SA being left without power as usage soared in the heat. Additionally, a transmission cable failed ~6:45 pm, prompting NEMMCO to order an immediate load shed, cutting power to ~300 000 homes and businesses in greater Melbourne. Dozens of city workers were trapped in lifts, while 200 sets of traffic lights were off. Basslink CE Malcolm Eccles said that in the past two days, temperatures at George Town exceeded the tolerance of Basslink's converter station, designed to operate at full capacity up to 33 °C. In hotter conditions transmissions had to be reduced and at 35 °C stopped to prevent damage to equipment. On 29th Basslink was slowed for 3.5 hours and stopped for 52 minutes; the stoppage on 30th lasted 74 minutes [Mounster B 2009]

- 28th-31st – business estimated the blackouts – culminating in loss of power to hundreds of thousands of businesses and homes during the night of 30th – left a damage bill of $100 million with employers forced to close and commuter chaos on the rail services. Andrew Blyth, CE of Energy Network Association, said energy ministers needed to order an independent review of a recent decision to reduce investment incentives by >$350 M, making it more difficult for ageing infrastructure to be replaced by new, smarter energy networks [Hannan E & Akerman P 2009]

- 28th-31st – government was slammed over the previous week's $100 million blackouts (in Vic & SA) over: 1) claims government departments could have foregone 100 MW; 2) authorities charged with running the national energy market decided in 2008 not to institute a back-up system that could have provided an extra 300 MW of power; 3) the fact that companies willing to forgo enough power to ease or prevent the previous week's blackouts (in Vic & SA) were blocked by bureaucracy and government inaction. The blackouts in Victoria occurred when supply fell 430 MW short of demand (a record of 10 494 MW on 29th) due to the failure of the cable between Victoria and Tasmania on 29th and the failure of a major connector in Melbourne's west on 30th [Wallace R 2009].

February

- ~3rd – Premier John Brumby said Victoria's infrastructure might need to be examined to ensure it was able to cope with the prospect of more extreme weather, but making the power system fail-safe would cost "huge amounts of money for something that occurs just one day in 100 years". NEMMCO had advised him that electricity supply was greater than demand last week and that disruptions, that may have cost business $100 M, were caused by two "catastrophic incidents": the failure of the $780 million Basslink interconnector cable linking Vic and Tas, which is unable to operate when temperatures in Tasmania pass 35 °C, and a fire that cut two high-voltage lines. Questions have once more been raised about the adequacy of the nation's electricity system – Energy Networks Association CE Andrew Blyth told a Senate hearing this week that $50 B of new investment was needed to upgrade 1950s infrastructure with technology "better able to cope with the demands of Australia's trillion-dollar digital economy" and to support the shift to new energy sources. Energy Users Associate executive director Roman Domanski says the answer is better management of a system that is "wilfully" constrained by regulatory "nonsense" that shuts available energy out of the grid, and that there is a clear failing in the system's ability to draw power from where it is in surplus and deliver it to where it is needed – e.g. last week, power crashed despite the availability of 2000 MW of spare capacity in NSW. Domanski also estimates demand-side voluntary shedding during periods of high prices and demand could deliver 1000–2000 MW of load reduction. Australian Institute (Canberra) executive director Richard Denniss says there is "a crisis of investment in infrastructure": population growth is placing heavy strains on it but the electricity industry is also bedevilled by internal contradictions that arose when the industry was deregulated in the 1990s: 'We separated out the generators, the distributors and the retailers, the people who own the power stations, the people who own the wires and the people who have contact with customers. The people that own the wires have got no incentive to stimulate investment in energy efficiency.' In October 2008, NEMMCO identified a 168 MW "reserve deficit" for Victoria and SA over summer but, based on "additional studies" of likely unserved energy, decided that the national electricity market had sufficient capacity to deliver reliable supply: as a result it decided not to run a reserve trader scheme, enabling firms to shed power. Energy Response chairman Ross Fraser (a private company that contracts for demand-side reduction) says that decision – and government inaction more broadly – prevented companies forgoing power that would have eased or prevented the blackouts: "The current rules say only generators can proved reserve capacity – that is ignoring >1000 MW of capacity in Victoria that could be contracted back into the system." [Rintoul S & Akerman P 2009].

Infrastructure – Water

- Melbourne Water figures showed water consumption soared, with Melbournians using an average of 207 litres/day: well above the government's target of 155 [Mounster B 2009].

Transport

January

- week prior to 28th-31st (heat peaked at 40 °C on 20th) – Connex (Melbourne's rail operator) cancelled 319 train services, including scores during peak hour [Lucas, C 2009a]

- 27th – by 5 pm there had been 31 train cancellations: nearly half of which had occurred by 8:30 am (when the mercury was still low) [ie basic problems in the rail network] [Anon 2009a]

- 28th – rails buckled and a record number of trains broke down in 43 °C heat: Connex cancelled >8% of the day’s trains. By 8 pm, at least 150 of the day’s 2000 suburban rail services had been cancelled. Cause: scores of trains breaking down due to faulty air-conditioning and heat-related faults. Worst hit: Hurstbridge and Epping lines. Tracks between Jolimont and Flinders Street Station buckled mid-afternoon. Rails on the Glen Waverley line, at Holmesglen Station, also buckled. A broken down tram on St Kilda Road delayed travellers on a dozen routes [Lucas, C 2009b]. The train tracks near Jolimont twisted in the heat [Johnston C & Battersby L 2009]

- 29th – 243 train services were cancelled. There were a string of complaints about train drivers, broken air-conditioning and buckled tram and train lines [Williams, B 2009]

- 30th – a massive power outage at ~6:30 pm plunged the train system into chaos: hundreds of services were cancelled and four suburban train lines were suspended in the night [Edwards V & Hannan E 2009]. Connex cancelled >25% of all services, with at least 500 of the day’s 2000 scheduled services not running. Many lines – and, at one point, the City Loop – were shut down mid-afternoon because of train breakdowns, lines buckling in the blistering heat, or power blackouts. Buses were not provided in some cases, leaving people stranded. At least 1300 train services had been cancelled in the past week [Lucas C 2009c]. Tracks on Melbourne’s suburban railway lines were buckling in the heat; train services were cancelled due to air-conditioning failures; passengers were sweltering on the many trams that have no air-conditioning: Public Transport Minister Lynne Kosky admitted that the rail network, in particular, had suffered from underinvestment over several decades [Anon 2009b]. All Melbourne train services were cancelled (?) [Wotherspoon S & Roberts G 2009]

- 28th-31st – the rail meltdown that occurred in Melbourne the previous week did not occur in Adelaide, despite it having similar trains (smaller Comengs built by the same manufacturer shortly after Melbourne’s trains were built) and experiencing an even worse heatwave. Over 28-30 January, Adelaide cancelled 7% of train services. In Melbourne, 24% of trains were cancelled: the aged Comeng trains (first in service 1982) had terrible problems with air-conditioning systems failing: hundreds of services did not run due to that. In Adelaide, near-identical trains (but powered by diesel) and no air-conditioning problems. Victorian Department of Transport spokesperson Chris Veraa would only say the mass cancellations occurred due to “air-conditioning faults, bucked rail and power supply affecting signals and points”. The train operator Connex said broken air-conditioning was a key factor in the high cancellation rates, which peaked on 30th with 730 out of 2012 scheduled services not running. In all, 1447 of 5966 scheduled services did not run in those 3 days in Melbourne. Adelaide’s train system is far smaller than Melbourne’s, with ~13 million trips made each year: Melbourne’s has >200 million. And Adelaide has only 5 lines compared to Melbourne’s 15. Melbourne’s tracks last week had ~40 buckles; Adelaide’s tracks also buckled badly, in one case far more seriously than any in Melbourne [Wahlquist A 2009]. [NB this paragraph is also included under South Australia.]

Human health

January

- 28th – 75-year-old man collapsed while walking 500m to his car; 24-year-old waiting for a tram also treated by ambulance service; paramedics called to ten cases of heat exposure between 3-4 pm [Jackson, A 2009]
- 29th – Ambulance Victoria was flat out, with 75 heat-related calls between 9 am and 5 pm [Jackson A & Ker P 2009]
- 30th – demand for emergency service leapt 50%. An Ambulance Victoria spokesperson said 50 new paramedics graduates had been called on to the job to help out. The service attended 105 heat-related cases in Melbourne between midnight 29th and 6 pm 30th [Dobbin M et al,2009]. 60 patients needed ambulances in a 16-hour period after suffering the effects of heat exposure [Mounster B 2009]
- ~30/31st – Victoria Police said the heatwave was believed to have caused the death of six people [Hannan E & Akerman P 2009]
- Parents advised to cancel their children's sporting events and nursing home staff stocked up on small generators, fans, oxygen cylinders and ice °C[Jensen E et al, 2009].
- Overall – "…the extreme heatwave, whose death toll when tallied will probably be in the hundreds and exceed that of the fires…" [Hamilton C et al, 2009]. [NB this paragraph is also included under South Australia.]
- Record temperatures resulted in Melbourne's morgue reaching capacity well before the deadly fires began on the weekend [7-8th February] [Smith B & Perkins M 2009].

Other impacts

January

- 29th – Streets were deserted as people took refuge indoors. The air-conditioning at the DFO outlet in Spencer Street failed, forcing many shops to shut and send staff home. Victorians are buying cinema tickets, fans, air-conditioners, icy-poles and watermelons; also bottled water, soft drinks and salads. Sales of swimwear also rose [Miletic D 2009]
- 30th – thousands of Melbournians continued to flood beaches, cinemas and shopping centres [Dobbin M et al 2009]. Lifesavers for the first time extended their safety patrols to weeknights to watch over thousands of people trying to cool down after work [Johnston C & Battersby L 2009; Mounster B 2009]. Air-conditioned rooms all over town were snapped up [Johnston C & Battersby L 2009]
- 30th – parts of the 40-storey $100 million Southern Star Observation Wheel cracked and buckled in the heat and safety concerns forced operators to close it, just 6 weeks after opening. It is not known when the tourist attraction will reopen. The heat caused a buckling of the bracing members toward the centre of the wheel, which caused cracks in the structure [Wallace R 2009]
- 28-31st – a record ten consecutive days of temperatures > 40 °C have left wine grape growers in Mildura facing huge financial losses, with much of the region's crop destroyed by heat, which could not have come at a worse time (with forecasts of 41 °C today and 46 °C for 7 February), as the growers are currently harvesting their grapes. Murray Valley Winegrowers chief executive Mike Stone estimated the crop would be reduced by 15-20% and said others thought the weather of 7 February could put the loss as high as 30%. He noted the Murray Valley is the second-biggest wine region in Australia [Wahlquist A 2009].

General facts

January

- 29th – 3rd hottest day on record in Melbourne, following the 3rd hottest overnight minimum. A one-in-100-year event. Melbourne last suffered through a severe heatwave in 1959, with three consecutive days of temperatures in the 40 °C s [Jackson A & Ker P 2009]. The hottest recorded temperature in Victoria was 45.8 °C at Avalon airport, near Geelong, at 5 pm on January [Johnston C & Battersby L 2009]
- 30th – the temperature reached 45.1 °C in Melbourne in the afternoon: the first time temperatures had gone over 43 °C for three consecutive days since records began in 1855 (43.4 °C, 44.3 °C, 45.1 °C) [Dobbin M et al 2009]
- 28-31st - The heatwave has not been matched since 1939 [Wahlquist A 2009].

South Australia

Infrastructure – Power

January

- 27th – a spate of power blackouts affected ~10 000 customers. ~15 power outages, including a blackout of almost 2000 homes in Alberton, Port Adelaide and West Lake Shores caused by a blown transformer, and a fire at Adelaide Brighton Cement's Birkenhead kiln. A further 7500 homes were without power throughout Paracombe, Inglewood and Chain of Ponds for >1 hour [Emmerson R & Owen M 2009]

- 28th – Adelaide's electricity usage record was smashed. Electricity demand surged past the record of 3171 MW by 5 pm and was increasing into the evening. At 8:40 pm, power was cut to customers in 37 suburbs and towns across SA [Jenkin C et al, 2009]

- 29th – 95 000 Adelaide households endured controlled blackouts in 43 °C heat. ETSA was forced to use load-shedding for the first time in eight years, as overworked air-conditioners helped to push power prices to record levels and demand to a new record peak usage of 3383 MW. ETSA was ordered to begin load shedding at 2:45 pm by market manager National Electricity Market Management Company, NEMMCO, which operates the electricity grid, after a technical failure with the Basslink interconnector from Tasmania to Victoria. ~40 Adelaide suburbs had their power cut for up to an hour, along with the Nyrstar plant at Port Pirie. Both SA and Vic were ordered to institute the rolling blackouts. Other blackouts affected >27 000 people across the state. St Mary's endured Adelaide's longest blackout: 15 hours. An overnight (28/29th) blackout ruined >$30 000 in perishable food at the Walkerville IGA supermarket. Power outages also affected traffic lights at Greenhill and Fullarton Roads [Wheatley K & Emmerson R 2009]

- 30th – rolling power blackouts occurred in the hottest part of the afternoon as distributor ETSA Utilities cut power to 81 suburbs. The load shedding to 170 000 households was enforced by NEMMCO, who said transmission faults on the Basslink line from Tasmania to Victoria had forced the company to order temporary cuts to 3% of customers in Melbourne and Adelaide. Spokesperson Paul Bird said, 'What we're dealing with now is a one in 70-year event. What we're dealing with is 42, 43 degrees during the day and 30 to 33 overnight and the equipment is not having the chance to cool down' [Edwards V & Hannan E 2009]. ETSA and the electricity grid failed to meet soaring demand for power for the second consecutive day: >170 000 homes and businesses in ~83 towns and suburbs were intentionally blacked out under the load-shedding policy. These forced power blackouts would e examined at a national conference of energy ministers in May 2009: Mr Holloway, acting for Energy Minster Patrick Conlon, said 'the electrical and mechanical systems do feel the pressure.' [Owen M & Wills D 2009b]

- 30th – a power cut along Jetty Rd, Glenelg, trapped 25 people, including a four-month pregnant woman, in a lift. During the Glenelg targeted blackout, vast quantities of the Wendy's store icecream melted. Other shops in zones affected by load-shedding have been unable to make sales, as tills and appliances are rendered useless. At Elizabeth Grove, power was cut for 12 hours overnight [Staff Reporters 2009]. Rolling power cuts decreed by NEMMCO lasted ~30 minutes and were rotated through various suburbs and regional locations [Mounster B 2009]

- From 29th – since 29 January (to 1 February) >265 000 homes and businesses in the metropolitan area have been affected by controlled blackouts as NEMMCO sought to balance demand and supply on the national grid by load shedding: rotating power interruptions to the schedule developed by the planning council. Critical infrastructure including major hospitals is exempt. ETSA, the privately owned electricity distributor, acted under NEMMCO's instructions and, while their spokesperson said they try hard to communicate with people, in some instances they literally get told to "push the button now". Criticism is mounting over the lack of warning about controlled blackouts and, when asked for a copy of the load-shedding schedule, the ETSA said only the Electricity Supply Industry Planning Council had the authority to release it [Owen M & Wills D 2009b]

- 28th-31st – Premier Mike Rann called for an inquiry into how NEMMCO handled the crisis, with blackouts continuing across Adelaide and the possibility of more load shedding as the city headed into its second week of the heatwave. Widespread anger among residents whose power was cut off without warning during the afternoon of 30th January – the one criticism of NEMMCO and the private companies is that they could have communicated better, explained what was going on and perhaps done it quicker [Hannan E & Akerman P 2009]

- ~ 1st Feb – Woolworths is running its stores at "half-light"; ovens traditionally used all day will be turned off at 10 am and lights will be turned off in some freezers and refrigerators, in an attempt to ease pressure on the power grid. Since 29th January, the use of lighting and electricity has been restricted in all SA stores as the state struggles to keep up with demand [Jenkin C & Vaughan J 2009]

- 28th-31st – at the height of the previous week's heatwave (29-30th January) 265 000 households and businesses across Adelaide had their power cut to avoid a system meltdown when the Basslink interconnector between Tasmania and Victoria shut down [Pengelly J & Wheatley K 2009].

Infrastructure – Water

January

- 28th – Adelaide's water usage soared. SA Water figures show Adelaide's water consumption on Tuesday [27th], when 43.2 °C was the max, was 710 Ml, an increase of 132 Ml on the previous day [Jenkin C et al, 2009]

- 30th – Adelaide's fragile water supplies are also under pressure, with the 4308 Ml consumed this week eclipsing the 3839 Ml used the previous week [Staff Reporters 2009].

Transport

January

- 27th – ~4pm a Belair train was cancelled after suffering heat-related mechanical problems, including a lack of air-conditioning and only one engine operating [Emmerson R & Owen M 2009]

- 28th – Adelaide's public transport system literally buckled under the strain of 45 °C heat. The closing of the Noarlunga train line and tram services sparked confusion on North Terrace during the afternoon city peak hour. A section of line at Clarence Park buckled in the extreme heat. Dozens of TransAdelaide and hired security staff manned the entrance of the Adelaide Railway Station and tram stops along North Terrace, advising commuters of alternatives; staff on other lines handed out bottled water. In Victoria Square, trams stopped running: shuttle buses were used (there was some confusion as some trams kept running for awhile, and commuters were misdirected) [Jenkin C et al, 2009]

- 29th – Adelaide's $6 million trams were affected by the heat: tracks buckled, and rail workers toiled through the night to repair them for morning commuters. Trams were being taken off the network to allow their engines to cool. TransAdelaide reported delays of up to 15 minutes on the Noarlunga, Gawler and Belair lines. Buses on Greenhill and Fullarton Roads were delayed due to power outages affecting traffic lights [Wheatley K & Emmerson R 2009]

- 30th – train and tram services were again cancelled across Adelaide yesterday, with buses used to transport commuters [Edwards V & Hannan E 2009]. Trams were withdrawn from service during the hottest part of the day as they overheated once again and the train system was thrown into chaos as rails along the Gawler line between Gawler and Salisbury buckled in heat that reached 43.1 °C at 2:36 pm and dipped to an overnight low of 29.4 °C at 7 am (31st January). Buses replaced trains on the Gawler, Grange, Tonsley and Outer Harbour lines, with 10-minute delays percolating through the system [Staff Reporters 2009]

- 28th-31st – the rail meltdown that occurred in Melbourne the previous week did not occur in Adelaide, despite it having similar trains (smaller Comengs built by the same manufacturer shortly after Melbourne's trains were built) and experiencing an even worse heatwave. Over 28-30 January, Adelaide cancelled 7% of train services. In Melbourne, 24% of trains were cancelled: the aged Comeng trains (first in service 1982) had terrible problems with air-conditioning systems failing: hundreds of services did not run due to that. In Adelaide, near-identical trains (but powered by diesel) and no air-conditioning problems. Victorian Department of Transport spokesperson Chris Veraa would only say the mass cancellations occurred due to "air-conditioning faults, bucked rail and power supply affecting signals and points". The train operator Connex said broken air-conditioning was a key factor in the high cancellation rates, which peaked on 30 January with 730 out of 2012 scheduled services not running. In all, 1447 of 5966 scheduled services did not run in those three days in Melbourne. Adelaide's train system is far smaller than Melbourne's, with ~13 million trips made each year: Melbourne's has >200 million. And Adelaide has only five lines compared to Melbourne's fifteen. Melbourne's tracks last week had ~40 buckles; Adelaide's tracks also buckled badly, in one case far more seriously than any in Melbourne [Wahlquist A 2009]. [NB this paragraph is also included under Victoria.]

Human health

January

- 27th – most students remained at school the whole day (first of term) and followed modified programs [Emmerson R & Owen M 2009]

- 28th – the SA Ambulance Service recorded an extra 79 call-outs and confirmed most of those would have been due to the hot weather [Jenkin C et al, 2009]

- 30th – at least 19 dead as a result of heatwave conditions: police were called to death scenes at suburban addresses across Adelaide. On 23rd January just two sudden deaths were reported to police in Adelaide; on 30th January, 23 were reported – but four had nothing to do with the heatwave. Most of the remaining 19 deaths that were potentially heat related involved people 70-years-old or over; the oldest being 95. Medical experts said while the cause of deaths had yet to be confirmed, the sudden increase in death rate was entirely consistent with an extreme heatwave. >105 patients required an ambulance after suffering heat exposure. Three elderly patients were taken to the emergency department of Royal Adelaide Hospital between 5:30-6 pm: all six ambulance bays were occupied. One patient, a man in his 80s, appeared to be semi-conscious; an elderly woman in evident distress was wearing an oxygen mask. Adelaide ambulance crews attended a record 1325 callouts in the 24 hours to midnight 29th January. SA hospitals had admitted 80 people with heat-related illnesses before 3:30 pm on 30th January; 86 people were admitted on 29th January. [Melbourne GP Harry Hemley had seen several elderly people during the heatwave and it was clear they became easily dehydrated: 'They often live in sub-standard housing, so they don't have insulation in the roof or walls… elderly people often have reduced renal function and as they don't feel well they don't tend to drink all the fluids necessary…'] [Edwards V & Hannan E 2009]

- 30th – a significant increase in the number of sudden deaths, ~14 of them elderly, was recorded across Adelaide: reaching 22 in the night. While the causes were yet to be investigated by the Coroner, Health Minister John Hill said it was obvious a significant number of them were associated with the heat. Extra ambulance crews had been called in to meet increased demand for paramedic call-outs; health officials would on 31st January ask GPs to contact vulnerable patients to ensure they were coping. SA Health chief medical officer Professor Paddy Phillips said 146 people had been admitted to hospital with symptoms of heat stress over the past two days (29-30th January): 'There has been increased activity from the ambulances and more people attending hospital with heat-related illnesses.' Cumberland Park man Christopher Swan, who had medical conditions and lived alone, was found dead at 11:30 am: he had been sleeping on his back porch to escape the heat that had built up inside [a neighbour checked in regularly with Mr Swan but didn't see him on 29th January because of the heat and by the time he dropped in on 30th January, Mr Swan was dead[[Owen M & Wills D 2009a]

- 30th – the number of ambulance callouts doubled, according to Premier Rann [Hannan E & Akerman P 2009]

- 1st Feb – by 7pm there were 22 sudden deaths across SA, bringing the total to 57 since 30th January. Many have been linked to heat-related causes. SA Ambulance Duty Director Neale Sutton said the demand on emergency medical crews had declined as temperatures eased and callouts had reduced between 10-15% since spiking to record levels on 29th and 30th January. SES is warning heat-affected trees pose a risk to life after >150 collapsed overnight on 31st January [Owen M & Wills D 2009a]

- 28th-31st – Homelessness SA said sleeping rough was as dangerous in heatwaves as it was in the depths of winter, particularly families sleeping in cars. Chairwoman Jo Wickes said "The emergency shelters are full, and there's nowhere for people to move out to." [Anon 2009d]

January/February

- 31st/1st – SA police declined to reveal the number of sudden deaths reported over the weekend but it is believed up to 12 on 1st February and a few more on 31st January. 19 people died on 30th January in circumstances thought to be heat-related [Hannan E & Akerman P 2009]

- 2nd Feb – the disturbing number of sudden deaths across SA continued: there were 15 sudden deaths reported up to 10:30 pm. There were 25 on 1st February, bringing the total to 75 since 30th January. Many of the fatalities have been linked to the heat but the causes will be investigated by the coroner [Jenkin C & Vaughan J 2009]

- 28th-31st – The Forensics SA morgue in Divett Place, Adelaide, normally holds ~25 bodies at any one time. It has a capacity of 72 and by 2nd February held 71 bodies. State Coroner Mark Johns said several deaths had been reported in recent days; the heat has been identified by investigators as a factor for further investigation [Kelton G 2009]. Adelaide has recorded >75 sudden deaths since 29th January but the Health Department will not say how many were related to the prolonged heatwave. SA chief medical officer Paddy Phillips said not all the recent deaths could be attributed to the heat, but there was no doubt many were related. State Coroner Mark Johns said, "While I can say there have been more sudden deaths reported than is usual in a given period, we don't yet have enough information to specify a number until the investigations have been completed. Health Minister John Hill told state parliament 4 February that 600 patients had been treated in hospital for heat-related illnesses. [Edwards V 2009]

- 28th-31st; as at 5th Feb – besieged hospitals are struggling to cope with an enormous workload: all non-urgent elective surgery has been postponed in metropolitan public hospitals until the following week; hospital staff were working extra shifts; all hospitals have beds in places they don't normally have beds. Since the heatwave began on 26th January, 674 people have been admitted to the state's hospitals with heat-related illnesses. SA's previous 15 heatwaves did not result in such big increases in deaths: the surge in sudden deaths is >70 since the heatwave began. Additionally, 500 trees or major branches fell during the heatwave and SES joined with CFS, Health Dept and Bureau of Meteorology in a news conference on 5th February to warn the community to prepare for the heat from 6th February [Wahlquist A 2009]

- 28th-31st; as at 6th February – Dozens of elderly people died in Adelaide in the extreme conditions. Nearly 90% of homes in the city are air-conditioned to some extent. But, disoriented by heat, one elderly person was found dead after switching the split system home air-conditioner to heat. Ambulance crews found others who became so heat stressed they had swaddled themselves in winter clothing. Police were called to 23 sudden deaths in Adelaide on 30th January, a ten-fold increase in such deaths from the Friday before. On 1st February the toll was 25 sudden deaths, according to police records. SA chief medical officer Paddy Phillips said SA Health had been prepared for the heatwave early: support agencies began calling pensioners, the elderly and the vulnerable when the temperatures began to rise. The Red Cross service phoning the elderly first picked up critical cases on 30th January [Edwards V et al, 2009].
    - 29th: near death: Ms Colleen Nun, late 60s, collapsed in her un-air-conditioned home, alone, in the afternoon heat of 43 °C after the extreme 45 °C of 28th January, and may have died if her son had not found her (unconscious on the couch). She had done the right things: drunk water, kept out of the sun… she spent four days in hospital on an intravenous drip [Edwards V et al, 2009]
    - 30th: The house of Hazel Quinn, 82, was like a sauna when her body was found by a neighbour on 30th January. Her western suburbs house had been subjected to repeated blackouts in the 26 hours before her death [Edwards V et al, 2009]
    - The body of Clarence Todd, 75: was found in his van at the Balaklava Caravan Park, 90 minutes north of Adelaide. In temperatures reaching 48 °C in the country town, the van would have felt like a heat chamber [Edwards V et al, 2009]
    - 31st:Mary Cahill, 78, died at her northern Adelaide one-bedroom unit, alone: she had gone through at least four blackouts the night before she died [Edwards V et al, 2009].
- As of the night of 6th February, 690 people had gone to hospital with heat-related illnesses. Among those fighting for their lives in intensive care: a (formerly) strapping 19-year old man who had suffered kidney failure while playing grade cricket. Up to 80 sudden deaths have been reported in Adelaide since the heatwave began on 26th January. SA health crisis controller Bill Griggs said a record number of people had presented to local hospitals with heatstroke [Edwards V et al, 2009]

- Overall – "…the extreme heatwave, whose death toll when tallied will probably be in the hundreds and exceed that of the fires…" [Hamilton C et al, 2009]. [NB this paragraph is also included under Victoria.]

Other impacts

- Estimated that 30% or more of SA's grape crop has been lost. Significant damage in numerous regions including Langhorne Creek, McLaren Vale, Barossa Valley and Clare, with some impact in the Limestone Coast and the Riverland. McLaren Vale grower Jock Harvey said growers estimated the region had lost 50-70% of its crop [Anon 2009c].

January

- 28^{th}-31^{st} – air-conditioner repairers have recorded a ten-fold increase in callouts during the heatwave and warned of a blackout catastrophe if people kept pushing their units to the limit [many people were running air-conditioning as low as 14-16 °C: well below the recommended 25 °C – and transformers would blow off the poles if the trend continued [Anon 2009d].

General facts

January

- 28^{th} – hottest day on record at Adelaide for 70 years: 45.7 °C [La Canna X 2009] and hottest night on record: min temperature was 33.9 °C [Jackson A & Ker P 2009; Dowling J & Rood D 2009]

- 30^{th} – Adelaide hit 43.1 °C [Kretawicz E 2009]

- 28^{th}-31^{st} – variously described as one in 70, one in 100 year event [Hannan E & Akerman P 2009]. As at 5^{th} February: during the peak of Adelaide's nine-day hot spell, the city recorded six days >40 °C, including a maximum of 45.7 °C on 28^{th} January [Wahlquist A 2009]. For the first time in 70 years, the mercury climbed well above 40 °C in Adelaide for six days in a row and there was little relief when the sun went down: after a maximum of 45.8 °C on 28^{th} January, the overnight minimum was 33.9 °C (the highest such temperature recorded) [Edwards V et al, 2009].

- The key difference between the current heatwave and previous ones was the high overnight temperatures, said Climatologist Barry Brook, who heads the Research Institute for Climate Change and Sustainability at the University of Adelaide [Edwards V et al, 2009].

References

AAP 2009, *Homes lost in bushfire outbreak,* The Hobart Mercury, 31 January, p.7.

Anon 2009a, *Responsibility is as responsibility does, minister.* The Age (Melbourne),28 January, p.12.

Anon 2009b, *A time of crisis, tragedy and too little vision,* The Age (Melbourne), 31 January, p.8.

Anon 2009c, *Heat hits grape crop,* The Advertiser (Adelaide), 3 February, p.2.

Anon 2009d, *At risk * No respite from heat for homeless,* The Advertiser (Adelaide), 3 February, p.4.

Anon 2009e, *Overload * Air conditioners pushed to limit,* The Advertiser (Adelaide), 3 February, p.4.

Dobbin M, Lowe A, Miletic D, Medew J, Koch E & AAP 2009, *State melts down in the heat,* The Age (Melbourne), 31 January, p.1.

Dowling, J 2009, *Thousands face power cuts*, The Age (Melbourne), 29 January, p.7.

Dowling J & Rood D 2009, *Households sweat as power cut off,* The Age (Melbourne), 30 January, p.4.

Edwards V 2009, *Morgue packed as city swelters,* The Australian, 5 February, p.3.

Edwards V & Hannan E 2009, *Nineteen die as the blast of summer begins to take its toll,* The Australian, 31 January, p.1.

Edwards V, Walker J, Lower G & Akerman P 2009, *Elderly fall prey to killer heatwave,* The Australian, 7 February, p.5

Emmerson R & Owen M 2009, *43.2 and there's plenty more heat to come,* The Advertiser (Adelaide), 28 January, p.1.

Hamilton C, Greer G & Blainey G 2009, *Greenie love of bushfires goes deeper than global warming,* The Australian, 10 February, p.15.

Hannan E & Akerman P 2009, *Warning of more heatwave blackouts,* The Australian, 2 February, p.3.

Jackson, A 2009, *Baking state hits 45 degrees,* The Age (Melbourne), 29 January, p.7.

Jackson A & Ker P 2009, *It's hot in the city – damned hot,* The Age (Melbourne), 30 January, p.4.

Jenkin C & Vaughan J 2009, *Below 40, but death toll rising,* The Advertiser (Adelaide), 3 February, p.5.

Jenkin C, Williams M & Owen M 2009, *Commuters were warned last night that the city's public transport system is 'not out of the woods yet',* The Advertiser (Adelaide), 29 January, p.4.

Jensen E, Benson K, Somerville E, Tsialis M & Hawkins P 2009, *Blackouts, bushfires and deaths feared in scorcher,* The Sydney Morning Herald, 7 February, p.7.

Johnston C & Battersby L 2009, *As train tracks melted and trees wilted, we all went a little bit troppo,* The Age (Melbourne), 31 January, p.5.

Kelton G 2009, *Morgue filled to capacity,* The Advertiser (Adelaide), 5 February, p.4.

Kretawicz E 2009, *Houses razed in heatwave hell,* Canberra Times, 31 January, p.3.

La Canna X 2009, *Records tumbling in heatwave states,* The Courier-Mail (Brisbane), 31 January, p.15.

Lloyd T 2009, *How another century coped,* The Advertiser (Adelaide), 7 February, p.46.

Lucas, C 2009a, *Trains on track for trouble,* The Age (Melbourne), 27 January, p.1.

Lucas, C 2009b, *Tracks buckle and so does rail system,* The Age (Melbourne), 29 January, p.1.

Lucas C 2009c, *Train system completely off the rails,* The Age (Melbourne), 31 January, p.4.

Miletic D 2009, *Movies and watermelon in cool bid,* The Age (Melbourne), 30 January, p.4.

Mounster B 2009, *Heat shuts cash flow Hydro loses money as Basslink closes,* The Hobart Mercury, 31 January, p.7.

Owen M & Wills D 2009a, *Today 40 tomorrow 39 Tuesday 38 Wednesday 38 fatal toll * 22 sudden deaths as temperatures soar * 146 admitted to hospital for heat stress,* The Advertiser (Adelaide), 31 January, p.1.

Owen M & Wills D 2009b, *Cover up * ETSA's secret blackout hit list,* The Advertiser (Adelaide), 2 February, p.1.

Pengelly J & Wheatley K 2009, *43 heat alert,* The Advertiser (Adelaide), 6 February, p.1.

Rintoul S & Akerman P 2009, *Hot under the collar,* The Australian, 4 February, p.13.

Smith B & Perkins M 2009, *Appeal for help as morgue overflows,* The Sydney Morning Herald, 10 February, p.4.

Staff Reporters 2009, *Blackouts, buckled rails, broken trams and 25 people stuck in an elevator: It's just madness,* The Advertiser (Adelaide), 31 January, p.7.

Wahlquist A 2009, *Winegrape farmers burnt as harvest withers,* The Australian, 6 February, p.5.

Wallace R 2009, *Electricity rescue bid blocked,* The Australian, 3 February, p.2.

Wheatley K & Emmerson R 2009, *Rolling blackouts were avoidable,* The Advertiser (Adelaide), 30 January, p.1.

Williams, B 2009, *Hot weather heads south,* The Courier-Mail (Brisbane), 30 January, p.10.

Wilson L 2009, *Heat stroke: even the big wheel buckles,* The Australian, 3 February, p.2.

Wotherspoon S & Roberts G 2009, *Crisis hits Victoria * Homes lost, rail chaos,* The Advertiser (Adelaide), 31 January, p.10.

Appendix B.2 Government of South Australia / SASES media alert issued 31 January, 2009

South Australian State Emergency Service — Extreme Heat Response Plan

Government of South Australia — SES RESCUE

Table 2.2.1 – MANAGEMENT Actions

LEVEL	TRIGGER (threshold)	COMMUNICATION	SASES HEADQUARTERS ACTIONS
Seasonal Preparation	Actions are taken in September in preparation for the lead up the hotter months (October - March) to prepare for and maintain a state of increased readiness	• Heat Advice to community and Agencies on mitigating actions to reduce impact of potential heat risks identified.	• Initial notification to Community and key stakeholders. • Review of existing plans, procedures and resources. • Encourage BCP process by agencies/ stakeholders. • Updating / validating notification processes. • Initiating awareness campaigns. • Conduct training of plans and procedures.
MODERATE (Advice)	*Adelaide forecast temperatures next 5 days* **Max ≥30° C on each day** **AND** **Min ≥20° C on each night** **(ADT 25 ° C)**	• Heat Advice to agencies to remind them of the possibility of excessively hot conditions • The Control Agency will issue a heat advice 3-5 days in advance of event where practicable	• Initial coordination call and periodic or daily calls as needed among the key state agencies and the potentially affected Operational Areas and Regions. • Consideration of debrief at SEC. • Increasing public information efforts. • Contacting local public health and other officials to ensure contact with those most vulnerable to excessive heat. • Confirmation of roles, identify specific local needs. • Confirm details of agency participation, staffing.
HIGH (Watch)	*Adelaide forecast temperatures next 5 days* **Max ≥35° C for 3+ consecutive days** **AND** **Min ≥21° C for 3+ consecutive nights** **(ADT 28 ° C)**	• Heat Watch to community and/or agencies for Heatwave conditions. • SEC Briefing (*as appropriate*) • The Control Agency will issue a heat Watch 2-3 days in advance of event where practicable	• Activation of State Comcen as 132500 calls increase. • Consideration of debrief at SEC or teleconference. • Consideration of partial or full activation of the SEC depending upon risk as appropriate. • Prioritise requests for assistance.
EXTREME (Warning)	*Adelaide forecast temperatures next 5 days* **Max ≥40° C for 3+ consecutive days** **AND** **Min ≥24° C for 3+ consecutive nights** **(ADT 32 ° C)**	• Heat Warning to community and/or agencies • SEC briefing or teleconference (*as applicable*) • The Control Agency will issue a heat Warning 0-48 hours in advance of event where practicable	• Activation of State Comcen as 132500 calls increase. • Consideration of debrief at SEC or teleconference. • Consideration of partial or full activation of the SEC depending upon risk as appropriate. • Prioritise requests for assistance for urgent life threatening emergencies.
Event Closure (Recovery)	**Nominally April as autumn season commences**	• Event closure communication forwarded by SASES	• Review and prepare summary of actions undertaken during extreme heat events. • Internal debriefs to occur for units/ Regions. • Summaries documented and forwarded to SASES

REF: EHRP001
Authorised By: SASES Chief Officer

Date: November 2009
Page 3 of XX

Status: DRAFT V0.1
Document Control: Restricted

Appendix B.3 Heatwave alert levels and agency actions as detailed in the SASES Extreme Heat Arrangements Plan

Media Alert
State Emergency Service

Government of South Australia
SES RESCUE

HEAT HEALTH WARNING

31 January 2009

Time of Issue: 2:05pm

Note: Please use SEWS with this message.
The following message must be read on air verbatim every hour until 10:00pm on 31 January 2009 and then each three hours from time of first receipt. The delivery of this message is to continue with the identified frequency until further advised.

<Message Starts>

The State Emergency Service (SES) and SA Health are warning South Australians that the current heatwave is a threat to public safety.

There have been significant SA Ambulance call outs and an increase in people presenting to Adelaide metropolitan hospitals, some suffering from heat associated illness. Heat related illness can result in severe health issues and can be fatal.

The SES and SA Health urge the public to exercise extreme care during the heatwave and to take the following precautions:

- Make contact with elderly relatives, friends and neighbours.
- Drink plenty of water and avoid alcoholic and caffeinated drinks.
- Be aware of the symptoms of heat stress.
- Stay indoors and close curtains during the day. Open up your home at night if cooler winds occur.
- Use air-conditioners and fans wherever possible or visit public facilities such as shopping centres, cinemas and libraries.
- Take cold baths or showers and use ice packs or wet towels to cool down.
- Remember that cordless telephones do not work during power outages. Make sure you have alternative means of communication.
- Limit outdoor activities to mornings and evenings.
- Consider the safety of your pets and animals. Wet them down and ensure they have adequate shade and water.

Stay tuned to this radio station on a battery powered radio for more information.

For up to date warnings and further information on the weather forecast please visit the Bureau of Meteorology's website at www.bom.gov.au

If you are feeling unwell, contact your local GP or telephone **Healthdirect Australia** on **1800 022 222**. For immediate medical attention telephone 000.

<Message Ends>

For SES response in storms or floods telephone 132 500. If the matter is life threatening telephone 000
For further information on the services provided by the SES go to www.ses.sa.gov.au

For media enquiries telephone the SES Media Line on (08) 8211 6176

Appendix B.4 Analysis of the Risk Frontiers database for recent historical Australian heatwaves in the southern area

Submitted by Katharine Haynes, Deanne Bird, Lucinda Coates and Megan Ling of Risk Frontiers, Macquarie University

Aim

To put the 2009 Southern Heatwave event into context in terms of historical and more recent heatwave events.

Method

All significant heatwave events that affected south-eastern Australia were identified from the existing Risk Frontiers' (RF) heatwaves database and the gap was closed between the last date of entry of the RF database and the 2009 heatwave event, using Bureau of Meteorology records, media reports and other data sources such as the EMA database. For each of these events, trends and patterns with respect to mortality were researched, both for the event (such as maximum daytime and minimum overnight temperatures, duration etc) and for societal responses (in terms of activity, clothing, awareness etc). A comparative analysis was performed on the three major heatwave events in Australia's history and separately on those heatwave events of Australia's more recent history (the past fifteen years), in order to achieve a clearer picture of the relative impact of the 2009 event.

Results

Table B4.1 Summary of heatwave events in south-eastern Australia causing deaths and illness (figures based on Risk Frontiers 2010; BoM 1996-2009; EMA 2010; Victorian Government, 2009)

Date of Event	No. of Deaths	No. Of Illnesses
Summer of 1895/96	437	5000 *
Summer of 1907/08	246	
Summer of 1909/10	109	
Summer of 1911/12	143	
Summer of 1913/14	122	
Summer of 1920/21	147	
Summer of 1926/27	130	
Summer of 1938/39	438	5000 *
Summer of 1939/40	112	1500 *
Summer of 1959/60	98	1000 *
Summer of 1972/73	99	1000 *
February 1981	15	200 *
December 1990	5	100 *
February 1993	17	500 *
January 1997	10	250 *
December 1998	4	40 *
January 2000	22	350 *

February 2000	7	500 *
January 2001	5	300 *
February 2004	12	n/a
January 2009	404	3334 **

* estimates, from EMA 2010

** Victorian Ambulance and Emergency Department presentations only, from Victorian Government, 2009

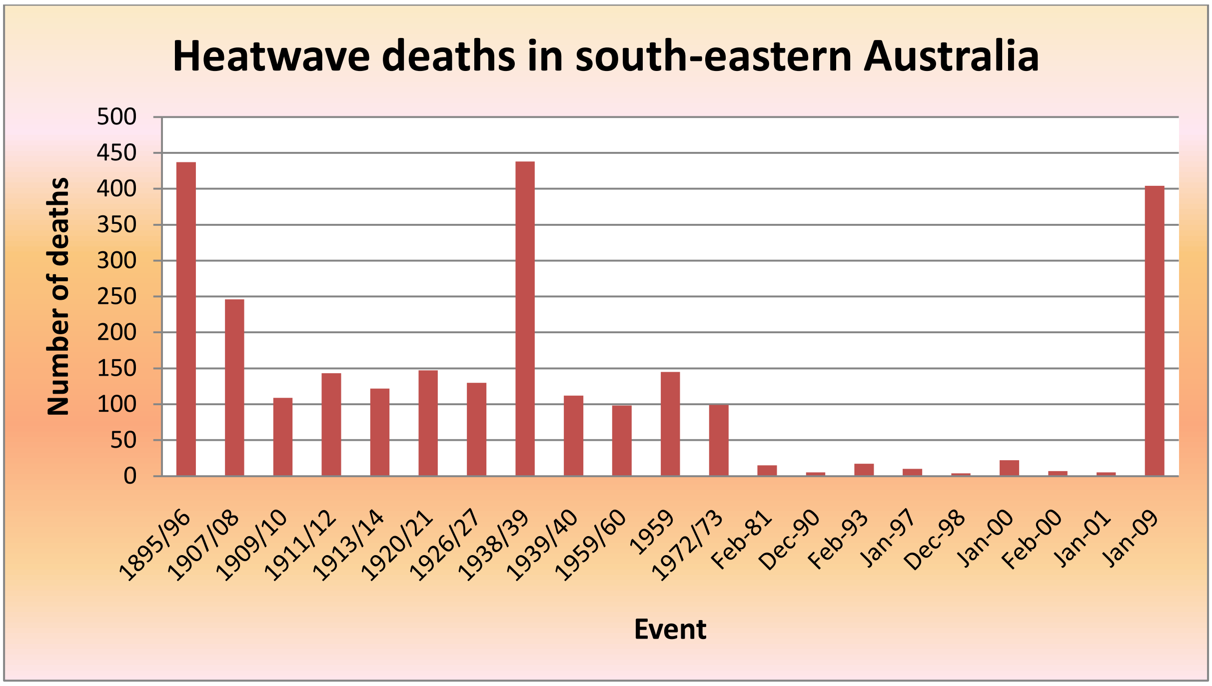


Figure B4.1 Heatwave deaths during events affecting south-eastern Australia

Analysis of the long-term record

There have been numerous heatwaves throughout Australia's history. Four events stand out from the rest in terms of human mortality: those of 1895, 1908, 1939 and 2009. These events were all similar in terms of meteorological conditions – long duration and hot dry northerly winds, which negate any relief of a sea breeze, and often coupled with bushfires. The first part of this report examines the trends in these 'stand-out' events; the second part investigates those of more recent years.

1895

Due to a lack of reliable data on both the event and mortality we have not used this event in our analysis, and have instead relied on data from the post-1900 heatwave events.

1908

January 1908 still remains the most sustained heatwave in Melbourne's history. Melbourne experienced six days with maximum temperatures over 40 °C and minimum temperatures over 20 °C. Adelaide also experienced six days with maximum temperatures over 40 °C and minimum temperatures of over 25 °C (Marcussen T 2010).

There are mixed accounts of the actual number of fatalities that occurred as a result of the heat: however, a total of 246 is the generally accepted figure. This includes three in Broken Hill, 21 in Melbourne city, 83 in country Victoria and 105 in South Australia (Risk Frontiers 2010; EMA 2010).

1939

Victoria, South Australia and country NSW were the areas most affected by this event, but it was a record-breaker for South Australia. Officially, heatwaves ran from 6 to 10 January and 12 to 14 January with 11 January just 0.2 °C below the 3 °C threshold. This was then followed by heatwave conditions returning from 7 to 14 February (EMA 2010).

Again, as with the 1908 event, there are mixed accounts of the actual number of fatalities. The generally accepted figure is 438, and we know this includes a reported 300 from country NSW: predominately older people or young male farmers. The figures include five in Sydney, 18 in the northwest slopes of NSW, 70 in NSW Riverina, 35 in central and western NSW and six in Melbourne (Risk Frontiers 2010; EMA 2010).

2009

The heatwave began in Adelaide and Melbourne on 27 January with daytime temperatures topping 43 °C in Adelaide and 36 °C in Melbourne. For the next four days both cities recorded daytime temperatures of above 41 °C and night time minimums of above 28 °C in Adelaide and 23 °C in Melbourne (BoM 2009).

There was an increase in sudden deaths of 374 during the heatwave in Victoria alone (Victorian Government, 2009). In addition, over 30 deaths in South Australia have been attributed to the heatwave (EMA 2010). As expected, the majority of fatalities were in the group aged over 75 years.

Localised power outages occurred in both capital cities throughout the week, with the worst day on 30 January: Victoria lost almost 10% of its power supply and an estimated 500,000 residents were without power, while 170,000 households or 3% of Adelaide customers were without power for the evening (ABC News 2009; Edwards V & Hannan E 2009; Lucas C 2009; Staff Reporters 2009; Owen M & Wills D 2009; AAP 2009). Over 28-30 January, 24% of Melbourne and 7% of Adelaide train services were cancelled due to buckling rail lines, air conditioner failures and power outages (Gardiner A 2009; Wahlquist A 2009).

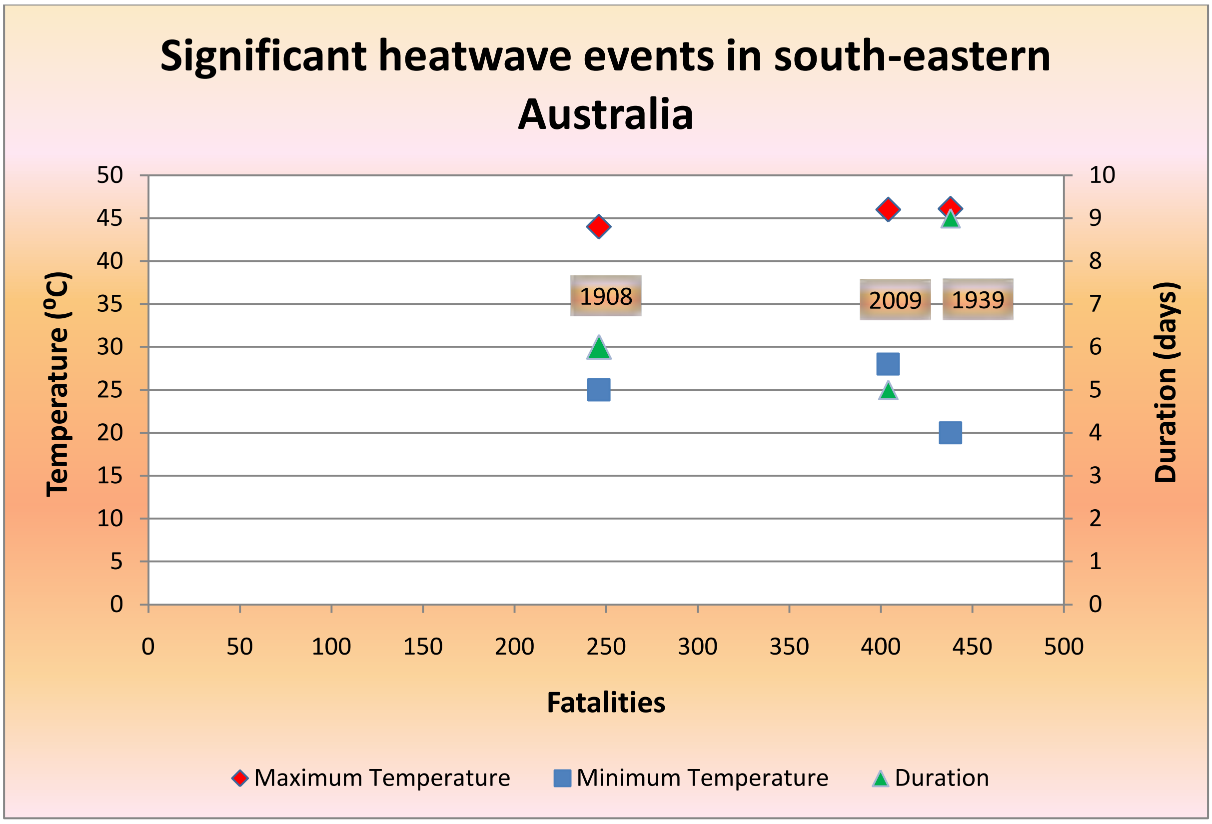


Figure B4.2 Fatalities versus maximum temperature and duration for significant heatwave events in south-eastern Australia (figures based on Risk Frontiers 2010; BoM 1996-2009; EMA 2010)

Analysis of the short-term record

In recent years (1994–2008) the southern states of Australia have experienced a number of heatwaves, but none as deadly as the 2009 event. These recent events, by comparison, had only slighter lower maximum temperatures but were generally of a shorter duration.

1997
During five consecutive days where the temperature rose to over 38 °C in both Adelaide and Melbourne, it was reported that ten people died directly due to heat. Ambulance call-outs for 'collapses' doubled over the period of the heatwave with the majority of these being for the elderly (EMA 2010). Major power failures contributed as those relying on air conditioning were left without.

1998
Hot weather is suspected to be the cause of the deaths of four elderly people when the temperature reached 39.4 °C in Adelaide on 10 December (BoM 1996-2009).

2000
This intense three-day event predominately affected Adelaide (South Australia) and north-western country Victoria. In Adelaide a maximum temperature of 42 °C was reached on 2 February, with temperatures reaching over 39 °C on 3 and 4 February. This was coupled with an unusually moist air mass from the Northern Territory creating much higher humidity and, therefore, much harsher conditions for many people (BoM 1996-2009; EMA 2010).

SA Ambulance reported treating close to 200 people (predominately the elderly and the very young) and a reported 31 people lost their lives throughout the extended heat of January and February, including seven people in the three-day heatwave event: however, it is believed that this number grossly underestimates the actual toll (BoM 1996-2009).

2001
January and February were particularly warm months with much of NSW, Victoria and South Australia recording the highest mean maximum and minimum temperatures on record. Adelaide experienced six consecutive days above 35 °C with the sixth day, 13 January, reaching 43.3 °C. A reported five people lost their lives throughout this extended heat (BoM 1996-2009; EMA 2010).

2004
Several locations within NSW experienced their longest hot spell on record: Dubbo – 17 days above 35 °C and seven days above 40 °C; Cobar – 17 days above 40 °C and Bathurst – seven days above 35 °C. Two very intense heatwaves saw an amazing 97 locations in Queensland, NSW, Victoria and South Australia break records for the highest maximum daily temperature for a February on either 14–15 February or 20–22 February (BoM 1996-2009).

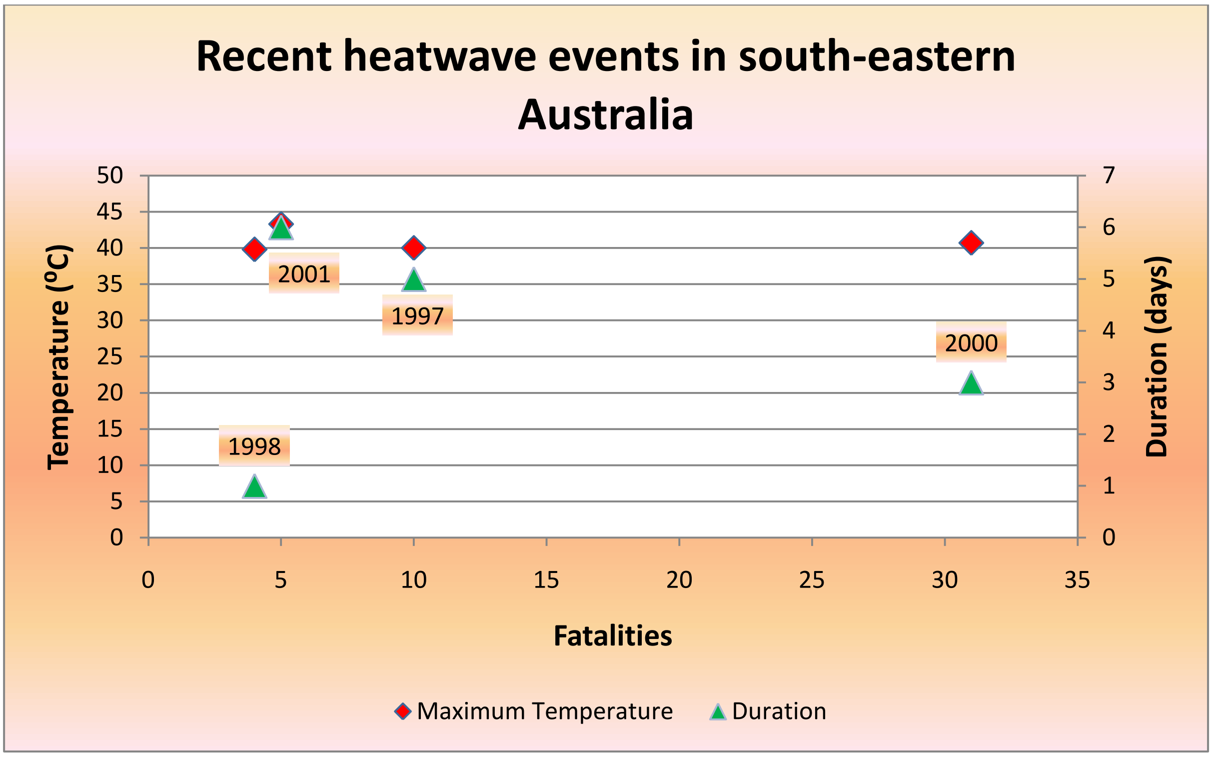


Figure B4.3 Fatalities versus maximum temperature and duration for recent heatwave events affecting south-eastern Australia (figures based on BoM 1996-2009; EMA 2010)

Discussion

It is difficult to put the 2009 heatwave into context over a lengthy period of record due to the great changes in both infrastructure and societal responses experienced over time. Heatwave events since 1900 which include, amongst their impacts, a comparable number of heat-related fatalities to that of the 2009 event are those of 1908 and 1939. For both these events there was much less reliance on electrical power, and so any damage to or shortcomings of infrastructure of this kind did not have a great impact. Certainly there were no air-conditioned buildings and even by the 1939 heatwave event refrigerators were rare [BoM 2010]. Polite dress in 1908 was thick, three-piece suits and long skirts and there was no effective sanitation: by 1939 lighter clothing was worn, men would at least take their coats off and there were by then no inhibitions about mixed bathing, so relief could be sought at beaches and baths [BoM 2010].

Nowadays there is a great dependency on infrastructure such as electrical supply – mainly used for air conditioning during heatwave events. The population has increased dramatically and is aging and this group of people tend to be more isolated. On the positive side, it has become perfectly acceptable to suit one's amount of clothing and/or actions (for example, visiting shopping malls or the beach) to environmental conditions, and the knowledge of how best to combat excess heat is widely available.

However, similarities can be drawn between these three events with regard to their meteorological effects, if not to their societal responses. In terms of duration, the 2009 event lasted five days closely followed by another three days, whereas the 1907/08 event was six days in duration and the 1938/39 event lasted for nine days. Maximum temperatures were very similar: 46 °C in 2009, 46.1 °C in 1938/39 and 44 °C in 1907/08. The highest recorded overnight minimum temperature for the 2009 event was 28 °C – a record. That of the 1908 event was 25 °C – fairly comparable – but the highest overnight minimum temperature reached for the 1939 event was only 20 °C. Certainly several sources (for example, Edwards V et al P 2009; Dowling J & Rood D 2009) note that overnight minimums were significantly higher during the 2009 event than in other heatwaves and that this could be in large part a determining factor in the increase in sudden deaths.

More recent events (over the past 15 years) were investigated in order to put the 2009 event into context where differences in societal behaviours and in infrastructure were not so great. Such a comparatively short record did not deliver any events where very great numbers of deaths were recorded from heat-related illnesses. However, it was surprising to note that two events had very similar durations to that of the 2009 event and, while their maximum temperatures were lower, it was not by any great margin. The 1997 event lasted for five days and had a maximum temperature of 40 °C. Much closer to the vital statistics of the 2009 event was that of 2001, which had a duration of six days and maximum temperatures of 43.3 °C. This begs the question of why events so similar in terms of duration and maximum temperature had such vast differences in outcomes of human mortality. Unfortunately, overnight minimum figures were not available for these two events for the brief time allotted to this project so we can only assume that it is this factor of very high overnight minimum temperatures that made the deadly difference between the 2009 event and the 1997 and 2001 events.

In conclusion, it would appear that the 2009 southern states heatwave differed from most previous heatwave events in that its overnight minimum temperatures were very high. While similar maximum daytime temperatures and similar event durations had occurred in previous heatwaves, no event had killed so many people in seventy years of record (the most similar event being that of 1939). The 2009 southern states heatwave stands out from the record as a very significant natural peril event due to its combination of extreme maximum and minimum temperatures and its extended duration, resulting in very large numbers of heat-related fatalities and illnesses as well as massive interruptions in infrastructure.

References

AAP 2009, *Homes lost in bushfire outbreak,* The Hobart Mercury, 31 January, p.7.

Australian Broadcasting Corporation (ABC News), 2009, 'Melbourne blackout causes chaos', viewed 20 May 2010, <http://www.abc.net.au/news/stories/2009/01/30/2478898.htm>.

Bureau of Meteorology (BoM) 1996-2009, 'Significant Weather Monthly Summaries', viewed April and May 2010, <http://www.bom.gov.au/inside/services_policy/public/sigwxsum/sigwmenu.shtml>.

Bureau of Meteorology (BoM) 2009, 'Special Climate Statement 17 The Exceptional January-February 2009 heatwave in south-eastern Australia' viewed April and May 2010 <http://www.bom.gov.au/climate/current/statements/scs17d.pdf>.

Bureau of Meteorology (BoM) 2010, 'Climate Education', viewed July 2009, <http://www.bom.gov.au/lam/climate/levelthree/c20thc/temp2.htm>.

Dowling, J, & Rood, D 2009, *Households sweat as power cut off,* The Age (Melbourne), 30 January, p.4.

Edwards, V & Hannan, E 2009, *Nineteen die as the blast of summer begins to take its toll,* The Australian, 31 January, p.1.

Edwards, V, Walker, J, Lower, G & Akerman, P 2009, *Elderly fall prey to killer heatwave,* The Australian, 7 February, p.5.

Emergency Management Australia (EMA) 2010, 'Disaster Database' – Environmental/Heatwave, viewed April and May 2010, <http://www.disasters.ema.gov.au/Browse%20Details/CategoryDetails.aspx?Entity=CategoryID

Gardiner, A 2009, *Victorian blackout causes commuter chaos*, News Limited, Herald Sun, 31 January, viewed 20 May 2010, <http://www.news.com.au/heraldsun/story/0,21985,24986957-2862,00.html>.

Lucas, C 2009, *Train system completely off the rails,* The Age (Melbourne), 31 January, p.4.

Marcussen, T 2010, University of Southern Queensland, pers. comm.

Owen, M & Wills, D 2009, *Today 40 tomorrow 39 Tuesday 38 Wednesday 38 fatal toll * 22 sudden deaths as temperatures soar * 146 admitted to hospital for heat stress,* The Advertiser (Adelaide), 31 January, p.1.

Risk Frontiers 2010, 'Heatwaves Database', pers. comm.

Staff Reporters 2009, *Blackouts, buckled rails, broken trams and 25 people stuck in an elevator: It's just madness,* The Advertiser (Adelaide), 31 January, p.7.

Victorian Government, 2009, *January 2009 Heatwave in Victoria: an Assessment of Health Impacts,* Department of Human Services, Melbourne, Victoria.

Wahlquist, A 2009, *Winegrape farmers burnt as harvest withers,* The Australian, 6 February, p.5.