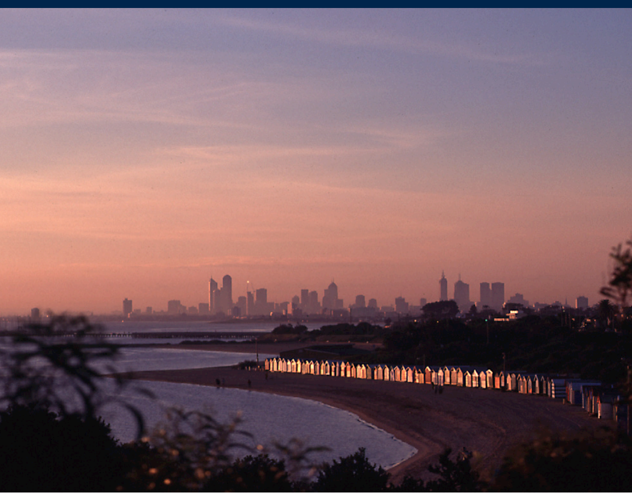
Part of the Victorian climate change adaptation program



Infrastructure and climate change risk assessment for Victoria

Report to the Victorian Government

March 2007

A Victorian Government initiative

Victoria The Place To Be

Infrastructure and Climate Change Risk Assessment for Victoria

Prepared for
Victorian Government

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Decisions made today – for example, in the creation of new infrastructure or other assets – need to occur in a way which ensures that the outcomes of those decisions are robust enough to cope with, or adapt to, changing climatic conditions in the future.
Victorian Greenhouse Strategy Action Plan Update, Victorian Government, 2005

The community … expects that our cities and infrastructure will cope with severe weather events efficiently and safely.
*Climate Change Risk and Vulnerability***.** Report to the Australian Greenhouse Office, Department of the Environment and Heritage by the Allen Consulting Group, 2005

There is a critical need for research to fill in the gaps between regional climate impacts and the requirements for designing infrastructure to withstand the climates of today and the future.
Cities and Communities: the Changing Climate and Increasing Vulnerability of Infrastructure, Adaptation and Impacts Research Group, Environment Canada, 2005

In designing buildings and communities, it is important to plan for the climate throughout the design life of the development, not just for the current climate.
Adapting to Climate Change: A Checklist for Development, Three Regions Climate Change Group, UK, 2005.

Melbourne Water estimates that 82,000 properties and their surrounds would be vulnerable to flooding and overland flows if a 1-in-100 year storm occurred.
Auditor General Victoria, 2005.

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Executive Summary

Introduction

Climate change poses a significant risk to infrastructure and its owners, managers and long-term operators. This report examines the likely impacts of climate change on Victoria's infrastructure, establishes the categories of infrastructure most at risk and outlines opportunities for adaptation responses. The report also details the current governance structures associated with each infrastructure type.

Victoria's climate is changing. It is simplistic to assume that future climate will be an extension of what we have experienced in the past. Recognition of the risks associated with climate change is a valuable first step towards better planning of new infrastructure investments and mitigating potential damage to existing infrastructure.

Major infrastructure items have long useful life spans. A bridge built today is expected to still be in use in tens, if not hundreds, of years. This means that recognition of likely climate change impacts and appropriate adaptation measures should occur now.

The climate change projections used in this report are based on CSIRO climate modelling, underpinned by findings from the Intergovernmental Panel on Climate Change. By 2030, average daily maximum temperatures are likely to rise by 0.5 to 1.5℃ over most of the state; by 2070, they are likely to rise by 0.7 to 5.0℃ compared to 1990. There will be more hot days and fewer cold days. Widespread decreases in atmospheric moisture are likely over Victoria. Increases in extreme daily rainfall are likely, but decreases are also possible in some regions and seasons. An increase in fire-weather risk is likely. Relative to 1990, sea-level may rise by 3 to 17 cm by 2030 and 7 to 52 cm by 2070.

For an introduction to the science of climate change, the potential impacts and risk management guidance, see www.greenhouse.gov.au/science/publications/,

Infrastructure Risk Assessment

This report assesses the following infrastructure types: water, power, telecommunications, transport and buildings. The Australian Standard for identification and assessment of risk, AS/NZS 4360:2004 + HB436 Risk Management, forms the basis for our approach. For each climate change variable identified, we have described a *worst-case scenario* for low and high climate change projections for the years 2030 and 2070. The assessment is on the basis of no adaptation responses to climate change.

The financial impacts estimated do not include consequential losses. Unless otherwise stated, financial information is presented in 2006 dollars.

For each infrastructure category, we have assessed the likely impact of climate change on infrastructure services (the infrastructure itself and its functions), social amenity (including health and public response), governance and the costs of maintenance, repair and replacement. The water sector stands out as a very high risk category. The buildings sector is a high risk priority, followed by the transport and power sectors. The telecommunications sector has the lowest risk priority.

Our comments reflect the law at the time of writing. It is likely that the regulatory framework and judicial consideration of the relevant laws will evolve significantly over the period contemplated by this report.

Governance Arrangements

The risks identified represent a significant governance challenge for infrastructure owners, managers and decision makers. The complexity and uncertainty surrounding the nature of climate change impacts pose challenges for decision making about the design, construction and management of infrastructure. These challenges are compounded by the variety of disciplines involved in such decisions, the long lifespan of infrastructure and the limited ability that infrastructure managers have to modify fundamental design parameters once infrastructure has been built.

It is the ultimate owner of any piece of infrastructure who must ensure that it is designed to operate effectively for its design life, since they will bear the primary liability in the event of failure. However, all involved in the design, financing, construction and regulation of infrastructure are obliged to exercise a level of care consistent with their expertise and any statutory obligations.

The modelling underpinning this report makes it clear that climate change presents a number of risks that courts would consider to be reasonably foreseeable. As a consequence, all involved in the development, ownership and management of infrastructure face the prospect of liability for negligence in the event losses are suffered because of a failure to properly address these risks.

Governments and their agencies will be in a special position in respect of such claims, as, although they may have the power or duty to take actions that may limit or prevent losses occurring, the law as it stands will not necessarily impose any legal liability for any failure to act. Courts have recently been reluctant to impose any legal liability on government for failure to exercise statutory powers. Moreover, for governments, courts see a distinction between their policy and operational decision making. Courts have shown a reluctance to impose liability on governments for negligence in policy decision making. These principles represent a significant limitation on the legal liability exposure of government bodies dealing with the issues generated by climate change. However, a liability exposure will remain for operational activities, in much the same way as will arise for private citizens and corporations. These comments reflect the law at the time of writing. It is likely that the regulatory framework and judicial consideration of the relevant laws will evolve significantly over the period contemplated by this report.

Many of the risks identified will be covered by existing insurance arrangements. However it is to be expected that as understanding of the risks associated with climate change improves, and are more widely understood, insurers will act to reduce their potential exposure. Such action is likely to include requiring those they insure to demonstrate that controls or risk mitigation measures are in place to manage this new class of risk. Some insurance companies have already begun this process.

For self-insurers, the challenge will be to ensure that they can achieve a similar risk management outcome with fewer resources.

Infrastructure Risk Assessment

Water

The main risks associated with climate change are the potential for increased frequency of extreme daily rainfall events, affecting the capacity and maintenance of storm water, drainage and sewer infrastructure. There are likely to be significant damage costs and environmental spills if water systems are unable to cope with extreme events or multiple events in a season.

Acceleration of the degradation of materials and structural integrity of water supply, sewer and stormwater pipelines may occur through increased ground movement and changes in groundwater. Water shortages may occur due to greater demand for water associated with increased temperatures, reduced available moisture and increased population. A decrease in annual rainfall in catchments would affect water supply.

Any costs associated with damage are likely to be borne by water users, probably through price increases. Liability for consequential losses suffered by third parties as a result of infrastructure failure will depend upon the individual facts and circumstance surrounding the damage in question. To the extent that the infrastructure owner or manager is liable, it is likely that such costs will ultimately be passed on to water users.

Energy

The potential for increased frequency and intensity of extreme storm events may cause significant damage to electricity transmission infrastructure and service. Increased wind and lightning could damage transmission lines and structures while extreme rainfall events may flood power substations. The increase in storm activity could potentially generate significant increases in the cost of power supply and infrastructure maintenance from increased frequency and length of power blackouts and disruption of services.

Coastal and offshore gas, oil and electricity infrastructure is potentially at risk of significant damage and increased shut-down periods from increases in storm surge, wind, flooding and wave events, especially when combined with sea level rise.

Acceleration of the degradation of materials and structural integrity of power generation and refinery plant foundations is likely as well as transmission lines, gas and oil pipelines through increased ground movement and changes in groundwater. If left unchecked, this accelerated degradation may reduce the life expectancy of infrastructure, increase maintenance costs and lead to potential structural failure during extreme events.

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 the transmission is likely to be reduced due to the impact of likely higher summer temperatures on transmission line conductivity.

Victoria's electricity and gas industries have been fully privatised. Private companies own the assets used for the production, transmission and distribution of natural gas and the generation, transmission and distribution of electricity. Privatisation means that increased costs associated with climate change will be borne by the private companies, not by the Victorian Government. It is likely that these companies will seek to pass any cost increases to consumers. Their ability to do this will be limited by competitive pressures and price regulation by the Essential Services Commission.

Telecommunications

Increased frequency and intensity of extreme wind, lightning and bushfire events may cause significant damage to above-ground fixed line transmission infrastructure and service. Increased extreme rainfall events are likely to effect underground telecommunications facilities (manholes and pits). The increase in storm activity could potentially generate a significant increase in the cost of telecommunications supply and infrastructure maintenance from increased frequency and length of network outages and disruption of communication services.

Transport

Increased frequency and intensity of extreme rainfall events may cause significant flood damage to road, rail, bridge, airport, port and especially tunnel infrastructure. Rail, bridges, airports and ports are susceptible to extreme wind events; ports and coastal infrastructure are particularly at risk when storm surges combine with sea level rise.

Accelerated degradation of materials, structures and foundations of transport infrastructure may occur through increased ground movement and changes in groundwater.

Increased temperature and solar radiation could reduce the life of asphalt on road surfaces and airport tarmacs. Increased temperature stresses the steel in bridges and rail tracks through expansion and increased movement. Increased temperature causes expansion of concrete joints, protective cladding, coatings and sealants on bridges and airport infrastructure.

Buildings

Increased frequency and intensity of extreme rainfall, wind and lightning events is likely to cause significant damage to buildings and urban facilities. Buildings and facilities close to the coast are particularly at risk when storm surges are combined with sea level rise.

Accelerated degradation of materials, structures and foundations of buildings and facilities may occur through increased ground movement and changes in groundwater. Increased temperature and solar radiation could reduce the life of building and facility elements due to temperature expansion and materials breakdown of concrete joints, steel, asphalt, protective cladding, coatings, sealants, timber and masonry. This accelerated degradation of materials may reduce the life expectancy of buildings, structures and facilities, increasing the maintenance costs and leading to potential structural failure during extreme events.

Of all the infrastructure sectors dealt with in this report, the building sector has the most diversity in ownership, the greatest number of individual owners, and the greatest level of public participation in ownership. This presents challenges regarding communication of the risks to owners, and ensuring that the risks are incorporated into decision making.

1.0 Introduction

1.1 Background to the Project

The Victorian Government's recent '*Victorian Greenhouse Strategy Action Plan Update'* (Victorian Government, 2005) acknowledges that "decisions made today – for example, in the creation of new infrastructure or other assets – need to occur in a way that ensures that the outcomes of those decisions are robust enough to cope with, or adapt to, changing climatic conditions in the future." Several policy responses have been framed to help ensure that the implications of climate change are considered early in the planning stage of new infrastructural investments. These responses have facilitated the commissioning of research (2005-2006), into reducing Victoria's risk exposure to key aspects of climate change of the following key areas:

- Victoria's water supply;
- Coastal areas;
- Changes to fire regimes;
- Biodiversity;
- Primary Industry;
- Community health, and;
- Infrastructure.

This project assesses the risk exposure of various aspects of Victorian infrastructure and opportunities to incorporate adaptation responses.

Victoria has integrated the following factors into the scope and priorities of work on projects related to climate change impacts and adaptation responses:

- An **integrated** approach, ensuring that social, financial and economic factors are considered, that abatement opportunities are addressed when relevant and that responses to other imperatives can also assist in delivering climate change risk reduction;
- A **risk management** approach to determine the nature and timing of responses to ensure that the best cost-benefit outcome is achieved;
- A recognition of the **shared responsibility** of government, business and the community in responses to climate change, and;
- **Flexibility**, to allow the integration of new information, technology and changes in pressures that may alter risk exposures.

The challenges of climate change pose a significant risk to infrastructure, and its owners (investors), managers and long-term operators. The recognition of these risks is a first step towards better planning of new infrastructure investments and mitigating potential damage to existing infrastructure.

A Steering Committee has provided guidance to the project, through meetings and advice; however, the information and analysis in the report are those of the project team. The project team is indebted to the following members of the Steering Committee for their participation:

Mr Andrew Trembath, Department of Infrastructure, Victoria
Ms Ruth Ahchow, Department of Infrastructure, Victoria
Mr Rod Anderson, Department of Sustainability and Environment, Victoria
Ms Jennifer Cane, Department of Sustainability and Environment, Victoria
Dr John Higgins, Australian Greenhouse Office - observer
Mr Dennis O'Neill, Australian Council for Infrastructure Development (AusCID)
Mr Bruce Thomas, Swiss Re
Mr Adrian Rizza, Babcock & Brown Investment Banking
Dr Thomas Montague, Australian Mathematical Sciences Institute/MASCOS, University of Melbourne

Infrastructure can take many forms including buildings, coastal developments, water pipelines, transmission lines and transport networks. The Australian Bureau of Statistics' National System of Accounts for the 2004-05 financial year puts the value of Australia's tangible fixed assets at $2,146.2 billion (excluding livestock and machinery and equipment) in 2005 dollars.

Most, if not all, of this infrastructure is typically designed, built and maintained on the premise that the future climate will be similar to that experienced in the past. Yet current indications show that increasing

concentrations of atmospheric greenhouse gases are already influencing change in climatic conditions and will continue to do so in the years and decades ahead. Planning on the basis of a flawed assumption in this way presents a significant risk to the State's infrastructure, its owners and managers and the communities and businesses that rely on it.
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Currently there is little information available on the likely impacts of climate change on infrastructure. While this information gap remains, it is likely that key decisions will continue to be made on the assumption that historical climate patterns will continue. Every time this occurs, the climate risk profile of the State's infrastructure is increased. Accordingly, there is considerable benefit for Victoria in assessing likely impacts of climate change on its infrastructure and ensuring that this information is understood and acted upon.

In order to drive action it will be necessary to effectively communicate the findings of this assessment, and convert these findings into a set of engineering, legal and financial actions. This will help ensure that infrastructure owners and managers plan for the effects of climate change, throughout the infrastructure lifecycle of design, infrastructure maintenance and renewal.

This project has brought together a multi-disciplinary team from a range of organisations to undertake a preliminary analysis of the implications of climate change for Victoria's key infrastructure sectors over the medium to long-term. The objective of the project is to document and communicate the team's findings in a scientific, engineering, and legal context. The report is intended to provide a basis for future engagement of stakeholders and serve as a practical, informative guide for decision-makers.

1.2 Assumptions and Report Limitations

The report aims to identify infrastructure risks attributable to climate change that will occur up to 2070. While it is certain that there will be climate change, it is important to note that there is some uncertainty surrounding the extent of the likely changes, the impact of these changes and the way in which infrastructure decision makers will respond to this impending change. The speed with which knowledge about likely climate change impacts develops and is acted on will have a large bearing on the effect that climate change has on Victoria's infrastructure.

Legal Framework

The examination of the legal framework governing infrastructure contained in this report considers only current law. The past 75 years has seen significant changes to the legal system. For instance 75 years ago the law of negligence was in its infancy, now there is a significant body of law dedicated to this form of liability. Regulatory legislation has also proliferated over this period.

It is beyond the scope of this report to consider possible changes in the law over the coming decades, and in any case there are inherent difficulties in predicting the future direction of law. For this reason, this report considers the current legal regime (as at February 2006) only.

Climate Change

The precise effects of climate change are uncertain. What is certain is that there is already a demonstrated change in Victoria's climate and that our climate will continue to change regardless of the abatement measures we as a community adopt. This report has used the best available data in order to estimate the likely changes that we will see over the next 65 years (i.e. up to 2070). Due to this inherent uncertainty the projected changes are generally presented in ranges. For example the temperature change might range between 0.7℃ and 5.0℃ (for average annual temperatures). Naturally the effects on infrastructure at each of these extremes will be considerably different.

In assessing the risks of climate change, the report assumes a worst-case scenario. That is, the impacts of climate change are assumed to be at the upper level of presented ranges. This approach is used because of the level of investment in infrastructure and economic risks and implications associated with failure of infrastructure projects.

Financial Impacts of Climate Change

References are made throughout this report to the costs associated with climate change impacts. The represented costs are all in Australian dollars at the dollar's value in 2006. This will assist reader in assessing the real costs and how climate change should affect their behaviours.

This report does not attempt to simulate economic conditions over the next 65 years.

The costs associated with climate change in this report do not include consequential costs. They are based solely on the replacement value of the infrastructure items. Consequential costs of infrastructure failure in the community would take account of a broad number of additional factors. These include lost productivity, negative social effects and the likely requirement for redirection of public money by governments.

Infrastructure Status

Turnover of infrastructure is a gradual process. Items are generally replaced or upgraded on a needs basis There are differences in the life span and need for different infrastructure items. For example, some stormwater items in inner urban areas date to the early part of the last century and are nearing the end of their useful lifespan. The water infrastructure in newer areas may not be scheduled for replacement throughout the period of time contemplated by this report. Advances in technology may render some forms of infrastructure obsolete.

It is beyond the scope of this report to predict detailed infrastructure requirements past the middle of this century. The risk assessment in this report highlights the general effects of climate change on infrastructure items by industry, but does not account for individual variances in infrastructure age in different areas.

2.0 Likely Future Climate Change

2.1 Introduction

Some human-induced changes in future climate are inevitable. While international efforts to reduce emissions in greenhouse gases may limit the changes, adaptation strategies are also necessary. Adaptation should be based on assessment of potential changes in regional climate and their impacts. This report provides Victorian climate change scenarios for use in an assessment of impacts on infrastructure, for the years 2030 and 2070.

2.2 Observed Climate Change

The Earth has warmed by about 0.7℃ on average since the year 1900 (Jones and Moberg, 2003). Most of the warming since 1950 is due to human activities that have increased atmospheric concentrations of greenhouse gases (IPCC, 2001). There has been an increase in heatwaves, fewer frosts, warming of the lower atmosphere and upper ocean, retreat of glaciers and sea-ice, a rise in sea-level of about 15 cm, acidification of the oceans and increased heavy rainfall in many regions (Alexander *et al*., 2005; Fu *et al*., 2004; Pelejero *et al*., 2005). Many species of plants and animals have changed their location or the timing of their seasonal responses in ways that provide further evidence of global warming (Hughes, 2003).

Australia's average temperature has risen by almost 0.9℃ from 1910–2004 (Nicholls and Collins, 2006). Most of this increase occurred after 1950. It is likely that a significant contribution to the warming is due to increases in greenhouse gases and aerosols (Karoly and Braganza, 2004). In Victoria, since 1950, the average temperature has risen almost 0.5℃, with daily maxima increasing more than minima (Whetton *et al*., 2002).

Australian rainfall has varied substantially over time and space. Since 1950, the northwest has become wetter, while the southern and eastern regions have become drier. In Victoria, there has been a decline in rainfall since 1950, especially since the mid-1990s in autumn and winter within the state's southern areas. This appears to be due to a southward shift in weather systems due to natural variability, increases in greenhouse gases and ozone depletion (Karoly, 2003).

2.3 Future Changes in Greenhouse Gases

To estimate future climate change, scientists have developed greenhouse gas and aerosol emission scenarios. These are not predictions of what will actually happen. They allow analysis of "what if?" questions based on various assumptions about human behaviour, economic growth and technological change. This report uses scenarios developed by the Intergovernmental Panel on Climate Change (IPCC, 2001), which are described in the Special Report on Emission Scenarios (SRES, 2000). These scenarios assume "business as usual" without explicit policies to limit greenhouse gas emissions (Appendix A), although some scenarios include other environmental policies that indirectly affect greenhouse gases, e.g. policies to reduce air pollution.

2.4 Projecting Changes in Victorian Climate

Best available tools in computer modelling of the climate system were used in the study for simulating climate variability and change. These models include representations of the dynamical behaviour of the atmosphere, oceans, biosphere and polar regions. A detailed description of these models and their reliability can be found in IPCC (2001). Projected changes in global-average temperature and sea-level are described in Appendix A.

The choice of climate simulations for this study was constrained by three factors:
1. Models that perform well over south-eastern Australia;
2. Availability of simulated data with fine resolution (grid-spacing of 50 km or less); and
3. Availability of simulated daily weather data from which to compute changes in daily extremes.

Assessments of the performance of 20 models over south-eastern Australia showed that 13 of the models adequately reproduced observed average patterns of temperature, rainfall and pressure (Hennessy *et al*., 2004; McInnes *et al*., 2005). Ten of these were global climate models with a grid-spacing of 200-400 km, while three had a grid-spacing of about 50 km and daily data. One of the 50 km simulations was based on a CSIRO model (DARLAM) that has been superseded, so the other two 50 km simulations were used for this report. These simulations were performed with CSIRO's "CCAM" model. CCAM is a global atmosphere-only model with fine resolution over Australia, that can be driven by boundary conditions from a global climate model (including ocean, atmosphere, ice and land). One CCAM simulation was driven by CSIRO's "Mark 2" global climate model and the other was driven by CSIRO's "Mark 3" global climate model, henceforth called CCAM (Mark 2) and CCAM (Mark 3). Their climate projections are considered independent. Both perform well over south-east Australia, although CCAM (Mark 2) has a better simulation of average temperature. Hence, slightly more confidence can be placed in results from CCAM (Mark 2). Regional climate change patterns from each model were scaled to include the full range of IPCC SRES scenarios of greenhouse gas and aerosol emissions, and the full range of IPCC uncertainty in climate sensitivity to these emissions (Appendix A).

Victorian scenarios are presented as low-high ranges rather than a single value. The ranges incorporate quantifiable uncertainties associated with:

(i) the range of future emission scenarios;
(ii) the range of global climate sensitivity (defined as the simulated global warming for a doubling of carbon dioxide concentration from the pre-industrial level of 280 ppm); and
(iii) model-to-model differences in the regional patterns of climate change.

The IPCC (2001) global warming scenarios incorporate (i) and (ii). The CCAM simulations provide information about (iii) but they are based on unique values of (i) and (ii) rather than the full range of uncertainty. The simulations assume that there is a linear relationship between annual global mean warming and the regional mean climate response patterns (Whetton, 2001; Mitchell, 2003; Whetton *et al.*, 2005). This allows regional patterns of climate change, per degree of global warming, to be extracted from the CCAM simulations, which are then scaled for the years 2030 and 2070 using the IPCC global warming values. Spatial changes are presented as contour maps for 2030 low, 2030 high, 2070 low and 2070 high, relative to 1990. These represent changes in average climatic conditions. The conditions of any individual year will continue to be strongly affected by natural climatic variability and cannot be predicted.

These Victorian scenarios differ from those in the report by Suppiah *et al.* (2004) that considered changes in temperature and rainfall only, from 12 different climate models. While the CCAM scenarios presented below are based on only two models, they have finer resolution and cover more climate variables, i.e. annual and seasonal average temperature, rainfall, humidity and solar radiation, plus extreme daily temperature, rainfall and wind. Since some impacts on infrastructure are dependent on changes in multiple climate variables, for example, temperature and humidity, it is recommended that separate impact assessments are performed for CCAM (Mark 2) and CCAM (Mark 3), rather than mixing the ranges of change from both models. This ensures that the impact assessments are based on scenarios that are internally consistent.

2.5 Average Temperature

By 2030, average daily maximum temperatures may to rise by 0.5-1.5°C over most of Victoria, with slightly more warming in spring and less warming in winter and in southern areas. By 2070, average daily maximum temperatures may rise by 0.7 to 5.0°C over most of Victoria with spatial variation similar to those for 2030. Increases in minimum temperature are slightly less than those for maximum temperature (0.5-1.5°C by 2030 and 1-4°C by 2070), with least warming in winter-spring especially in the south. Projected changes in annual and seasonal average maximum and minimum temperature are shown in Appendix B Figure 14, Figure 15, Figure 16 and Figure 17. CCAM (Mark 2) has slightly greater warming than CCAM (Mark 3) in all seasons except winter.

2.6 Extreme Daily Temperatures

Small changes in average seasonal temperature can be associated with large changes in extreme daily temperatures. In Australia, the frequency of extreme hot events (e.g. hot days and nights) has generally increased since the mid-1950s, and the frequency of extreme cold events (e.g. cold days and nights) has generally decreased. From 1957 to 2004, the Australian average shows an increasing trend in hot days (35°C or more) of 1 day per decade, an increasing trend in hot nights (20°C or more) of 1.8 nights per decade, a decreasing trend in cold days (15°C or less) of 1.4 days per decade and a decreasing trend in cold nights (5°C or less) of 1.5 nights per decade (Nicholls and Collins, 2006).

Further changes in extreme daily temperatures are likely to occur due to global warming. Although these changes can be analysed directly from climate model simulations, a potential disadvantage of this approach is that a model's present climate simulation can contain biases in the frequency of extremes and this lowers confidence in the reliability of the enhanced climate simulation. The alternative and preferred approach for analysing extreme temperatures is to apply the range of projected change in average temperature to observed daily temperature data, then analyse the modified data for changes in extreme events above or below specific thresholds. A disadvantage of this approach is the assumption that the warming occurs with no change in daily temperature variability. However, results from climate models analysed over the Australian region by CSIRO show small and inconsistent changes in variability, so the assumption of no change in variability is reasonable. The observed maximum temperature frequency distribution for Melbourne is shown in Figure 1. The approach simply shifts this distribution to the right.

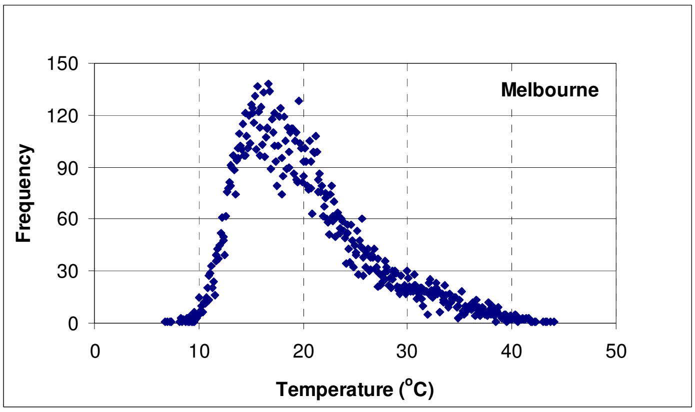

Figure 1: Observed maximum temperature frequency distribution for Melbourne, based on high quality daily temperature from the Bureau of Meteorology from 1964-2003. The frequency is the number of days within 0.1°C intervals.

Projected changes in extreme daily maximum temperatures were calculated for eight Victorian sites for which high quality observed daily data were available from the Bureau of Meteorology for 1964-2003. The projected average warming values for 2030 and 2070 in Appendix B Figure 14 and Figure 15 were applied to the observed data. The annual frequencies of six types of extreme temperature events were considered:

- days above 30°C
- three consecutive days above 30°C (warm spells)
- days above 35°C
- three consecutive days above 35°C (hot spells)
- days above 40°C
- three consecutive days above 40°C (extremely hot spells).

Table 1 and Table 2 present results for CCAM (Mark 2) and CCAM (Mark 3), respectively. The average number of days above 35°C increases 10-60% by the year 2030, and 20-100% by 2070. For example, CCAM (Mark 2) scenarios for Melbourne indicate that the number of days over 35°C increases from 9.6 currently to 10.9-12.9 by 2030 and 12.8-22.0 by 2070. At Mildura, CCAM (Mark 2) shows that the number of days over 40°C increases from 6.6 currently to 8.0-11.1 by 2030 and 10.8-26.2 by 2070. Results based on CCAM (Mark 3) are very similar.

2.7 Average Rainfall, Atmospheric Moisture and Run-Off

Projected changes in annual and seasonal average rainfall are presented in Appendix B (refer Figure 18 and Figure 19) show that there are significant differences between the CCAM (Mark 2) and CCAM (Mark 3) scenarios – the former gives widespread decreases in all seasons while the latter gives increases in spring-summer and decreases in autumn-winter. In CCAM (Mark 3), annual rainfall decreases 0-5% by 2030, with slightly greater decreases in the northwest and increases of 0-5% in the southeast. By 2070, the decreases are generally 0-20%, with decreases of 10-30% in the northwest and increases of 0-10% in the southeast. Increases in rainfall affect central and eastern Victoria in autumn and winter, while decreases affect the whole State in spring and summer. In CCAM (Mark 2), annual rainfall decreases 0-5% by 2030 and 5-10% by 2070, with slightly smaller decreases along the southwest and central coasts. Decreases are largest in spring and summer (0-20% by 2030, 5-40% by 2070), while increases occur in the north in autumn (0-5% by 2030, 0-20% by 2070).

Table 1: Average number of days per year above 30°C, 35°C or 40°C at eight Victorian sites for present conditions (1964-2003), 40 years centred on 2030 and 40 years centred on 2070, based on CCAM (Mark 2). Also shown is the average number of 3-5-day spells above 30°C, 35°C or 40°C. High and low warming scenarios are based on different assumptions about greenhouse gas emissions and climate sensitivity.

Site	Threshold Temp (°C)	Present	Present	2030 Low	2030 Low	2030 High	2030 High	2070 Low	2070 Low	2070 High	2070 High
		Days	*Spells*	*Days*	*Spells*	*Days*	*Spells*	*Days*	*Spells*	*Days*	*Spells*
Cape Otway	30	9.08	0.33	9.40	0.33	10.28	0.40	10.28	0.40	15.53	0.88
	35	2.38	0.03	2.45	0.03	2.75	0.03	2.75	0.03	4.65	0.08
	40	0.25	0.00	0.25	0.00	0.28	0.00	0.28	0.00	0.93	0.00
Kerang	30	68.68	14.93	73.20	16.08	82.73	19.25	82.00	19.05	120.98	31.53
	35	23.25	3.63	26.55	4.25	32.50	5.38	32.33	5.35	58.43	11.88
	40	4.33	0.25	5.25	0.38	7.10	0.75	7.08	0.75	17.85	2.35
Melbourne	30	30.45	3.33	33.00	3.90	36.53	4.53	36.23	4.48	55.08	7.40
	35	9.58	0.65	10.90	0.80	12.90	1.00	12.80	0.98	22.98	2.13
	40	1.18	0.00	1.45	0.00	2.00	0.00	2.00	0.00	6.13	0.35
Mildura	30	82.08	18.48	88.45	20.30	100.05	23.75	98.40	23.25	143.30	38.23
	35	32.83	5.45	36.95	6.13	44.00	7.75	43.10	7.53	73.73	15.38
	40	6.55	0.53	8.03	0.78	11.10	1.33	10.75	1.28	26.20	3.63
Nhill	30	53.50	10.08	58.03	11.33	63.80	12.75	63.55	12.73	94.08	21.05
	35	18.45	2.40	20.45	2.75	24.93	3.73	24.78	3.70	43.50	7.40
	40	3.10	0.08	3.73	0.10	4.95	0.20	4.93	0.20	12.05	1.38
Orbost	30	25.03	1.93	28.50	2.60	32.63	3.15	32.50	3.13	57.13	7.75
	35	7.33	0.28	8.15	0.35	9.90	0.48	9.85	0.48	21.05	1.30
	40	1.25	0.00	1.68	0.03	2.25	0.03	2.25	0.03	5.75	0.18
Rutherglen	30	62.75	15.10	70.10	17.20	80.25	20.13	79.40	19.88	123.08	34.18
	35	17.08	2.60	21.20	3.45	27.25	5.08	26.60	4.95	62.88	15.15
	40	1.50	0.10	2.30	0.18	3.95	0.35	3.68	0.33	19.23	3.08
Sale	30	19.93	1.18	21.88	1.33	25.45	1.73	24.85	1.63	41.23	4.50
	35	5.20	0.13	6.30	0.20	8.13	0.38	7.73	0.35	15.08	0.85
	40	0.63	0.00	0.70	0.00	1.13	0.00	0.95	0.00	3.53	0.08

The possibility of increases and decreases in rainfall implies significant uncertainty for impacts on infrastructure. However, when projected increases in potential evaporation are included, widespread decreases in atmospheric moisture occur. Potential evaporation is essentially evaporative demand: the potential of the local air to evaporate available water from open water or soil, and transpire water from plants. Figure 20 and Figure 21 in Appendix B show projected annual-average decreases in atmospheric moisture balance (rainfall minus potential evaporation) are 15-100mm by 2030 and 15-600 mm by 2070, with greatest decreases in the north, especially in spring and summer. Slightly larger decreases are simulated by CCAM (Mark 2). Small increases in moisture balance occur in coastal Victoria in autumn and winter in CCAM (Mark 3) and in winter in CCAM (Mark 2).

In a separate study based on climate change projections from ten climate models (Jones and Durack, 2005), the impact of climate change on runoff has been estimated for 29 Victorian catchments. In 2030, the most favourable outcome is a change in mean annual runoff of 0% to minus 20% occurring in catchments in the east and south of the state (East Gippsland shows a small chance of an increase) and, at worst, the possible change ranges from -5% to -45% in the west of the state. In 2070, increased runoff of 20% in East Gippsland is possible, but the minimum change across most of the state ranges between -5% and -10%. At worst, the model indicates changes that exceed a 50% reduction in all catchments.

Table 2: Average number of days per year above 30°C, 35°C or 40°C at selected Victorian sites for present conditions (1964-2003), 40 years centred on 2030 and 40 years centred on 2070, based on CCAM (Mark 3). Also shown is the average number of 3-5-day spells above 30°C, 35°C or 40°C. High and low warming scenarios are based on different assumptions about greenhouse gas emissions and climate sensitivity.

Site	Threshold Temp (°C)	Present *Days*	Present *Spells*	2030 Low *Days*	2030 Low *Spells*	2030 High *Days*	2030 High *Spells*	2070 Low *Days*	2070 Low *Spells*	2070 High *Days*	2070 High *Spells*
Cape Otway	30	9.08	0.33	9.48	0.33	10.30	0.40	10.30	0.40	15.93	0.95
	35	2.38	0.03	2.45	0.03	2.75	0.03	2.75	0.03	4.85	0.08
	40	0.25	0.00	0.25	0.00	0.28	0.00	0.28	0.00	1.00	0.00
Kerang	30	68.68	14.93	72.78	15.98	81.20	18.95	80.43	18.78	113.53	28.93
	35	23.25	3.63	26.43	4.23	31.93	5.28	31.70	5.25	54.80	11.05
	40	4.33	0.25	5.23	0.38	7.05	0.75	7.00	0.75	16.48	2.23
Melbourne	30	30.45	3.33	32.83	3.85	36.10	4.45	35.78	4.43	52.80	7.15
	35	9.58	0.65	10.85	0.78	12.73	0.95	12.70	0.95	22.23	2.10
	40	1.18	0.00	1.45	0.00	2.00	0.00	2.00	0.00	5.98	0.35
Mildura	30	82.08	18.48	87.70	20.25	97.73	23.10	96.70	22.78	135.35	35.83
	35	32.83	5.45	36.65	6.08	42.88	7.63	42.18	7.38	70.28	14.95
	40	6.55	0.53	7.98	0.78	10.78	1.33	10.43	1.25	25.18	3.68
Nhill	30	53.50	10.08	57.93	11.33	63.38	12.80	62.58	12.58	91.55	20.93
	35	18.45	2.40	20.40	2.75	24.95	3.70	24.45	3.63	41.70	7.23
	40	3.10	0.08	3.73	0.10	5.08	0.23	4.88	0.20	12.03	1.43
Orbost	30	25.03	1.93	28.50	2.60	32.23	3.13	32.23	3.13	54.20	7.33
	35	7.33	0.28	8.15	0.35	9.80	0.48	9.80	0.48	19.85	1.25
	40	1.25	0.00	1.68	0.03	2.23	0.03	2.23	0.03	5.53	0.15
Rutherglen	30	62.75	15.10	68.88	17.03	78.28	19.50	77.00	19.10	110.88	30.15
	35	17.08	2.60	20.73	3.38	25.38	4.78	24.83	4.58	54.85	12.93
	40	1.50	0.10	2.13	0.13	3.48	0.33	3.30	0.30	14.23	2.05
Sale	30	19.93	1.18	21.83	1.33	25.50	1.68	24.98	1.65	42.80	5.23
	35	5.20	0.13	6.28	0.20	8.48	0.38	8.28	0.38	15.83	0.98
	40	0.63	0.00	0.70	0.00	1.13	0.00	1.08	0.00	3.95	0.08

2.8 Extreme Daily Rainfall

Analysis of extreme daily rainfall observations from 1910-1998 (Haylock and Nicholls, 2000) shows a strong decrease in both the intensity of extreme rainfall events and the number of extremely wet days in the far south-west of Australia and an increase in the proportion of rainfall falling on extremely wet days in the northeast. Further analysis of daily rainfall over south-eastern Australia from 1900-2005 (Gallant, in preparation) shows a significant decrease in autumn total rainfall, mean rainfall, 95th percentile intensity and raindays, and a decrease in annual raindays; changes in other seasons were not significant.

Under enhanced greenhouse conditions, increases in extreme rainfall are simulated in mid-latitudes where average rainfall increases, or decreases slightly (IPCC, 2001). For example, the intensity of the 1-in-20 year daily-rainfall event may increase by 5 to 70% by the year 2050 in Victoria (Whetton et al., 2002). An updated analysis for Victoria, based on the CCAM (Mark 2) and CCAM (Mark 3) 1-in-40 year events, confirms that increases in extreme daily rainfall are likely, but decreases are also possible in some regions and seasons. This analysis is for a mid-range emission scenario, rather than the full IPCC (2001) range.

CCAM (Mark 3) simulates a 2-15% increase in the intensity of the annual 1-in-40 year event by 2030 in all regions except south-east and south-central Victoria where there is a decrease of around 10%). Increases tend to occur in summer and winter, while decreases tend to occur in winter and spring. By 2070, the annual 1-in-40 year event becomes 8-14% more intense in all regions except south-central Victoria. Seasonal increases are larger and more widespread in 2070 than 2030.

Table 3: CCAM (Mark 3) percent changes in regional average intensity of 1-in-40-year daily rainfall, relative to the average simulated for 1961-2000. (ANN = Annual; DJF = December, January, February; MAM = March, April, May; JJA = June, July, August; SON = September, October, November; NE = North East; NC = North Central; NW = North West; SE = South East; SC = South Central; SW = South West.)

Region	ANN		DJF		MAM		JJA		SON	
	2030	2070	2030	2070	2030	2070	2030	2070	2030	2070
NE	+4%	+14%	-13%	+10%	+22%	+40%	-4%	+8%	+14%	+20%
NC	+2%	+9%	+12%	+20%	-4%	+8%	+13%	+23%	-5%	+5%
NW	+10%	+13%	+24%	+6%	-3%	+9%	-2%	+11%	+14%	+21%
SE	-9%	+8%	-12%	-7%	-9%	+25%	-2%	+14%	-1%	+15%
SC	-10%	-8%	+5%	-14%	-17%	-3%	+2%	+14%	-25%	-11%
SW	+15%	+11%	+27%	=	-10%	-1%	+8%	+27%	-5%	+7%

CCAM (Mark 2) simulates a 7-21% decrease in the intensity of the annual 1-in-40 year event by 2030 in Victoria (Table 4). The decreases are strongest from autumn to spring. By 2070, the annual 1-in-40 year event decreases 1-9% in all regions except north-eastern and north-western Victoria where there are increases of around 8%. There are larger increases and smaller decreases in 2070 than 2030. Decreases remain widespread in winter, but increases dominate in summer and autumn.

Table 4: CCAM (Mark 2) percent changes in regional average intensity of 1-in-40-year daily rainfall, relative to the average simulated for 1961-2000. (ANN = Annual; DJF = December, January, February; MAM = March, April, May; JJA = June, July, August; SON = September, October, November; NE = North East; NC = North Central; NW = North West; SE = South East; SC = South Central; SW = South West.)

Region	ANN		DJF		MAM		JJA		SON	
	2030	2070	2030	2070	2030	2070	2030	2070	2030	2070
NE	-7%	+9%	-8%	+3%	-1%	+24%	-19%	-14%	-3%	+5%
NC	-21%	-9%	+2%	+3%	-20%	-16%	-16%	-17%	-12%	+5%
NW	-19%	+8%	-1%	+43%	-15%	-12%	+1%	-13%	-17%	-11%
SE	-14%	-4%	-1%	=	+14%	+20%	-21%	-24%	-24%	+5%
SC	-10%	-1%	+12%	+11%	=	+28%	-4%	=	-4%	-18%
SW	-12%	-8%	-3%	-12%	-18%	=	+3%	-8%	-10%	-4%

2.9 Extreme Wind-Speed

Projected changes in extreme daily wind-speed were based on daily 99th percentile values (the highest 1% of events). This was determined by ranking daily wind-speeds for each season within a window of three years centred on the year of interest (i.e. current year ± 1 year). For each 90-day season, this yielded 270 days that could be ranked, with the third-highest equating to the 99th percentile. Changes in the 99th percentile are shown in Appendix B Figure 22 and Figure 23. Increases in extreme wind are simulated by CCAM (Mark 3) while decreases are simulated by CCAM (Mark 2). The CCAM (Mark 3) increases are 0-6% by 2030 and 0-15% by 2070, with greatest increases in summer. The CCAM (Mark 2) decreases are 0-3% by 2030 and 0-12% by 2070, with greatest decreases in summer in the southwest. Hence, there is significant uncertainty about changes in extreme wind speed over Victoria.

2.10 Relative Humidity

Projected changes in annual and seasonal average humidity are shown in Appendix B Figure 24 and Figure 25. By 2030, the annual average humidity decreases 0-3% in both models, with greatest decreases in spring and summer. By 2070, humidity decreases 1-11%, with small increases along the coast in CCAM (Mark 2). Both models have widespread decreases in all seasons except autumn, in which CCAM (Mark 3) has small increases in Gippsland and CCAM (Mark 2) has widespread increases. Humidity also increases slightly in winter in south-western and central Victoria in CCAM (Mark 2).

2.11 Solar Radiation

Projected changes in annual and seasonal average downward (incoming) solar radiation at the surface are shown in Appendix B Figure 26 and Figure 27. Simulated changes in radiation are caused by changes in cloud cover, which are reasonably consistent with the changes in rainfall shown in Appendix B Figure 18 and Figure 19.

CCAM (Mark 3) simulates annual-average increases in radiation of 0-2% by 2030 and 0-4% by 2070, with largest increases in north-central Victoria. While increases are widespread in spring, they are confined to northern Victoria in autumn and winter, and Gippsland in summer. The summer and autumn patterns of radiation change are not very consistent with the changes in rainfall.

CCAM (Mark 2) simulates annual-average increases in radiation of 0-2% by 2030 and 0-12% by 2070, with largest increases in north-central Victoria. Increases are widespread in all seasons and greatest in spring.

2.12 Sea-Level Rise

Global-average sea-level has risen 1.8 ± 0.3 mm per year from 1950-2000 (Church *et al*., 2004). In future, sea-level is likely to continue rising due to thermal expansion of sea water, melting of land-based glaciers and melting of ice-sheets in Antarctica and Greenland (IPCC, 2001). Relative to the 1990 level, IPCC estimates that sea level will rise by 9-88 cm by 2100. Estimates of future regional variations from the global-average rise are uncertain.

2.13 Hail

Hail is not simulated by the models used in this study. However, Niall and Walsh (2005) analysed hail occurrence at Mount Gambier and Melbourne, over the months August to October for the period 1980-2001. A statistically significant relationship between hail incidence and a measure of atmospheric instability (CAPE) was established. The CSIRO Mk3 climate model simulated values of CAPE for Mount Gambier under double pre-industrial concentrations of CO2. The results showed a significant decrease in CAPE values in the future. Assuming the relationship between CAPE and hail remains unchanged under enhanced greenhouse conditions, it is possible that there will be a decrease in the frequency of hail in south-eastern Australia. At the time of the study CSIRO indicated plans to undertake an analysis of potential changes in hail risk in the next year.

2.14 Drought

Drought is a normal, recurrent feature of climate. Although drought has many definitions, it originates from a deficiency of rainfall over an extended period, usually a season or more. Droughts can be grouped into four types (American Meteorological Society, 1997):

- **Meteorological drought**: a period of months to years when atmospheric conditions result in low rainfall. This can be exacerbated by high temperatures and evaporation, low humidity and desiccating winds.
- **Agricultural drought**: in the context of this report, agricultural drought refers to periods of low soil moisture.
- **Hydrological drought**: prolonged moisture deficits that affect surface or subsurface water supply, thereby reducing streamflow, groundwater, dam and lake levels. This may persist long after a meteorological drought has ended.
- **Socio-economic drought**: the effect of elements of the above droughts on supply and demand of economic goods.

Resources were not available to calculate drought indices for the CCAM (Mark 2) and CCAM (Mark 3) models. However, Mpelasoka *et al.* (in preparation) calculated an agricultural drought index, defined as a period of extremely low soil moisture. Soil moisture deficit was calculated using a soil moisture balance model (Jones *et al*., 2001) driven by observed daily inputs of rainfall and potential evaporation from the QDPI Data Drill (http://silo.eoc.csiro.au/) on a 25 km grid. Projections of rainfall and potential evaporation from the Canadian (CCCma1) and CSIRO (Mark 2) global climate models were applied to observed daily data from 1974 to 2003. The IPCC (2001) low and high climate global warming values for the SRES emission scenarios allowed results from the models to be scaled for the years 2030 and 2070.

The soil moisture capacity was specified as 150 mm, i.e. when the soil moisture reaches 150 mm, excess moisture becomes run-off. The accumulated monthly soil moisture deficit is the amount of moisture needed to return the soil to its full capacity at the end of each month. For example, if the accumulated January soil moisture is 100 mm, the deficit is 50 mm. Pseudo-agricultural drought was identified by examining 3-month periods to see whether a soil moisture deficit would occur that was within the lowest 10% on record. Once a 3-month period was classified as a drought, it remained in the drought category until the deficiency was removed. Drought was considered removed if the soil moisture for the past three months was at a level within the highest 30% on record.

Agricultural drought frequency increases 0-20% by 2030 over most of eastern Australia in the CSIRO model, with increases of 0-20% being more widespread in the Canadian Climate Centre model. By 2070, the CSIRO worst-case scenario shows increases of 0-20% over most of Australia, reaching 40-80% in Victoria. The Canadian Climate Centre model worst-case scenario is an increase of 0-40% over most of Victoria by 2030, and 20-80% by 2070.

2.15 Fire

Bushfires, often occurring in times of drought, have been a regular feature of the Australian environment, costing hundreds of lives and causing extensive economic damage. The Bureau of Transport Economics (2001) estimated that the total cost of Australian bushfires during 1967-1999, excluding death and injury costs, was more than $2.4 billion. The 'Ash Wednesday' fires of February 1983 in South Australia and Victoria occurred at a time of a severe El Niño-induced drought, with strong winds and high fuel loads contributing to very high intensity fires that resulted in 75 deaths. In the summer of 2002–03, the most extensive and severe fires since 1939 occurred in New South Wales, the ACT and Victoria.

A study on climate change and fire weather in the ACT, NSW, Victoria and Tasmania (Hennessy *et al.*, 2006) was based on climate change scenarios from CCAM (Mark 2) and CCAM (Mark 3). An increase in fire-weather risk is likely in 2020 and 2050, as measured by the Forest Fire Danger Index (FFDI). The combined frequencies of days with very high and extreme FFDI ratings are likely to increase 4-25% by 2020 and 15-70% by 2050. For example, Melbourne is likely to have an annual average of 9.8-11.1 very high or extreme fire danger days by 2020 and 10.8-14.7 days by 2050, compared to a present average of 9 days. The period suitable for control burning is likely to contract toward winter, due to higher fire danger from spring to autumn. It is assumed that this trend in fire-weather risk would increase in 2070.

2.16 Lightning

Changes in lightning frequencies are uncertain, although there are some arguments for expecting increases as temperatures rise.

3.0 Infrastructure Risk Assessment

3.1 Objectives

The objectives of this study were to:
- Assess the risk to various types of infrastructure against a range of climate change variables;
- Determine the priority infrastructure areas for further focus and investigation;
- Identify gaps in knowledge and available research; and
- Communicate the findings in an easily identifiable form.

CSIRO climate change modelling was used to inform the assessment of risk to types of infrastructure with a minimum asset value of $1 million individually or $5 million collectively.

3.2 Risk Assessment

To conduct a high-level risk assessment of climate change impacts to infrastructure, the Australian Standard for identification and assessment of risk is AS/NZS 4360:2004 + HB436 Risk Management was used. This Standard is designed to provide a consistent vocabulary and assists risk managers by outlining a four-step process (risk identification, risk analysis, risk evaluation, and risk treatment) that allows infrastructure designers and managers to incorporate risk mitigation into their planning.

3.2.1 Infrastructure Categories

To enable the assessment to proceed in a systematic and comprehensive way, infrastructure assets were divided into the following categories:

- Water
    - Water - Storage reservoirs, waterways and irrigation channels
    - Sewer - Reticulated sewage systems, trunk sewers and treatment plants
    - Stormwater - Drainage assets and land prone to flood
- Power
    - Electricity - Power generation and transmission to substations includes power supply peak demand
    - Gas and Oil - Extraction, refining and distribution networks
- Telecommunications
    - Fixed Line Network - Trunk lines to exchanges
    - Mobile Network - Transmission towers
- Transport
    - Roads - Main and municipal roads
    - Rail - All networks
    - Tunnels - All transport tunnels
    - Bridges - All transport bridges
    - Airports - All airports
    - Ports - All jetties, piers and seawall protection
- Buildings
    - Buildings and Structures - All residential, commercial, industrial buildings and storage structures
    - Urban Facilities - All recreational, parks, community and public space facilities including major event facilities

3.2.2 Climate Change Variables

The range of climate change variables considered in this report includes:
- Solar radiation – Changes to solar radiation levels and exposure
- Available moisture – Changes to evaporation rates and levels of rainfall impacting available moisture
- Variation in wet/dry spells – Changes to water table, surface and subsoil inundation cycles
- Temperature and heatwaves – Changes in frequency of extreme max temp, and length of heat spells
- Rainfall – Changes in annual rainfall
- Extreme daily rainfall – Changes to flood levels of extreme rainfall events
- Frequency and intensity of storms – Changes to the intensity and number of storm events.
- Intensity of extreme wind - Changes in the intensity of low pressure system wind events
- Electrical storm activity - Changes in frequency and intensity of lightning events

- Bush fires – Changes in the frequency and intensity of bush fires
- Sea-level rise – Changes to average sea level
- Humidity - Changes in annual average relative humidity

As an example of some of these climate change variables, Table 5 below provides a comparison of the two CCAM models with a range from the low to the high scenarios for 2030.

Table 5: Scenarios for 2030 based on Victorian simulations by the CCAM (Mark2) and CCAM (Mark3) climate models, relative to 1990. *Fire danger scenarios are for the number of very high and extreme FFDI days by the year 2020.

Climate variable	CCAM (Mark2)	CCAM (Mark3)
Annual average temperature	Increase by 0.5-1.5°C	Increase by 0.5-1.5°C
Days over 35°C	Increase by 10-60%	Increase by 10-60%
Annual average rainfall	Decrease by 0-5% with slightly smaller decreases along the southwest and central coasts	Decrease 0-5%, with slightly greater decreases in the northwest and increases of 0-5% in the southeast
Potential evaporation	Increase	Increase
Atmospheric moisture balance	Decrease by 15-100mm	Decrease by 15-100mm
1-in-40 year daily rainfall intensity	Decrease by 7-21%	Increase by 2-15% in all regions except south-east and south-central Victoria where there is a decrease of around 10%
Extreme daily wind speed	Decrease by 0-3%	Increase by 0-6%
Annual average relative humidity	Decrease by 0-3% inland, with an increase of 0-1% along the coast. Decrease of 3-7% in spring and summer, but widespread increases of 0-1% in winter and autumn	Decrease by 0-3%. Decrease of 3-7% in spring and summer, with an increase of 0-1% restricted to southern regions in winter.
Annual average solar radiation	Increase by 0-2%, with largest increase in north-central Victoria	Increase by 0-2%, with largest increase in north-central Victoria
Sea level	Increase by 3-17 cm	Increase by 3-17 cm
Fire danger*	Increase by 4-20%	Increase by 6-25%

Generally, CCAM (Mark 3) presents a worst-case scenario for most infrastructure, forming the basis for assessments that follow. However, results from CCAM (Mark 2) are also referred to since these are plausible. Where the two models produced results that run in different directions, specifically extreme rainfall and wind speed events, the worst-case scenario was tempered by using a reduced likelihood of events occurring due to increased uncertainty.

Further investigation of extreme daily rainfall and wind speed events needs to be undertaken to inform more detailed risk assessments at a local or regional scale.

3.3 Climate Change Exposure and Infrastructure Sensitivity Matrix

The climate change exposure and infrastructure sensitivity matrix below highlights the types of infrastructure that are sensitive to exposure from particular climate change variables. Subsequent sections of this report support this matrix with high-level assessment summaries of the identified high to extreme risks. This is further supported in the Appendices, which provide a full risk assessment for each infrastructure sector and the specific risk related to governance and due diligence issues.

Table 6: Climate Change Exposure and Infrastructure Sensitivity Matrix

Infrastructure Type	Climate Change Impacts											
	Increased Solar Radiation	Decrease in Available Moisture	Increased Variation in Wet/Dry Spells	Increased Temperature & Heatwaves	Decrease in Rainfall	Increase in Extreme Daily Rainfall	Increase in Frequency and Intensity of Storms	Increase in Intensity of Extreme Wind	Increased Electrical Storm Activity	Increase in Bush Fires	Sea-Level Rise	Humidity
Water	Negligible	Definite	Definite	Definite	Definite	Definite	Definite	Negligible	Negligible	Definite	Negligible	Negligible
Sewer	Negligible	Definite	Definite	Negligible	Definite	Definite	Definite	Negligible	Negligible	Negligible	Definite	Negligible
Stormwater	Negligible	Definite	Definite	Definite	Negligible	Definite	Definite	Negligible	Negligible	Negligible	Definite	Negligible
Electricity	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Negligible	Negligible
Gas and Oil	Negligible	Definite	Definite	Negligible	Negligible	Definite	Definite	Negligible	Negligible	Definite	Definite	Negligible
Fixed Line Telecom Network	Definite	Negligible	Negligible	Definite	Negligible	Definite	Definite	Definite	Definite	Definite	Definite	Negligible
Mobile Network	Negligible	Definite	Negligible	Negligible	Negligible	Negligible	Negligible	Definite	Negligible	Negligible	Negligible	Negligible
Roads	Definite	Definite	Definite	Definite	Negligible	Definite	Definite	Negligible	Negligible	Negligible	Negligible	Negligible
Rail	Negligible	Negligible	Negligible	Definite	Negligible	Definite	Definite	Negligible	Definite	Negligible	Negligible	Negligible
Bridges	Definite	Negligible	Negligible	Definite	Negligible	Definite	Definite	Definite	Negligible	Negligible	Negligible	Negligible
Tunnels	Negligible	Negligible	Negligible	Negligible	Definite	Definite	Definite	Negligible	Negligible	Negligible	Definite	Negligible
Airports	Definite	Definite	Definite	Definite	Negligible	Definite	Definite	Definite	Negligible	Definite	Negligible	Negligible
Ports	Negligible	Negligible	Negligible	Negligible	Negligible	Definite	Definite	Definite	Negligible	Negligible	Definite	Negligible
Buildings and Structures	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite
Urban Facilities	Definite	Definite	Definite	Definite	Negligible	Definite	Definite	Definite	Definite	Definite	Definite	Negligible

Table Legend

Green	**Negligible Risk – Presents "negligible" risk within the probability of natural variation**
Orange	**Definite Risk – Presents "definite" risk within the probability of natural variation**

3.4 Positive Impacts of Climate Change on Infrastructure

In addition to the risk of impacts from climate change on infrastructure that have been assessed, several positive impacts were identified. All of these positive impacts derived from either the expected decrease in annual rainfall or the decrease in available moisture (a combination of less rainfall and increased evaporation rates), or the combination of the two may decrease corrosion rates of both steel and concrete, including reinforced concrete. This will benefit:

- Electricity transmission infrastructure;
- Gas and oil distribution infrastructure;
- Telecommunications transmission infrastructure;
- Transport bridges and tunnels;
- Airport infrastructure; and
- Buildings and structures.

These positive impacts will most likely be overshadowed by the combination of several negatively impacting variables interacting with the materials over the same period, such as increased temperature and extreme rainfall events. Further investigation of the positive impacts combined with the negative impacts on various infrastructure materials would be beneficial to inform specification of materials.

3.5 Risk Assessment Procedure

The following qualitative risk assessment procedure was used to evaluate the risks as a result of the various potential climate change impacts on particular infrastructure in Victoria. The key steps in undertaking the risk assessment involved:

1. Identification of the actual and potential climate impacts for particular infrastructure;
2. Describing a worst-case scenario for each climate change variable identified both for low and high climate change projections for 2030 and 2070. A matrix for climate change variables and climate change impacts was created for each scenario and presented in the Appendices;
3. Risk is defined as the combination of consequences and likelihood. For each worst-case scenario, the consequences and likelihood of occurrence were determined in accordance with Table 7 and
4. Table 8 for infrastructure service, social, governance and financial aspects. The consequences and likelihoods have been considered using the current (2005) level of adaptation response to climate change and does not include any uptake of potential adaptation responses by 2030 and 2070;
5. Determination of the risk rating for infrastructure service, social, governance and financial aspects using Table 9 below. The inherent risk rating can then be determined by taking into account the level of consequential risk across the four aspects of infrastructure service, social, governance and finance; and
6. Suggestion of mitigation measures for consideration in a climate change vulnerability risk control framework (Note that determining the cost of these mitigation measures and the resultant residual risk are outside the scope of this assessment).

3.5.1 Assumptions Underpinning the Risk Assessment

There are a number of assumptions underpinning the risk analysis undertaken in this study. Of particular note are the following:

1. In assessing the risk using the Australian Standard AS/NZS 4360:2004 + HB436 Risk Management, the consequences were assessed using the worst case scenario for an event or impact on materials over time;
2. No adaptation response has been undertaken to mitigate against climate change impacts for 2030 and 2070;
3. The financial impacts estimated do not include consequential losses;
4. All dollar figures are in 2006 dollars;
5. The social and governance risks are considered in the risk assessment, with some of the risks identified being directly related to forced management responses imposed by a combination of climate change impacts to infrastructure and expectations of service delivery;
6. Where possible quantitative measures were used to classify the level of risk, and link likely consequences to historical events; and
7. It is acknowledged that a proportion of the infrastructure assessed would be near the end of its design life and was intentionally included as replacement of these assets is at risk of not being designed for future climatic conditions.

3.5.2 Aspects Assessed

The aspects assessed are defined as follows:

- Infrastructure services – Negative impacts to human-made physical infrastructure and the intended service it provides to the community, industry, government and the natural environment;
- Social – Negative impacts to human health, amenity and community. Level of public response to impacts;
- Governance – Negative impacts to management of organisations and government. Legal, regulatory and management responses; and
- Finance – Costs including necessarily ancillary plant/equipment to maintain (e.g. air conditioning equipment), repair and replace infrastructure and the intended service it provides. Wider economic impacts are not implied.

Table 7: Qualitative Measures of Consequence

Level	Descriptor	Infrastructure Service	Social	Governance	Financial
1	**Insignificant**	No infrastructure damage.	No adverse human health effects or complaint.	No changes to management required.	Financial loss of less then $2M[1].
2	**Minor**	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 10-20%. Need for new/modified ancillary equipment.	Short-term disruption to employees, customers or neighbours. Slight adverse human health effects or general amenity issues. Negative reports in local media.	General concern raised by regulators requiring response action.	Additional operational costs. Financial loss $2$10M).
3	**Moderate**	Widespread (state) infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. Partial loss of local infrastructure. Early Renewal of Infrastructure by 20-50%.	Frequent disruptions to employees, customers or neighbours. Adverse human health effects. Negative reports in state media.	Investigation by regulators. Changes to management actions required.	Financial loss ($10M-$50M).
4	**Major**	Extensive infrastructure damage requiring extensive repair. Permanent loss of regional infrastructure services, e.g. a bridge washed away by a flood event. Early renewal of Infrastructure by >50%.	Permanent physical injuries and fatalities may occur from an individual event. Negative reports in national media. Public debate about infrastructure performance.	Notices issued by regulators for corrective actions. Changes required in management. Senior management responsibility questionable.	Major financial loss ($50M-$200M).
5	**Catastrophic**	Permanent damage and/or loss of infrastructure service across state. Retreat of infrastructure support and translocation of residential and commercial development.	Severe adverse human health effects – leading to multiple events of total disability or fatalities. Emergency response. Negative reports in international media.	Major policy shifts. Change to legislative requirements. Full change of management control.	Significantly high financial loss (>$200M).

Table 8: Qualitative Measures of Likelihood

Level	Descriptor	Description
A	Almost Certain	The event is expected to occur in most circumstances
B	Likely	The event will probably occur in most circumstances
C	Moderate	The event should occur at some time
D	Unlikely	The event could occur at some time
E	Very Unlikely	The event may occur only in exceptional circumstances

[1] Dollar values are in 2006 $AUD terms

Table 9: Risk Rating Matrix

Likelihood	Consequences				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (almost certain)	L	M	H	E	E
B (likely)	L	M	M	H	E
C (moderate)	L	L	M	H	E
D (unlikely)	L	L	M	M	H
E (very unlikely)	L	L	L	M	M

E - Extreme risk, requiring immediate action.
H - High risk issue requiring detailed research and planning at senior management level.
M - Moderate risk issue requiring change to design standards and maintenance of assets.
L - Low risk issue requiring action through routine maintenance of assets.

3.6 Summary of Prioritised High and Extreme Risks

A summary of the climate change risks to the various infrastructure sectors is provided below in Tables 11 to 14. The summary tables indicate for each climate change scenario (i.e. 2030 Low), the identified infrastructure risks for risk categories High and Extreme. The total range of risks identified for each scenario is indicated in the infrastructure risk assessments in section 5 to 9 of this report. The details of each individual risk for any given scenario in provided in Appendix C to G of this report.

For the 2030 Low scenario, the water sector stands out as the only infrastructure sector at high risk from climate change impacts as indicated in Table 11. No extreme risks have been identified for this scenario.

Table 10: 2030 Low Scenario - Summary of High and Extreme Risks

Sector	High Risks	Extreme Risks
Water (Details in Appendix C)	Water shortage	Nil
	Storm water drainage and flooding damage	

For the 2030 High scenario, the water, power, telecommunications, transport and buildings sectors all have high risks from climate change impacts as indicated in Table 12. No extreme risks have been identified for this scenario.

Table 11: 2030 High Scenario - Summary of High and Extreme Risks

Sector	High Risks	Extreme Risks
Water (Details in Appendix C)	Water shortage	Nil
	Bushfire damage on catchment and storage	
	Storm water drainage and flooding damage	
Power (Details in Appendix D)	Increase in demand pressure blackouts	Nil
	Substation flooding	
Telecommunications Details in Appendix E)	Exchange station flooding of exchanges, manholes and underground pits	Nil
Transport (Details in Appendix F)	Bridge structural material degradation	Nil
	Storm impacts on ports and coastal infrastructure	
Buildings (Details in Appendix G)	Degradation and failure of foundations for buildings and structures	Nil
	Increased storm and flood damage to buildings and structures	
	Coastal storm surge and flooding to buildings and structures	
	Increased bushfire damage to buildings and structures	

For the 2070 Low scenario, all infrastructure sectors are exposed to high risks, with the water sector having an extreme risk as indicated in Table 13. The 2070 Low scenario is very similar to 2030 High scenario (Table 12), with exceptions being influenced by greater potential increases in extreme rainfall events in 2070 in comparison to 2030 (therefore greater storm water flooding damage to drainage infrastructure, bridges and tunnels). The only other exception was the relative reduction in risk of coastal storm surge and flooding to coastal buildings and structures due to lower sea level rise in a 2070 Low scenario (7 cm) than in a 2030 High scenario (17 cm).

Table 12: 2070 Low Scenario - Summary of High and Extreme Risks

Sector	High Risks	Extreme Risks
Water (Details in Appendix C)	Water shortage	Storm water drainage and flooding damage
	Bushfire damage on catchment and storage	
Power (Details in Appendix D)	Increase in demand pressure blackouts	Nil
	Substation flooding	
Telecommunications Details in Appendix E)	Exchange station flooding of exchanges, manholes and underground pits	Nil
Transport (Details in Appendix F)	Bridge structural material degradation	Nil
	Storm damage to bridges	
	Tunnel flooding	
	Storm impacts on ports and coastal infrastructure	
Buildings (Details in Appendix G)	Degradation and failure of foundations for buildings and structures	Nil
	Increased storm and flood damage to buildings and structures	
	Increased bushfire damage to buildings and structures	

For the 2070 High scenario, the water, power, transport and buildings sector all have high and extreme risks, while telecommunications has only high risks as indicated in Table 14. 2070 High scenario indicates a significant increase in high and extreme risk to infrastructure in Victoria.

Table 13: 2070 High Scenario - Summary of High and Extreme Risks

Sector	High Risks	Extreme Risks
Water (Details in Appendix C)	Degradation and failure of water supply piping	Water shortage
	Degradation and failure of sewer piping	Bushfire damage on catchment and storage
	Sewer spills to rivers and bays	Storm water drainage and flooding damage
	Degradation and failure of drainage infrastructure	
Power (Details in Appendix D)	Storm damage to above ground transmission	Increase in demand pressure blackouts
	Substation flooding	
	Reduction in hydroelectricity generation	
	Reduction of coal electricity generation	
	Offshore infrastructure storm damage	
Telecommunications Details in Appendix E)	Storm damage to above ground transmission	Nil
	Flooding of exchanges and underground pits, manholes and networks	
Transport (Details in Appendix F)	Road foundations degradation	Storm impacts on ports and coastal infrastructure
	Rail track movement	
	Bridge structural material degradation	
	Storm damage to bridges	
	Tunnel flooding	
	Sea level rise impacts on tunnels in proximity of coast	
	Extreme event impacts to airport operations	
	Sea level rise impacts on port infrastructure materials	
Buildings (Details in Appendix G)	Degradation and failure of foundations for buildings and structures	Increased storm and flood damage to buildings and structures
	Degradation and failure of urban facilities' materials	Coastal storm surge and flooding to buildings and structures
	Increased storm and flood damage to urban facilities	Increased bushfire damage to buildings and structures
	Coastal storm surge and flooding to urban facilities	

The exposure to high and extreme infrastructure risks from climate change will clearly escalate over time, as indicated by Table 15. This table also indicates that there are a significant range of moderate infrastructure risks generated by climate change.

Table 14: Total Number of Identified and Assigned Risks for Each Scenario

Scenarios	Risks Assigned			
	Low	*Moderate*	*High*	*Extreme*
2030 Low	19	27	2	Nil
2030 High	8	28	12	Nil
2070 Low	9	26	12	1
2070 High	1	16	23	8

3.7 Comparison of Infrastructure Sector Risk Ratings

Each of the infrastructure sectors in Victoria have a different climate change risk profile for each scenario described in this report. Each sector's risk rating (i.e. Transport, Buildings, Power, Telecommunications and Water) is compared in Figure 2 providing a quantitative risk profile against each climate change scenario.

The infrastructure sector risk ratings in Figure 2 were determined by using a summary of identified risks to establish the percentage of the total assigned risks that each individual risk category represented (i.e. if 3 out of 12 assigned risks were determined to be High, this represents 25% of the risks assigned to that Sector for a climate change scenario). Lastly, a weighting was applied to each risk category to ensure that sectors of particular concern are highlighted for prioritisation.

The risks to water infrastructure in 2030 are considerably higher than the rest of the infrastructure sectors for a 2030 Low and High scenario. Of these other sectors, the building infrastructure is considerably more vulnerable under a 2030 High scenario when compared to transport, power and telecommunications.

In 2070, the risk profile is more than double that of 2030 for all infrastructure sectors. Again water infrastructure is clearly a priority risk in 2070, followed by buildings being distinctly vulnerable under a 2070 High scenario.

Transport and power infrastructure also have a significant risk profile in 2070. Telecommunications in 2070 is less of a priority when compared to impacts on water infrastructure, yet the risks to this sector will obviously still need to be managed.

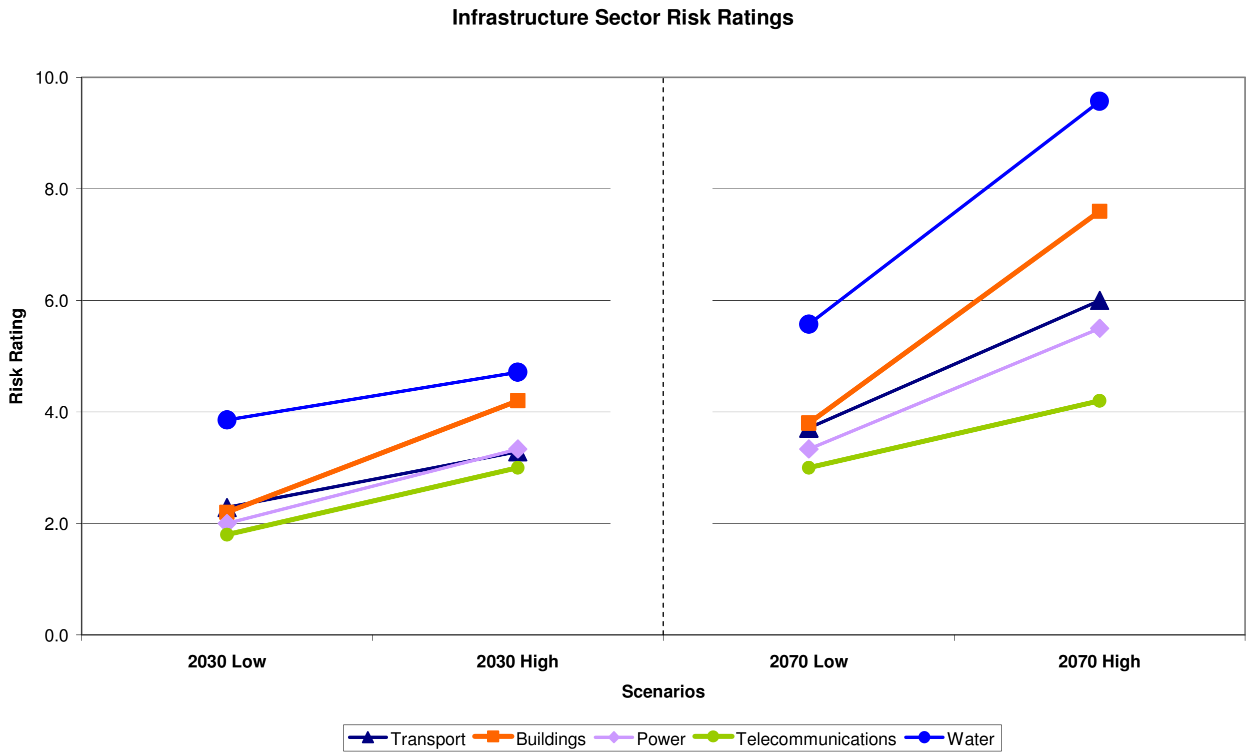

Figure 2: Infrastructure Sector Risk Ratings for Scenarios

3.8 Location of Infrastructure at Risk

When considering climate change risk to infrastructure, it is important to acknowledge the relationship between the density of infrastructure, and the aggregation of potential risk of climate change impacts to infrastructure services and life expectancy of assets.

The two figures below are provided to help describe the infrastructure risk in a spatial sense, by showing the density of infrastructure throughout the State. These figures clearly communicate priority areas that may need to be focused on for further study and action.

The data used was existing Geographic Information Systems (GIS) data used by the Department of Sustainability and Environment. For any further investigation using GIS data at a regional or local level, it is suggested that information is also sourced from a combination of utilities, local government and statutory agencies (such as VicRoads) GIS data to improve the analysis and prioritisation of risk areas. The weighting of risks in GIS analysis will also improve clarity of priority risks. Telco infrastructure data was not available for this study, although the intensity of telco infrastructure would be highest within urban and regional centres.

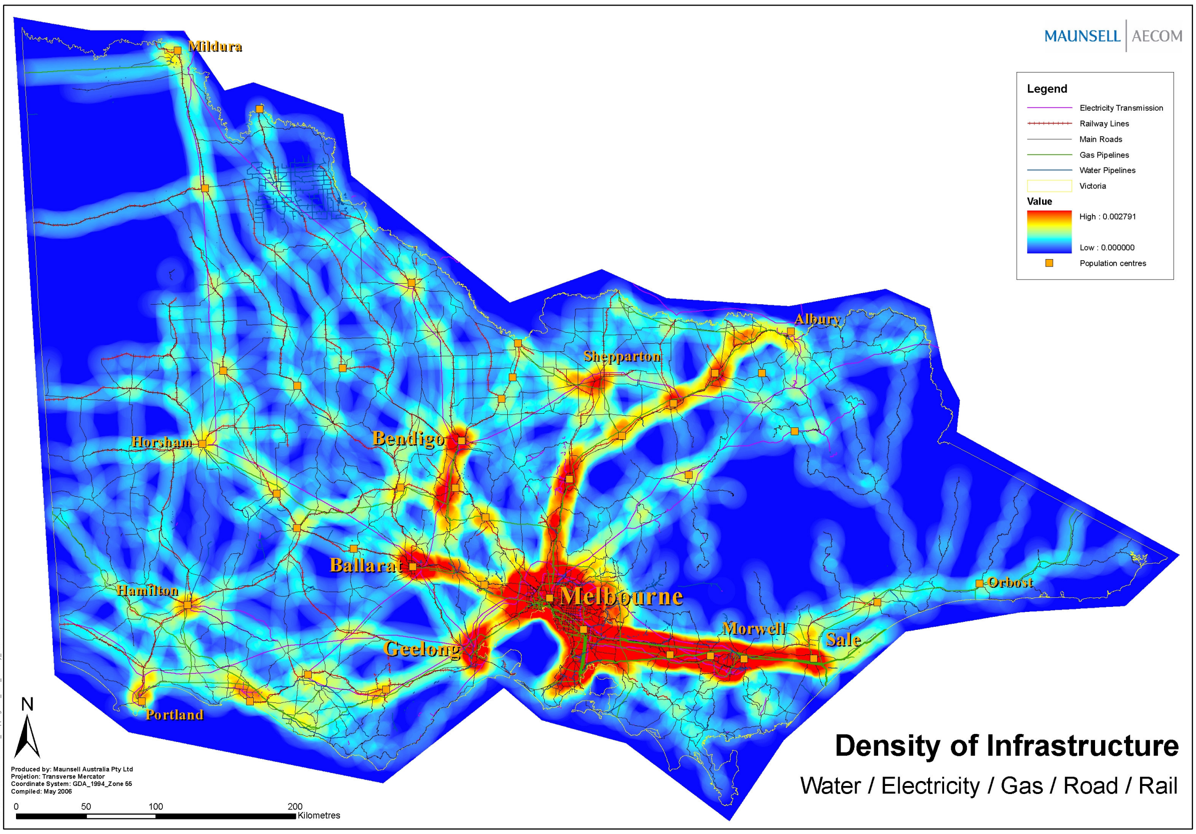

Figure 3: Density of infrastructure

Figure 3 clearly demonstrates the accumulation of infrastructure around settlements. The red areas indicate the highest infrastructure density and these areas of concentration include:

- Melbourne
- Geelong
- Ballarat
- Bendigo
- Castlemaine
- Shepparton
- The Hume Highway corridor
- The Gippsland corridor from Melbourne's south-east, through Morwell to Sale

In the State's north-west, south-east of Mildura, there is a lightly marked, dense grid. This represents irrigation infrastructure, and was the only area where information on the irrigation infrastructure was provided. This gives an indication that irrigation infrastructure should be included in any further investigations using this tool, given its heavy density in the northern part of the State.

Figure 4, with its west-east and north-south profiles, provides an indication of where the risk is located in the context of the relative size of the risk distributed across the state. It was to be expected that Melbourne would have a major density of infrastructure. However, a distinct risk corridor through Gippsland from Melbourne to Morwell stands out as an area of significant infrastructure density.

The GIS based risk profile approach as a communication tool would be particularly useful when assessing infrastructure risk at a local or regional level in order to clearly identify risk priorities across a landscape.

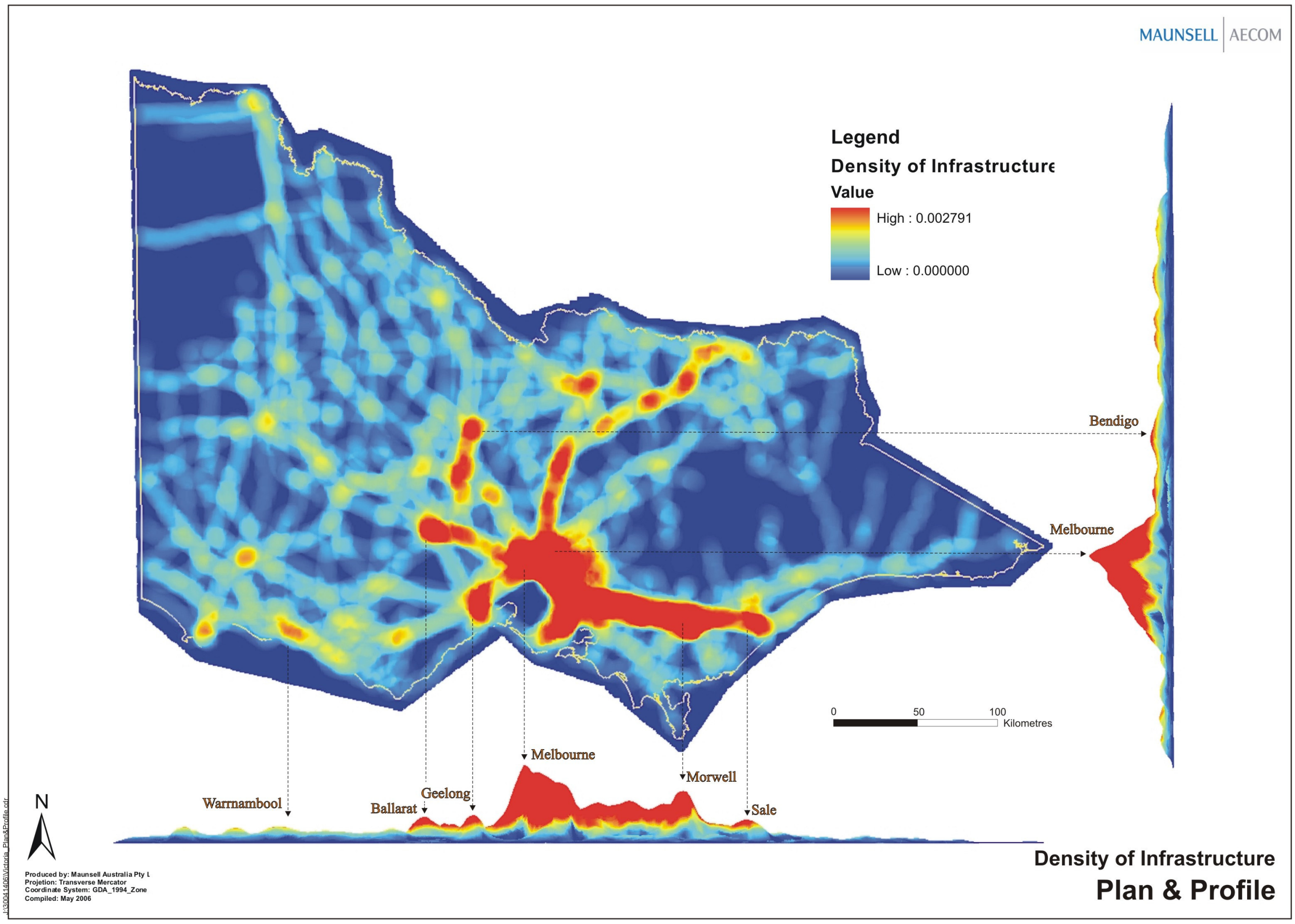

Figure 4: Plan and profile of infrastructure density

4.0 Governance Implications

4.1 Introduction

The risks identified in this report represent a significant governance challenge for infrastructure owners, managers and decision makers. It is clear that all infrastructure sectors will be affected to some degree, and that current assumptions about the likely range of future climate conditions require review.

Unfortunately, responding to the report findings is not as straight forward as replacing current assumptions with a set of new ones that account for predicted changes in climate. For while there is a strong scientific understanding of likely global changes in climate, specific local impacts are much more difficult to predict.

This complexity and uncertainty pose challenges for decision making about the design, construction and management of infrastructure. These challenges are compounded by the large number of people from differing disciplines who are involved in such decisions, and the limited ability that infrastructure managers have to modify fundamental design parameters once infrastructure has been built.

An additional, important consideration from a governance viewpoint is the extent to which the owners of assets should spend what might be considered to be unreasonable sums mitigating perceived risks of uncertain probability. Clearly, an authority or company must determine the balance between additional current capital expenditure designed to secure the improved security and performance of an asset against the imposition of that cost on taxpayers or customers.

The implications of climate change for governance frameworks need to be carefully considered. Currently, there are a wide range of public and private sector owners and managers of infrastructure of varying ages and conditions. These owners and managers face the challenge of identifying the risks from climate change to the continued provision of services and taking appropriate mitigation measures, as outlined throughout this report. Regarding existing assets, the challenge is achieving the balance between current expenditure in response to a perceived risk and the level of mitigation necessary to maintain service levels. If inadequate action is taken in the face of clear knowledge of these risks, any person who suffers loss or damage may be entitled to bring a claim. It is with the knowledge of that potential liability that governance frameworks must be structured to adequately manage the risks.

In respect of new assets, it is to be expected that both regulatory frameworks will be amended to respond to the climate change challenge, and that professionals working in key disciplines will become better aware of the need to incorporate climate change- based design responses.

In this way, bodies having governance responsibilities will be able to ensure that service objectives can be achieved within an informed cost environment. As this is a matter that will need to be weighed in respect of individual investment decisions by each government agency or authority, the discussion here has an emphasis on the legal risks and liability issues.

4.2 Legal Framework for New Infrastructure Design

In Victoria, the design, siting and construction standards for new infrastructure are primarily controlled by two main pieces of legislation: the *Building Act* 1993 (Building Act) and the *Planning and Environment Act* 1987 (PE Act). Both of these acts establish a broad framework of control, with specific requirements being introduced through the *Building Code of Australia* (BCA) and local Planning Schemes. The BCA and planning schemes also make reference to relevant *Australian Standards*. The Victorian building regulations is the state law that applies the BCA in Victoria.

Some infrastructure classes have additional design standard imposed on them through their regulatory regime that governs activity in this sector. For example, the *Pipelines Act* 1967 provides for specific design standards to be imposed in respect of gas pipelines, either through regulation or as a condition of the required permits.

Control of new development is primarily achieved through requirements to obtain permits prior to undertaking certain actions. Under the Planning and Environment Act, permits can be required for the use of land, the development of land, or both. Under the Building Act a building permit will be required for almost all building activity, and inspections need to be made at certain stages of the building process, so as to ensure compliance with relevant standards.

Planning permits are issued by the planning authority for the area in which the use or development is proposed (usually the local council). Building permits are issued by municipal or private building surveyors, in accordance with the Building Act.

For major infrastructure, additional approvals are often required under relevant environmental impact assessment legislation (i.e. the *Environment Effects Act* 1970 (Vic) and the *Environment Protection and Biodiversity Conservation Act* 1999 (Commonwealth). Also, more specific standards and controls are applied to the individual infrastructure sectors, through sector specific legislative frameworks. These items are dealt within the governance section of each of the chapters that follow.

The design and construction of most infrastructure commonly involves a range of different professionals, including architects, town planners, engineers, lawyers and surveyors. The individuals or firms that provide these services are to some extent reliant on each other, and all are subject to professional responsibilities particular to their discipline. Many of these professional responsibilities are supported by legislation that regulates conduct of the members of the profession in question.

Almost all infrastructure, whether in public or private ownership, is built in accordance with formal building contracts between the builder and the ultimate owner of the building. Such contracts commonly require minimum levels of performance from the builder, including (typically) compliance with relevant *Australian Standards*. Some *Australian Standards* are probably so universally adopted that there is an implied requirement in such contracts that they be adhered to.

4.3 Responsibility for Addressing Climate Change in Infrastructure Design and Management

Fundamentally, it is the ultimate owner of any piece of infrastructure who must ensure that it is designed to operate effectively for its design life, since they will bear the primary liability in the event of failure. Of course, it is not quite as simple as that, since as already noted, the design process for major infrastructure projects involves a complex interaction between the owner(s), financiers, design (and other) professionals and development regulators. All involved in the process are obliged to exercise a level of care consistent with their expertise and any statutory obligations that they may have.

The wide implications of climate change mean that it is likely that most, if not all, parties involved in the design of particular project will be obliged to address it in some form. However, it is unlikely that any one party will 'naturally' take ownership of the issue, and as a consequence many may assume that the issue is being dealt with by others (to the extent they consider it at all). Therefore, one challenge of dealing with the demands of climate change will be ensuring that the relevant issues are not overlooked. This may require intervention from government to effectively distribute responsibility.

4.4 Liability for Climate-Change-Induced Losses

The risks of damage to infrastructure resulting from events caused or contributed to by climate change assessed in this report potentially give rise to major costs due to property damage, economic loss, death or injury and community health problems. Those costs will have to be borne by those who directly suffer the losses, those who may be legally liable, and insurers. Indirect losses will be felt by the community more broadly, and in many cases may be considerable.

Those who suffer loss will inevitably look to recover those losses where possible. Insurance, whether first party or third party, will play a significant role in this regard. However, it is unlikely to be a panacea. Indeed, if increases in extreme weather events produces claims with a value significantly greater than what can be sustained by the income generated through premiums, it is to be expected that the insurance market will adapt to the new conditions by altering premiums and risk exposures. Insurance issues are dealt with separately (and in more detail) in this report.

Each of the categories of infrastructure assessed involves elements of planning, construction, exercise of statutory power or obligations (or failure to do so) and civil obligations. Each of these activities or obligations generates potential legal liabilities for the entities involved, from both the public and private sectors. Government and its agencies finds it itself in a significantly different position to the private sector organisations, in that it can claim the benefit of immunity in respect of policy decisions, and claims resulting from its failure to act in circumstance where it has statutory or other power to do so.

As a matter of broad principle, although the risk of harm from events generated by climate change will be reasonably foreseeable and government bodies may have the power or duty to do things that may limit or prevent that harm, the law as it stands will not necessarily impose any legal liability for a failure to exercise the duty or power. In recent times, Courts have been reluctant to impose any legal liability on Government for failure to exercise statutory powers.

A key example of this trend is the decision in *Graham Barclay Oysters Pty Ltd v Ryan*, which concerned the contamination of oysters in Wallis Lake, NSW. Here, the High Court declined to find against State and Local Governments, concluding that they did not owe a duty of care to exercise their powers to ensure proper oyster management in the lake. The claim against the NSW Government failed because the Court did not consider it appropriate to examine the reasonableness of the Government's decision to allow substantial self regulation in the oyster industry. The claim against Council failed because the claimant was unable to establish any specific act or omission on the part of Council that would have prevented the harm that occurred.

However, courts are willing to find liability for losses arising out of operational decisions made by Government. A good example of this is the decision in *Brodie v Singleton Shire Council*, which concerned the collapse of a bridge when used by a cement truck weighing significantly more than the bridge's carrying capacity. There was no signage indicating the bridge's load limits. The High Court ultimately found the Council that maintained the bridge liable for the losses suffered. This overturned an historical exemption from liability for highway managers.

The *Brodie* case indicates that the Courts see a distinction between policy and operational decision making by Governments. In relation to operational decisions, courts will deal with the actions of Government bodies in the same way as they deal with the actions of private citizens or corporations. That will lead to the imposition of duties of care and appropriate standards. However, it is important to remember that the standards that are imposed on Government may be set differently than for private interests, because the Courts recognise that often Governments have limited resources to apply to responsibilities that they cannot walk away from. As a consequence, courts may be willing to excuse a Government’s failure to take precautions that would be considered reasonable for a private entity, where resource constraints can be demonstrated.

There is one other relevant limit on the liability exposure faced by the infrastructure sector - generally speaking purely economic losses will not be recoverable. Courts draw a distinction between losses arising through damage to property or personal injury, and losses resulting from the economic disruption caused by such damage. These economic losses are recoverable when suffered by person or company that has suffered physical damage, but not when such damage has not occurred. An example of purely economic loss is, the losses suffered by an industrial customer as a result of a utility's failure to supply water or power.

Claims of this type were made against Esso after the Longford gas explosion. The Victorian Supreme Court determined that Esso did not owe a duty of care to gas users not to interrupt the supply of natural gas, so as to avoid causing economic loss. However, a duty of care did arise for persons or companies who suffered actual property damage or personal injury. An important factor in this decision was the fact that gas users' vulnerability was limited: they were aware of their own vulnerability and were able to take steps to avoid or minimise its effect. The availability of insurance against the risk was also considered to be relevant.

Relevantly for Government, the Court considered that essential services are the responsibility of Government and that in light of the existing statutory regime governing the industry, liability for the stoppage of a gas supply was ultimately a question for government. The principles applied by the Court here would limit Government exposure for pure economic loss claims associated with the failure to supply or provide access to infrastructure systems.

As noted above, every aspect of infrastructure design and construction involves multiple players. Builders, designers, town planners, building surveyors and local authorities may all face a liability arising from defects and failures of buildings which they have been involved in the approval of,. That liability will also extend to third parties who may suffer injury by reason of negligent design or construction of building structures. One limitation imposed on this liability is that a subsequent purchaser of a commercial building may not recover damages for pure economic loss from a local government or other planning authority. However, this principle is not absolute and is still an evolving area of law.

In more general terms, statutory immunities may arise under the legislation governing the activities of government and quasi government bodies. These specific statutory provisions vary across the different infrastructure segments, and are dealt with in the chapters that follow.

Finally, it is noted that these comments reflect the current status of the law and themselves demonstrate the changing nature of law (e.g. the *Brodie* decision above). Over the next 65 years we will see a continued evolution of the law. This evolution will itself be guided by community needs and opinions upon which infrastructure failures may have an effect.

4.5 Insurance for Climate Change Losses

Although insurance is a vital part of the resources available to manage the risks of climate change, it is only part of the picture. The risks identified in this report represent a major issue for the general insurance industry, which is already confronting growing numbers of large scale losses and increasing magnitudes of individual events.

Over the last two decades, the largest catastrophe losses borne by insurers have been weather related. A 2004 SwissRe survey of claims from weather related losses documented a global record claims total of US$107 billion. SwissRe (2006) shows that losses in 2005 totalled US$230billion, of which Hurricane Katrina cost US$125billion, Hurricane Wilma US$20billion and Hurricane Rita US$15billion. That compares with an average of US$4 billion per year during the 1950s, rising to US$46 billion per year in the 1990s. Loss estimates from Munich Re (2006) are lower, but equally concerning (Figure 5).

In this context, it is not surprising that major players in the insurance market have been working to better understand the risks of climate change for some time. One of the key issues for insurers is that the traditional technique used to model risk, historical analysis, appears inappropriate in the face of what is known about climate change. The continued pricing of insurance products on the basis of historical analysis may mean that insurance products are systematically under priced, threatening the validity of some existing business models,

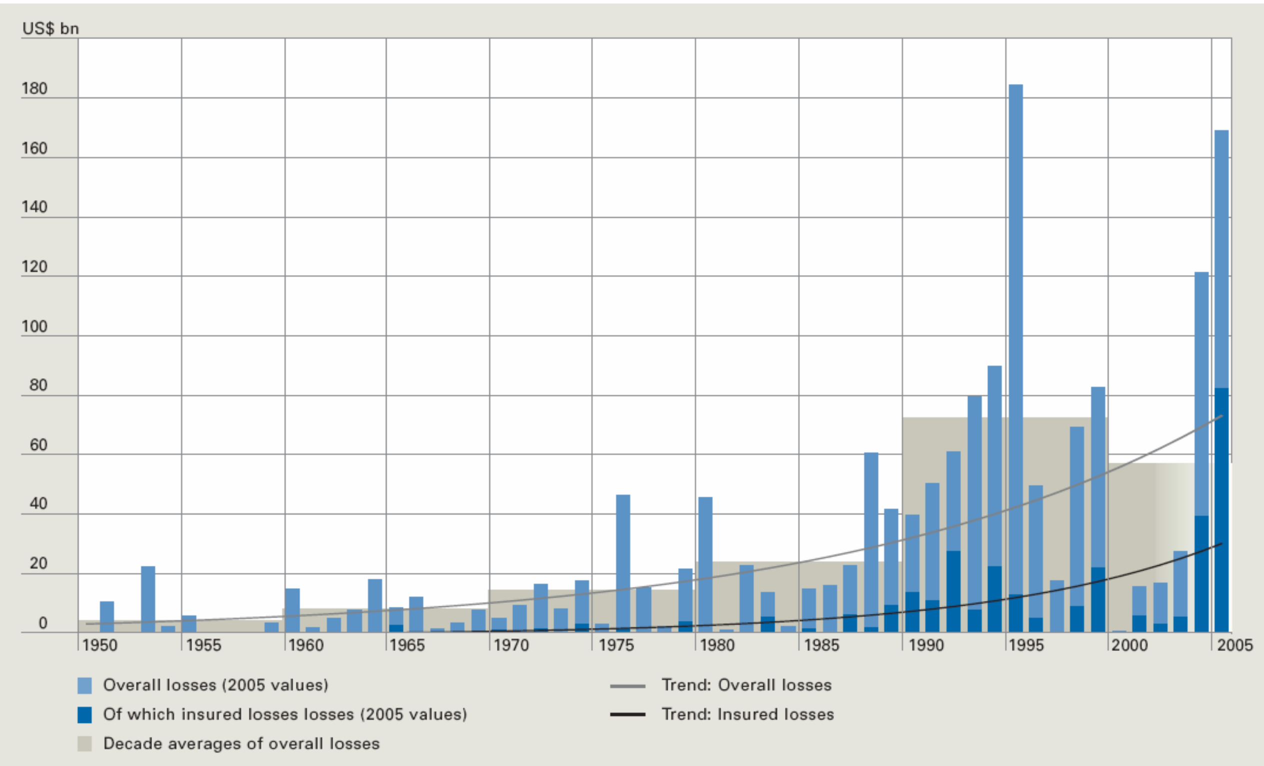

Figure 5. Overall losses and insured losses, adjusted to present values (Munich Re, 2006).

As insurers increasingly base risk assessments on future climate and weather projections rather than historical records, we can expect to see a reassessment of current business practices. It may be that the terms of available coverage will alter significantly, in light of the changed risk profile that modelling is likely to indicate. In this context, it is important to remember that insurers are (generally) private corporations with a duty to shareholders to generate profits. As such they are not obliged to underwrite risks that will not generate profit. An example of how changing risk profiles can affect the availability of insurance coverage is the recent difficulty faced by small sporting associations and clubs obtaining public liability insurance. Where risks become too great, insurance markets often retract.

However, the current trends appear to be running in the opposite direction. The percentage of catastrophe losses that are insured is steadily increasing. The capital backing and the premium pool of funds is expected to continue to increase, particularly as insurance becomes more fully utilised in developing countries. This raises the stakes for the insurance companies and the communities that rely on them while climate change risk is not widely understood. The danger is that a series of 'worst case scenario' events occur over a short space of time, resulting in claims that exceed the pool of funds available to cover them. This is a significant issue for Governments, as in such a situation they may be forced to intervene.

A good example of this process is the universal approach of insurers to the exclusion of terrorism risks subsequent to the US World Trade Centre losses. In Australia, the response at government level was the introduction of the *Terrorism Insurance Act 2003*. This established a government-funded reinsurance pool which, for certain classes of insurance, effectively imposes compulsory cover for terrorist risks. The funding structure, backed by the Commonwealth, is aimed at facilitating the return of the private sector insurance market into the provision of this cover.

In Australia, the insurance industry has traditionally excluded claims arising from flooding. More recently the industry recognised that an appropriate solution needs to be found. The exclusion of flood risks is not reflective of the frequency and severity of floods in Australia. By way of comparison, the damage arising from incidents such as the Sydney hail storm and Newcastle earthquake gave rise to significantly higher losses. Similarly, heatwaves and bushfires have caused extensive loss and injury.

An example of the role of government in providing security to citizens for flood-related losses is the US Federal Emergency Management Agency, which provides backup flood cover. Significant tracts of New Orleans are below sea level and the program provided cover for those who could not afford commercial flood cover. That has led to a proposal that the US government create a reinsurance system for catastrophic losses in the same way that the Australian *Terrorism Insurance Act* 2003 (Cth) has dealt with terrorist risks. Schemes of this kind may be introduced within Australia at both Federal and State level to meet the risks posed by climate change. The most appropriate approach to these issues would be pre-emptive Government action.

Munich Re (2006) states that it 'has long been warning that increasing global warming will be accompanied by extraordinary weather-related natural catastrophes'. The company's fears were confirmed in 2005. The international insurance industry managed to cope with 2005's record losses, but the ability to provide cover for natural hazards in future will depend on the development of adequate insurance solutions for catastrophe scenarios that have hitherto been inconceivable.'

This is a clear message that climate change is already forcing major insurance players to rethink their current approaches. As noted above, further change seems likely, with increased premiums, altered product offerings and more stringent eligibility requirements expected to be part of an insurance future driven by predictive modelling rather than historical analysis. A solid understanding of this new landscape will be strategically important for infrastructure players and Governments.

The above comments put the insurance industry in context when considering the funding of losses resulting from damage to infrastructure generated by climate change. The insurance market has shown remarkable resilience and adaptability to new challenges. The key challenge at present is to facilitate pre-emptive consideration of climate change risks, rather than to wait for the risks to materialise.

Currently, a large proportion of the losses identified in this report will be covered by insurance. In the first instance, property and consequential losses will be covered by first party insurance. However, a significant proportion of government-owned property and legal liability exposures are self-insured.

Many of the statutory bodies and quasi-government entities that are responsible for the ownership, operation or functioning of the infrastructure systems dealt with in this report do have comprehensive insurance cover covering both property and legal liability risks. In many instances this cover is placed through the Victorian Managed Insurance Authority. However, there is a significant retention of risk by those entities.

Local governments in Victoria also carry property and liability insurances that would respond to the risks identified in this report. Builders, designers, engineers, town planners and building surveyors also carry liability insurance that potentially would respond to claims resulting from defective design or construction. Accordingly, losses that in the first instance may be sustained by Government or its instrumentalities maybe recoverable from other parties and their insurers. Obviously, that is only in the event of a legal liability being established against those parties. Such liability will be founded when the Courts are prepared to extend the duty owed by these professions to include climate change related issues. With the expanding knowledge of climate change, consideration of climate change is likely to be considered in what constitutes a reasonable standard of care.

Many of the potential losses caused by events resulting from climate change will not create a legal liability on any party. Clearly, future planning and design issues will have to take account of these increasing risks. Over time, relevant standards and specifications will become more onerous. The level of care expected of those involved in planning and design is traditionally based on current standards. The interesting challenge for these disciplines and, ultimately, for the Courts, will be the extent to which current standards have to anticipate future trends. For the same reasons that insurers will have to base risk modelling on predictions and not just historical data, planners and designers will have to do the same in risk-prone areas.

For maintaining insurance cover, or maximising the level of insurance undercover, it is an obligation, particularly for the corporate and government sectors, to demonstrate that it has taken (reasonable) steps to avoid an insurable loss. For example, the insured must demonstrate how risks will be controlled and mitigated should a particular event arise. Insurance is not about waiting for a predictable loss to occur. (As an analogy – house insurance is limited if you don’t put window locks on the house, deadlocks on the doors, etc.). Therefore, insurers are likely to require that infrastructure owners can demonstrate how potential impacts of climate change will be mitigated to reduce potential loss exposure.

5.0 Water Infrastructure Risk Assessment

5.1 Introduction

Water infrastructure was assessed against climate change impacts to determine the risk to the assets and the services they provide. The water infrastructure services are divided into the following:

- Water storage and supply - Storage reservoirs, waterways and irrigation channels;
- Sewer - Reticulated sewage systems, trunk sewers and treatment plants; and
- Stormwater and drainage - Land prone to 100-year flood level and the drainage system.

A Water Infrastructure Risk Summary is provided in Section 5.2. The full comprehensive risk assessment of water infrastructure is located in Appendix C: Water Risk Assessment.

5.1.1 Value of assets

The assets used to deliver Victoria's water services can be valued in excess of $30 billion in current replacement cost terms and include over 100,000 km of water, wastewater, irrigation and stormwater mains and channels, 182 dams, 532 treatment plants and 3260 water and wastewater pumping stations.

Water supply infrastructure replacement costs are approximately $5.32 billion in metropolitan Melbourne, $2.55 billion in regional urban areas and $2.69 billion in regional areas. The values of infrastructure used in the provision of wastewater services are approximately $6.32 billion in metropolitan Melbourne and $1.97 billion in regional urban areas. The current replacement cost of stormwater drainage assets is approximately $6 billion.

The capital expenditure forecast for the next three years (2004-2007) in Victoria is $1.55 billion, with $370 million of that going to renewal and replacement of assets (Engineers Australia, 2005).

5.2 Water Infrastructure Risk Assessment

Based on current climate change projections, Victoria's water infrastructure is considered to be acutely vulnerable to climate change impacts as indicated by Table 15. The main risks generally relate to:

a) *Extreme Events*

It is predicted that extreme daily rainfall events will increase in frequency and intensity, affecting the capacity and maintenance of storm water, drainage and sewer infrastructure. There are likely to be significant damage costs, environmental spills and potential fatalities from the inability of water systems to cope with extreme events or even multiple events in a season. Older developed areas, such as inner city locations or older developments on floodplains, are at greater risk. Loss of electricity to major trunk sewer pumping stations during a flood event is also a significant risk that should be managed.

It is predicted that enhanced conditions for major bushfires events in the catchments of dams and reservoirs will generate immediate impacts on water quality and availability as well as medium-term reduction in water yield. Costly short-term water quality solutions will be needed should this occur in major catchments.

b) *Accelerated Degradation of Materials and Structures*

The degradation of materials and used in the construction of water supply, sewer and stormwater pipelines may accelerate through impacts caused by increased ground movement, changes in groundwater affecting the chemical structure of foundations and fatigue of structures from extreme stormwater events. This accelerated degradation has the potential to reduce the life expectancy of infrastructure, increase maintenance costs and possibly lead to structural failure.

c) *Resource Demand Pressures*

Water shortages may occur due to greater demand for water associated with increased temperatures, reduced available moisture and increased population. The forecast decrease in the annual rainfall in catchments due to climate change would also affect water supply. The resultant water shortage in regional areas and cities would be costly to the public and private sectors, and could lead to health and economic impacts. Adaptive responses could include construction of infrastructure to support local capture and reuse of stormwater or costly, large scale and politically-sensitive infrastructure developments such as desalination plants or dams.

Table 15: Water Infrastructure Risk Summary

Water Sector	Risk Scenario	Climate Variable	Risk Rating			
			2030		2070	
			Low	High	Low	High
Water storage and supply	Water shortage	• Decrease in Available Moisture • Decrease in Rainfall • Increased Temperature and Heatwaves	High	High	High	Extreme
	Degradation and failure of water supply piping	• Increased Variation in Wet/Dry Spells • Decrease in Available Moisture	Moderate	Moderate	Moderate	High
	Bushfire impacts on catchment and storage	• Increase in Bushfires • Decrease in Available Moisture	Moderate	High	High	Extreme
Sewer	Degradation and failure of sewer pipes	• Increased Variation in Wet/Dry Spells • Decrease in Available Moisture	Moderate	Moderate	Moderate	High
	Sewer spills to rivers and bays	• Increase in Extreme Daily Rainfall • Increase in Sea Level	Low	Moderate	Moderate	High
Storm water Drainage	Storm water drainage and flooding damage	• Increase in Extreme daily rainfall • Decrease in available moisture • Sea level rise	High	High	Extreme	Extreme
	Degradation and failure of drainage infrastructure	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms	Moderate	Moderate	Moderate	High

5.2.1 Example of a Climate-Related Impact on Infrastructure

Canberra fires, 19 Jan 2003: Three large bushfires joined to form a 35-km long fire-front that descended upon the city. The impacts were extensive (Lavorel and Steffen, 2004). About 500 houses were totally destroyed, four people were killed and hundreds were injured. The total damage to Canberra's infrastructure approached A$400 million. Three of the city's four dams were rendered temporarily unusable by post-fire runoff laden with charcoal and sediment from the bare, charred ground in the catchments.

5.3 Governance

5.3.1 Summary

The majority of Victoria's water infrastructure lies in public ownership. However, some assets are privately held, often as a result of public private partnership projects. The ownership of public assets is primarily split between local government and water authorities. Within metropolitan Melbourne there is a further division of the water authority assets between Melbourne Water and the three water retailing companies.

Water authorities and local government operate under different legislative frameworks. These frameworks impose specific and general obligations relating to:

- management of water infrastructure;
- protection of third parties from the escape of water from infrastructure; and
- management of the design and location of new structures so as to reduce flooding risks.

The obligations of private asset owners will be largely defined by the terms of the contractual arrangements surrounding the infrastructure concerned. Where third parties suffer loss or damage as a result of the operation of a privately owned facility, the public authority on whose behalf the infrastructure has been developed may also have vicarious and/or statutory liabilities.

Obligations are also imposed on water infrastructure managers (both public and private) to properly manage risks to third parties through the common law doctrine of negligence.

As a result of these obligations, failure to properly consider and address the information considered in this report may lead to liability where third parties suffer loss or damage as a result.

With regard to the costs of any necessary upgrades, improvements or repairs, these will primarily be borne by the infrastructure owner. In the case of water authorities, such costs are likely to be passed on to customers. However, the role of the Essential Services Commission in setting prices (on a three-year cycle) will constrain this. In the case of private infrastructure owners, their ability to pass on these costs to the entity on whose behalf the asset was developed will depend on the contractual arrangements entered into. The ability to recover unexpected replacement, maintenance and upgrade costs through insurance will depend on the coverage that each asset owner has in place.

5.3.2 Introduction

The majority of Victoria's water infrastructure lies in public ownership, with responsibility for operation and maintenance being spread across a number of government agencies. The water industry was placed into a corporate structure in the early 1990s as part of the broad privatisation strategy being pursued at that time, although sales did not follow. The current Government has committed to maintaining public stewardship of all water resources (and, by implication, of the infrastructure used to manage these resources).

Consequently, this means that any costs associated with climate change will be borne directly by water users paying increased prices, or by the Victorian Government (and hence the people of Victoria). The extent to which costs will be able to be recovered through the price of water (and other services) will be limited by regulation of the pricing framework, which is controlled by the Essential Services Commission.

5.3.3 Existing Legal Framework

The responsibility for planning, funding, managing, operating and maintaining water infrastructure depends significantly on the authority or body responsible for carrying out the relevant function that the infrastructure serves.

The Minister for Water, supported by the Department of Sustainability and Environment, is responsible for carrying out long-term planning in relation to water resources, and also for issuing bulk entitlements, licences to take and use water and licences to construct works under the *Water Act 1989* ('Water Act'). In practice, much of this responsibility is delegated to the relevant water authority at a regional level.

In a broad sense, Catchment Management Authorities have oversight of the 'natural infrastructure' of the catchment, in so far as they have statutory responsibility for managing catchments and for maintaining catchment health, under the *Catchment and Land Protection Act* 1994. Melbourne Water, together with Parks Victoria, has responsibility for managing catchments in the vicinity of the Melbourne metropolitan area.

The water supply, wastewater and irrigation sectors are currently made up of three metropolitan retail companies and one bulk water supplier, thirteen regional urban water authorities, two authorities providing combined regional urban and rural water services, and three rural water authorities. Within metropolitan Melbourne, the collection, treatment and supply of water and waste water services are generally undertaken by Melbourne Water (acting as a wholesaler), and at the retail level by metropolitan water companies (licensees) pursuant to the *Water Industry Act* 1994 'Water Industry Act'). Within the rest of the State, these functions are undertaken by water authorities pursuant to the *Water Act* 1989.

Drainage services are generally handled by local government or specific authorities vested with that purpose, specifically Melbourne Water, which monitors Melbourne's waterways, undertakes water quality improvement works, and manages regional drainage services in the greater Melbourne area.

Other bodies with water-related functions are noted in Figure 6. They include the Environment Protection Authority, which controls environmental standards, particularly for wastewater discharge; the Drinking Water Regulatory Unit, within the Department of Human Services, which regulates drinking water quality; and the Essential Services Commission, which regulates pricing and service quality for the water industry.

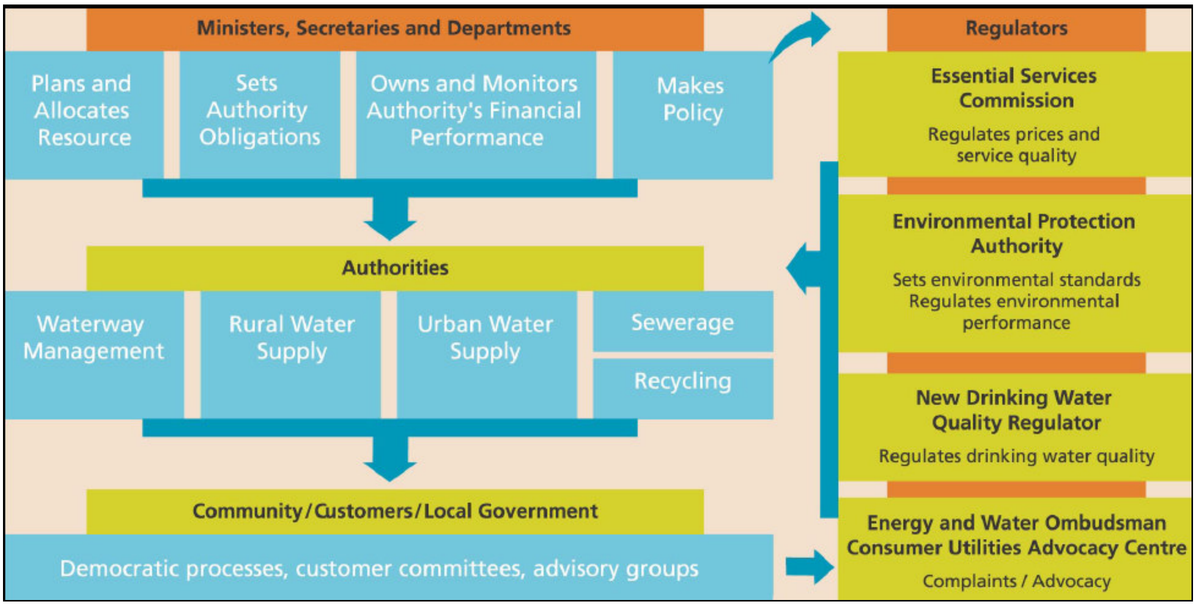

Figure 6: Water governance arrangements (Source: Our Water Our Future, Victorian Government, 2004)

Water and Waste Water Services

Metropolitan Area

In the metropolitan area, Melbourne Water is a statutory authority that operates as a wholesale service provider, established pursuant to the *Melbourne and Metropolitan Board of Works Act* 1958. Melbourne Water provides catchment management; water collection, treatment and trunk distribution; and wastewater trunk collection and treatment services (including Melbourne's two major sewage treatment plants). It has responsibility for reservoirs, dams, water supply mains and major water treatment plants.

Three retail water companies, Yarra Valley Water, South East Water and City West Water (corporations established under the *Corporations Act* 2001(Cth) manage the retail supply of water to households and businesses. They have responsibility for the network of pipes and associated infrastructure that deliver water to customers from the trunk distribution system, and that collect sewerage and trade waste from customers and carry it to the trunk sewers. These functions are performed within the framework established by the *Water Industry Act* and the *Essential Services Commission Act* 2001 ('ESC Act'). The normal governance arrangements for corporations also apply to these companies.

Rural and Regional Areas

Outside metropolitan Melbourne, the *Water Act* establishes the powers and responsibilities of water authorities and vests in them the ownership or operation and control of water supply and wastewater infrastructure. In practice, regional urban water authorities provide water and wastewater services, while rural water authorities provide services including irrigation, stock and domestic supply, and the wholesale supply of water to regional urban distributors.

Water authorities operate within water supply, sewerage, and irrigation districts, managing the infrastructure associated with the relevant service. Within districts, land owners may be required to connect to the water supply and wastewater systems. Water authorities are also responsible for dams, reservoirs, holding basins and other assets used to collect, store and distribute water.

Under the *Water Act,* water authorities are bodies corporate, in the nature of a statutory corporation that may buy, hold and sell assets, sue and be sued, enter into contracts and agreements and otherwise behave as a corporate entity. In some cases, ministerial or treasury approval is required for certain decisions. Under the *Water Act,* the Minister for Water (in whom responsibility for the *Water Act* is vested via an administrative order) has the power to direct water authorities in respect of certain matters, to issue licences and develop and implement policy. In addition, the Minister has the power to issue specific orders and approve by-laws.

Governance arrangements for authorities under the *Water Act* are generally equivalent to those applying to corporations, with board member (director) liability for the decisions and operations of the authority. The only difference is the opportunity for the Minister to directly intervene in the operations of authorities by issuing directions, making orders or otherwise requiring compliance with particular matters of government policy.

Drainage

Metropolitan Area

Infrastructure provision for drainage is usually managed separately from water supply for historical reasons. In metropolitan Melbourne, drainage responsibility is shared between local government and Melbourne Water. Melbourne Water prepares drainage schemes for catchments having an area of greater than 60 hectares that, once developed, pass to the relevant local government for ongoing management. Melbourne Water has control of certain declared drains, together with the watercourses that provide the main drainage through the metropolitan area.

Local government is responsible for areas smaller than 60 hectares, and for ongoing drainage management, operations and maintenance. This includes providing a drainage system connected to the main system, and ensuring the provision of a legal point of discharge, for each property. Local government also has a role in setting required building floor heights in relation to flood levels, and declaring areas subject to flooding in which special designs are necessary to respond to potential flood conditions.

Local governments operate as semi-autonomous statutory authorities pursuant to the *Local Government Act* 1989 ('Local Government Act'). A local government is a body corporate that may sue and be sued, hold property and act as a legal entity. However, local governments are subject to direction from various Ministers as they exercise statutory power pursuant to a wide range of legislation. Many actions, whether under the Local Government Act or other legislation, require the approval of the Minister for Local Government, Minister for Planning or other relevant Ministers. In relation to drainage functions, local governments are relatively autonomous as drainage has been a core local government responsibility since the earliest local governments were established in Victoria as 'roads and drainage boards' in the 1870s and 1880s.

Regional and Rural Areas

Parts of Victoria are subject to regular flooding and have been the subject of special declarations under the *Water Act* creating drainage districts. Particularly in north central Victoria, between Shepparton and the Murray River, there are large areas of relatively flat, low lying country that are subject to regular flooding. These areas have had extensive drainage schemes introduced often using levees and other devices to manage flood waters and protect properties.

In regional centres, local governments are responsible for urban drainage in the same way as described above but without the presence of Melbourne Water. In rural areas responsibility is split between local governments and rural water authorities, which also have a drainage role under the *Water Act*. Provisions within the *Water Act* regulate drainage of private property and create liabilities in water authorities for any flow of water from the assets of a water authority that causes loss or damage to a person. The *Water Act* also provides that a person must not prevent or obstruct the natural flow of water from an adjoining property onto their property and, similarly, a person must not concentrate or otherwise modify the natural flow of waters from their property onto another property.

Governance arrangements in relation to drainage and flooding are therefore split between Melbourne Water in respect of the Melbourne metropolitan area and local governments in both Melbourne and rural areas, with Rural Water Authorities having responsibility within declared districts. The Water Act empowers water authorities to declare flood level, flood fringe areas and building lines as a way of managing areas that are subject to inundation. They are also involved, with local planning authorities, in the preparation of controls within the planning scheme that achieve similar objectives.

Irrigation

Water authorities may also be appointed as irrigation authorities. Irrigation authorities are responsible for the provision, management and operation of systems for the supply of water to land for irrigation, and for appropriate drainage and protection of that land. Goulburn Murray Water, Southern Rural Water, Wimmera-Mallee Water, Lower Murray Water (created from the merger of Sunraysia Water and the Lower Murray Region Water Authority) and First Mildura Irrigation Trust are the owners and managers of a number of reservoirs, and operators of the irrigation systems.

Role of the Essential Services Commission

The Victorian Water Industry has recently been made the subject of regulation by the Essential Services Commission (ESC). The Water Industry Regulatory Order (WIRO) establishes certain policies, objectives and performance requirements for the water industry. The WIRO is made by the Minister for Water, and given effect by the ESC.

In respect of the three metropolitan water companies, the ESC issues operating licences and requires those companies to meet operational benchmarks and service standards set in the licences. The regional urban water authorities are required to prepare water plans setting out their proposed capital works for the next three-year period together with estimates of expenditure and revenue. The plans, which include a works program, revenue and expenditure estimates, service standards and tariffs, must be reviewed and approved (with modifications) by the ESC.

For the purposes of their financial operations, the authorities have a regulated asset base and are permitted to depreciate only those assets that have been recognised by the ESC. Revenue requirements have been estimated based on approved expenditure, including the cost of maintaining the regulated asset base. This financial framework may constrain the speed at which the water industry can respond to improvements in understanding of likely climate change impacts. The most recent price determination occurred in 2005, meaning that maintenance budgets are now set until 2007. Accordingly, a good opportunity for water authorities to consider their readiness for climate change will be when they are preparing for the 2007 price review.

5.3.4 Current Ownership Structure

Water and Waste Water

For metropolitan Melbourne, Melbourne Water owns or has operational responsibility for a number of major dams including the Thompson and Sugarloaf Dams, YanYean and Maroondah reservoirs. Melbourne Water also owns a large network of trunk supply mains that transfer water from the dams and reservoirs to a point within the metropolitan area where ownership of the water transfers to the relevant Melbourne retail company. The retail companies have ownership of distribution mains and some local reservoirs or holding tanks used to maintain supply and pressure within the system.

Similarly, in relation to the wastewater treatment system, Melbourne Water owns the large trunk mains and two major treatment plants. The three retail entities own local sewerage reticulation systems, pump stations and collection mains that feed the large trunk mains.

Water authorities in non-metropolitan Victoria evolved from small rural and urban water trusts established in the 19th century to manage systems in which the dams, reservoirs and irrigations channels or other distribution assets were generally on Crown land. Over time these trusts were restructured into the current system of authorities. However, the framework of ownership and management of assets is not always clear. In some cases, assets are clearly vested in the relevant authority, or the authority has acquired the assets and has outright ownership. In many cases, assets remain on Crown land and are owned by the State. In some cases, the absolute ownership or management of dams or reservoirs cannot be identified. Therefore the ownership may remain with the State and the liability for management or operation may be shared between several authorities.

For rural Victoria, ownership of major water supply reservoirs is split between Southern Rural Water, south of the Great Dividing Range, and Goulburn Murray Water to the north. In addition, some regional urban water authorities also own dams or reservoirs. Ownership of regional urban water and sewerage systems is vested in the relevant local authorities.

The emergence of alternative funding arrangements including build-own-operate-and-transfer schemes, public-private partnerships and other mechanisms may mean that assets funded in this way are owned by the private sector until the termination of the financial arrangements, after which ownership passes to the water authority.

When new subdivisions are undertaken, water and sewerage infrastructure is provided by developers, which vests in the relevant retail business or authority upon completion of the works and after final commissioning.

Drainage

In the Melbourne metropolitan area, drainage infrastructure is owned by Melbourne Water and local governments. Melbourne Water owns a number of main drains and related drainage assets, including wetlands. The Crown retains ownership of the bed and banks of creeks and rivers that flow through the metropolitan area including the Yarra and Maribyrnong Rivers, Moonee Ponds Creek, Merri Creek and a number of other creeks. Although Melbourne Water may have operational control of these, the ownership remains with the State of Victoria.

Within each metropolitan and regional municipality, the local drainage system contained within the roads and servicing houses and other buildings are owned by the local government. In rural areas, drainage assets will generally be owned by the relevant waterway manager, local government or by some other statutory body such as VicRoads.

Irrigation

Irrigation authorities generally own the distribution assets and pipe and channel systems comprising the irrigation network. In some cases, the assets are located in easements over private land or on Crown land.

5.3.5 Legal Responsibility for Planning and Management

Ultimate legal responsibility for planning and management rests with the Minister for Water under the W*ater Act* and *Water Industry Act 1994* ('WI Act'). However, while the Minister may have ultimate responsibility in the sense of being able to issue directions, create policy and make orders restructuring authorities and establishing operational standards, the Minister only has limited liability for operational decisions. As most operational decisions are made by individual authorities, it will be at this level that legal liability attaches to particular decisions, acts or omissions, as it will be these that lead to loss or damage and trigger a potential claim.

As Melbourne's primary water supply provider, Melbourne Water undertakes ongoing planning for water demand and supply. In recent years, as the effects of climate change and drought conditions have been monitored, Melbourne Water has worked closely with the three retail water companies to introduce demand management and community education programs, together with additional water restrictions, in an effort to reduce demand. While not having any formal legal planning obligations, Melbourne Water has institutional planning functions within the framework of water management for the State. These functions include the planning for, and the operational management of, the major supply dams and sewerage treatment plants under its operation, and the sizing of trunk infrastructure to provide appropriate capacity for services for the metropolitan area.

The three metropolitan water businesses operating under the WI Act have legal responsibilities including the planning and co-ordination of infrastructure provision for new subdivisions, and the ongoing planning role associated with operations and maintenance and routine replacement (including increasing) of existing water and sewerage mains within the established metropolitan area. The general town planning policy objective to increase urban consolidation, which has been pursued over the past 20 years, has meant that in some parts of the metropolitan area, existing infrastructure may not be adequate to serve the increased densities. The metropolitan water businesses and the regional and rural water authorities are referral authorities under the *Planning & Environment Act* 1987 ('P&E Act') and the *Subdivision Act* 1988. This role imposes obligations to consider the future planning of infrastructure and requires the provision of appropriate infrastructure and any easements or other property rights to allow protection and management of the assets.

Regional and rural water authorities operating under the Water Act have specific liability in relation to the management and operation of their systems. The Water Act provides that an authority is liable for injury, loss (including economic loss) or damage that results from the flow of water from its works onto any land, where that flow occurs intentionally or negligently in the exercise of the authority's functions under the Act.

The functions of a water authority that has a water district include:

- to provide, manage, operate and protect water supply systems, including the collection, storage, treatment, transfer and distribution of water;
- to identify community needs relating to water supply and to plan for the future needs of the community relating to water supply;
- to develop and implement programs for the conservation and efficient use of water;
- to investigate, promote and conduct research into any matter related to its functions, powers and duties in relation to water supply; and
- to educate the public about any aspect of water supply.

The same functions apply in relation to provision of sewerage infrastructure and services for those authorities that have sewerage districts, and also include the requirement to develop and implement programs for the recycling and reuse of treated waste water.

Authorities with waterway management districts are required to develop and to implement effectively schemes for the use, protection and enhancement of land and waterways; and to identify and plan for State and local community needs relating to the use and to the economic, social and environmental values of land and waterways.

Drainage

Melbourne Water has responsibilities for the planning and management of drainage catchments in metropolitan Melbourne. It has recently undertaken a review of its drainage policies and produced a new catchment drainage policy manual. Melbourne Water works closely with developers in the design of drainage systems with the twin objectives of managing drainage flows so as to prevent downstream flooding and other impacts, and of maintaining or improving water quality.

Local government has responsibility for planning and management of drainage systems within the established urban area. Local governments and Melbourne Water work together to manage areas subject to flooding or subject to inundation and to plan and carry out works for drainage improvements where there are known drainage problems.

Local government can use the town planning system to recognise areas that have drainage problems and prevent or restrict development in those areas.

5.3.6 Possible Claims in the Event of Failure

The risk analysis has identified a number of key risks to existing infrastructure. Each has the potential to generate a range of claims, as outlined in Section 4. Specific issues that may arise in the water sector include:

- Water authorities' statutory liability under the *Water Act*
- Inaccuracies in declared flood levels, flood fringe areas and building lines under the Water Act
- Inaccuracies in flood levels set out in planning schemes
- Breaches of mandated water quality standards as a result of increasing heavy rainfall events.

5.3.7 Insurance

As noted previously, while current insurance arrangements will respond to most of the likely losses identified here, there will be increasing pressure on the insurance industries ability to meet growing claims. There will also be an increasing need for companies to demonstrate controls or mitigation measures in place to reduce insured loss potential. Where additional costs arise for maintenance activities (such as increases in repairs for cracked pipes, as a result of greater variability in soil moisture) it is unlikely that existing insurance arrangements will respond. Beyond this, no water-sector-specific insurance issues arise.

6.0 Power Infrastructure Risk Assessment

6.1 Introduction

Victoria's power infrastructure was assessed against climate change impacts to determine the risk to the assets and the services they provide. Power infrastructure services were divided into the following:

- Electricity – Power generation and transmission to substations includes power supply peak demand and renewable energy generation; and
- Gas and Oil – Extraction, refining and distribution networks.

A Power Infrastructure Risk Summary is provided in Section 6.2. The full comprehensive risk assessment of power infrastructure is located in Appendix D: Power Risk Assessment.

6.1.1 Value of assets

Victoria's privately owned electricity transmission system consists of 6,000 km of high-voltage wires and approximately 200,000 km of overhead power lines and underground cables for electricity distribution. Over the next five years, the network may require up to nine augmentations in order to meet the energy demands and growth and renewal in the distribution network. Potential augmentations costing approximately $105 million have been identified. Victoria's distribution network is ageing, with asset replacement capital expenditure set to rise from a low point in 2002 of $350 million to $700 million in 2010 (Engineers Australia, 2005).

Victoria has a 1900 km principal transmission system for natural gas (Engineers Australia, 2005).

6.2 Power Infrastructure Risk Summary

The climate change scenarios considered by this report present significant risks to power infrastructure in Victoria, as indicated by Table 16. The main risks generally relate to:

a) Extreme Events

Should infrastructure not change, it is likely that increased frequency and intensity of extreme storm events will cause significant damage to electricity transmission infrastructure and service. More frequent extreme wind events and increased lightning strikes have the potential to cause additional damage to transmission and distribution lines and structures, while extreme rainfall events may cause the flooding of power substations. The increase in storm activity may lead to an increase in the cost of power supply and infrastructure maintenance from an increased frequency and duration of blackouts and service disruption.

It is also predicted that coastal and offshore gas, oil and electricity infrastructure (such as offshore gas and oil platforms, pipelines, refineries, oil tanker wharves and coastal substations) will be at risk of significant damage and increased shut down periods from increases in storm surges and extreme wind, flooding and wave events, especially when combined with sea level rise. Infrastructure at risk could include offshore gas and oil platforms, pipelines, refineries, oil tanker wharves and coastal substations.

An increased frequency and intensity of bushfires may cause damage to major transmission and distribution infrastructure as well as temporarily closing down coal power plants if their associated coal mine ignites due to ember attack as has occurred during previous bushfires in Victoria.

b) Accelerated Degradation of Materials and Structures

Degradation of materials used in the construction of power generation and refinery plant foundations may accelerate due to changes in soil moisture and groundwater. Additionally, degradation in the structural integrity of transmission lines, gas and oil pipelines may accelerate due to increased ground movement, changes in groundwater affecting the chemical structure of foundations and fatigue of structures from extreme storm events. This could reduce the life expectancy of infrastructure, increase maintenance costs and potentially lead to structural failure during extreme events.

Additionally, it is predicted that an increase in the frequency and intensity of droughts will occur due to climate change. It is anticipated that this will cause more dust to build up on high voltage transmission lines due less regular rain to wash the infrastructure. This may lead to an increase in the costs involved in transmission line maintenance to prevent the risk of dust build up on insulators which can cause arcing and a subsequent interruption in electricity supply. The anticipated increased frequency of dust storms would further increase this risk.

c) Resource Demand Pressures

Current climate predictions anticipate that extreme heatwaves will increase in frequency and intensity, potentially generating an increase in electricity demand for air conditioning at the same time as the efficiency of the transmission is reduced by up to 30% due to high temperatures. High temperatures significantly reduce transmission line conductivity (SEC, 1989). The strain on the system as the population grows and more people install air conditioners could result in brown outs or black outs, system failures and, at its most extreme, fatalities as those most vulnerable may be unable to find relief from heat stress. Planning cycles for energy suppliers might allow a response to changing conditions. However, this would depend on the ability of the suppliers to respond within their regulated frameworks and the availability of capital for system augmentation.

Available responses include distributed power generation to support local transmission systems as well as environmental building design standards for all existing buildings to reduce the need for air conditioning. An increase in peak energy generation capacity (probably gas-fired) may be needed.

To further exacerbate this problem, the anticipated decrease in annual rainfall may reduce the power supply capacity of hydroelectric dams and the water supply necessary for cooling for coal-fired power stations during power generation. The increase in extreme wind events is likely to extend the shutdown periods for wind farms unless technological change and adaptation measures are implemented.

Considering the above, there is likely to be an impact on consumers by an increase in electricity costs and reduced security and reliability of supply.

Table 16: Power Infrastructure Risk Summary

Power Sector	Risk Scenario	Climate Variable	Risk Rating			
			2030		2070	
			Low	High	Low	High
Electricity Generation, Transmission and Demand	Increase in demand pressure blackouts	• Increased Temperature and heatwaves	Moderate	High	High	Extreme
	Decline in stability of structures and foundations	• Decrease in Available Moisture • Increased variation of wet/dry spells	Moderate	Moderate	Moderate	Moderate
	Storm damage to above ground transmission	• Increase in intensity of extreme wind • Increase in frequency and intensity of storms. • Increased electrical storm activity.	Low	Moderate	Moderate	High
	Increased bushfire damage	• Increased electrical storm activity • Increased bushfires • Increased temperature and heatwaves	Moderate	Moderate	Moderate	Moderate
	Substation flooding	• Increase in extreme daily rainfall • Sea-level rise • Increase in frequency and intensity of storms	Moderate	High	High	High
	Arching faults of transmission lines	• Decrease in rainfall • Increased variation in wet dry spells	Low	Low	Low	Moderate
	Reduction of hydroelectricity generation	• Decrease in rainfall	Low	Moderate	Moderate	High
	Reduction of coal electricity generation	• Decrease in Rainfall	Low	Moderate	Moderate	High
	Wind power inhibited	• Increase in intensity of extreme wind	Low	Low	Low	Moderate
Oil and Gas Extraction, Refining and Distribution	Decline in stability of structures and foundations	• Decrease in available moisture	Moderate	Moderate	Moderate	Moderate
	Offshore infrastructure storm damage	• Increase in intensity of extreme wind • Sea-level rise • Increase in frequency and intensity of storms	Moderate	Moderate	Moderate	High
	Inundation of refineries	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms	Low	Moderate	Moderate	Moderate

6.3 Governance

6.3.1 Summary

The majority of Victoria's energy infrastructure lies in private ownership. The reticulated supply of electricity and gas is comprehensively regulated as a result of the privatisation process. Petroleum (and some gas) distribution occurs outside the reticulation network, and is less comprehensively regulated. The focus of this section is the governance arrangements pertaining to the reticulated network for electricity and gas.

The electricity and gas networks operate under different legislative frameworks. These frameworks impose specific and general obligations relating to:

- the management of electricity and gas infrastructure;
- service and performance standards for infrastructure operators; and
- terms and conditions of supply to customers, including the prices that may be charged.

The obligations of asset owners are defined through this statutory framework, and the terms of any contractual arrangements that they have entered into. Obligations are also imposed on asset managers to properly manage risks to third parties through the common law doctrine of negligence, as modified by the statutory framework. Where the private asset owners are public companies, a range of additional obligations may arise under the Corporations Act and elsewhere, particularly with respect to the company's dealings with its shareholders.

As a result of these obligations, in the future, the failure to properly consider and address the kind of information presented in this report may lead to liability where third parties suffer loss or damage as a result.

With regard to the costs of any necessary upgrades, improvements or repairs, these will primarily be borne by the infrastructure owner. The ability of asset owners to pass such costs on to their customers, will be constrained by the role of the Essential Services Commission in setting prices (on a five year cycle), and the prevailing conditions in the national electricity and gas markets. The ability to recover unexpected replacement, maintenance and upgrade costs through insurance will depend on the coverage that each asset owner has in place.

6.3.2 Introduction

Victoria's electricity and gas industries have been fully privatised and in consequence, private companies own the assets used for the production, transmission and distribution of natural gas and the generation, transmission and distribution of electricity. The practical effect of privatisation is that increased costs associated with climate change, whether they are of a capital nature, or in the nature of operating and maintenance expenses, will initially be borne by these private companies, not by the Victorian Government.

Some scope may exist for these costs to be passed through to consumers, although the extent to which this may occur is affected by the following:

- The prices that may be charged for the transmission and distribution of both electricity and gas are regulated. As such, the extent to which increased costs may be passed through is determined by the regulator;
- The prices set by regulators in relation to transmission and distribution apply for a set period (e.g. five years). There is very limited scope to alter the prices that may be charged during a period for which prices have been set (although there is a greater scope for the adjustment of prices during the next regulatory reset);
- Electricity generators operate in a national market conducted by NEMMCO and so the ability of generators to pass through costs depends upon the operation of this market.

The Australian Energy Market Commission (AEMC) is responsible for making amendments to the National Electricity Rules. The National Electricity Rules contain the technical standards that largely govern the operation of the electricity industry.

VENCorp is responsible for making amendments to the Market and System Operations Rules that govern the transmission of natural gas.

The Essential Services Commission is responsible for issuing licences to natural gas distributors and may also amend the operation of any industry codes that are referred to in such licence for the purposes of that code's application to that licence.

The Minister for the Department of Primary Industries is responsible for issuing petroleum production licences.

6.3.3 Existing legal framework

Electricity

The *National Electricity (Victoria) Act* 2005 gives force in Victoria to the National Electricity Law, which is set out in the Schedule to the *National Electricity (South Australia) Act* 1996.

The National Electricity Law in turn provides that the National Electricity Rules (Rules) have the force of law. Furthermore, the National Electricity Law prohibits anyone from engaging in generation, transmission or distribution on the interconnected system unless they are a registered participant (or subject to some other exemption).

The initial Rules were made by the South Australian Minister for Energy on the recommendation of the Ministerial Council for Energy and impose various obligations upon participants in the national electricity market. The Rules may be amended by the AEMC.

The *Electricity Industry Act 2000* (Vic) (EI Act) regulates the generation, transmission and distribution of electricity industry in Victoria. The EI Act prohibits a person from engaging in transmission, distribution or commercial generation unless that person holds a relevant licence or is otherwise exempted. Significant regulation is incorporated in the licences that are granted by the Essential Services Commission.

Figure 7 sets out the principal governing statutes in relation to each part of the electricity industry in Victoria.

Natural Gas

The *Gas Industry Act 2001* (Vic) incorporates the Market and System Operation Rules (MSOR) that were originally made under the *Gas Industry Act 1994*. The MSOR places various obligations upon transmission service providers and distribution service providers.

In particular, with respect to transmission, the MSOR provides for VENCorp to produce the:

- System Security Guidelines, which set out general operational strategies employed by VENCorp;
- Gas Quality Guidelines that regulate the specifications of the gas that is injected into the system; and
- VENCorp Emergency Procedures, which regulate procedures in case of emergency.

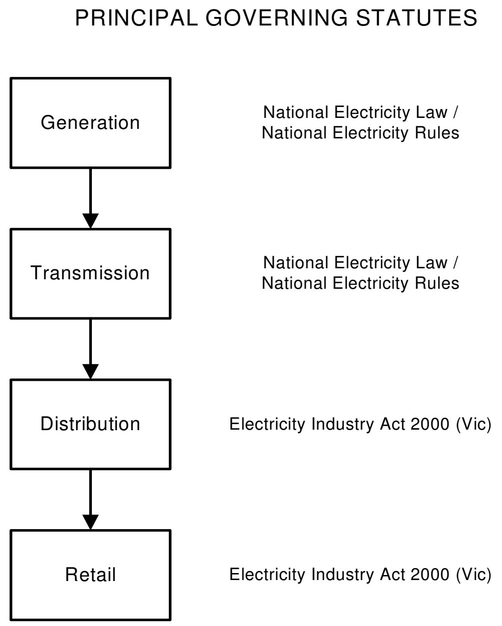

Figure 7: The principal governing statutes associated with Victoria's electricity industry

The *Gas Industry Act 2001* also provides that distributors and retailers must be licensed in order to undertake distribution activities. The Essential Services Commission is responsible for granting licences. Distributors are, by virtue of their licences, required to comply with the Gas Distribution System Code, which sets out minimum standards for the operation and use of the distribution system.

The *Petroleum Act 1998 (Vic)* provides that it is an offence to carry out any petroleum production operation in Victoria except under, and in accordance with, a production licence or as otherwise permitted by that Act. Production licences may be granted by the Minister of the Department of Primary Industries.[2]

The *Petroleum Act 1998 (Vic)* further provides that the holder of a production licence must not carry out petroleum production unless the Minister has approved its petroleum production development plan. A production development plan outlines how petroleum production will be undertaken in the licence area.

[2] We have not been able to obtain a copy of a publicly available production licence.

Figure 8 sets out the principal governing statutes for each part of the natural gas industry in Victoria.

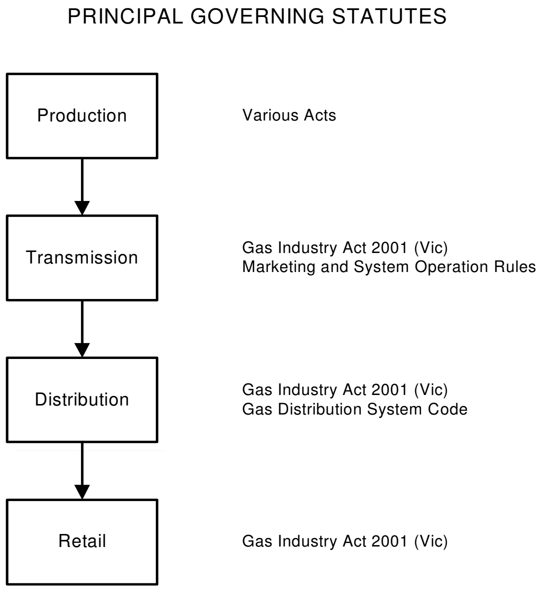

Figure 8: The principal governing statutes associated with Victoria's gas industry

6.3.4 Current Ownership Structure

Electricity

Victoria's electricity infrastructure broadly comprises three components: generation, transmission and distribution. All parts of the Victorian electricity industry have been privatised. Figure 9 sets out the structure of ownership in the electricity industry in Victoria.

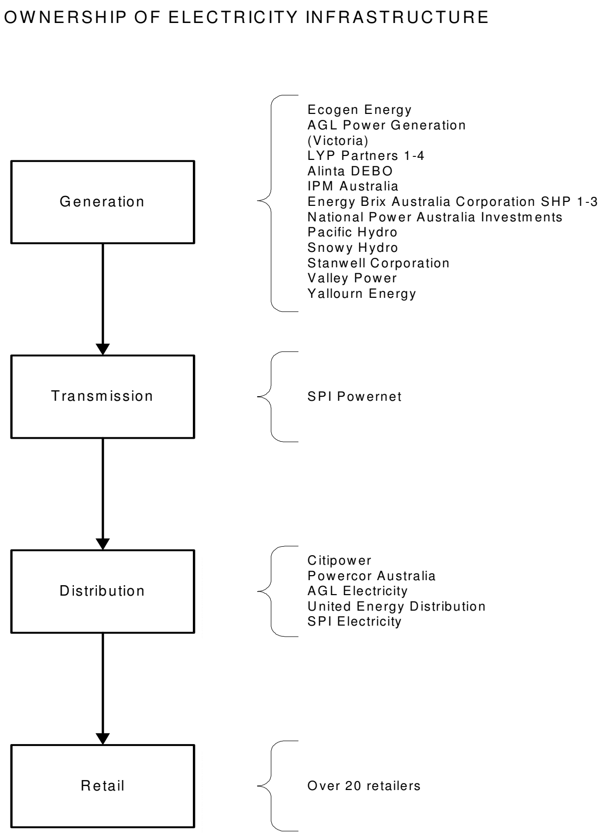

Figure 9: Ownership of Victoria's electricity infrastructure

Natural Gas

Victoria's natural gas infrastructure broadly comprises three components: production, transmission and distribution.

The majority of Victoria's natural gas is sourced from the Gippsland Basin and is produced at the Longford processing plant. A small but growing amount of gas is supplied from other gas fields in the Gippsland and Otway Basins and increasingly gas is being supplied interstate from Victoria (DoI, 2006)

The exploration and production of natural gas in Australia is undertaken by many companies including BHP Billiton, BP, Chevron Texaco, ExxonMobil, OMV, Origin Energy, Santos, Shell and Woodside Energy (ENA, 2006a)

Natural gas is transmitted throughout Victoria predominantly through the transmission network owned by GasNet Australia and operated by VENCorp. Coastal Gas Australia owns and operates the transmission pipeline from Carisbrook to Ararat/Horsham. Australian Pipeline Trust and GasNet Australia own and operate the Interconnect Pipeline between Wodonga and Wagga Wagga, while Duke Energy International owns and operates the Eastern Gas Pipeline between Longford (in Victoria) and Horsley Park (near Sydney). A pipeline from the Western Underground Storage facility at Iona (near Port Campbell) to Lara (near Geelong) links the south-western Victorian transmission system of the Otway Basin to the transmission system throughout Victoria. (ENA, 2006b)

Figure 10 shows the major transmission pipelines in Victoria.

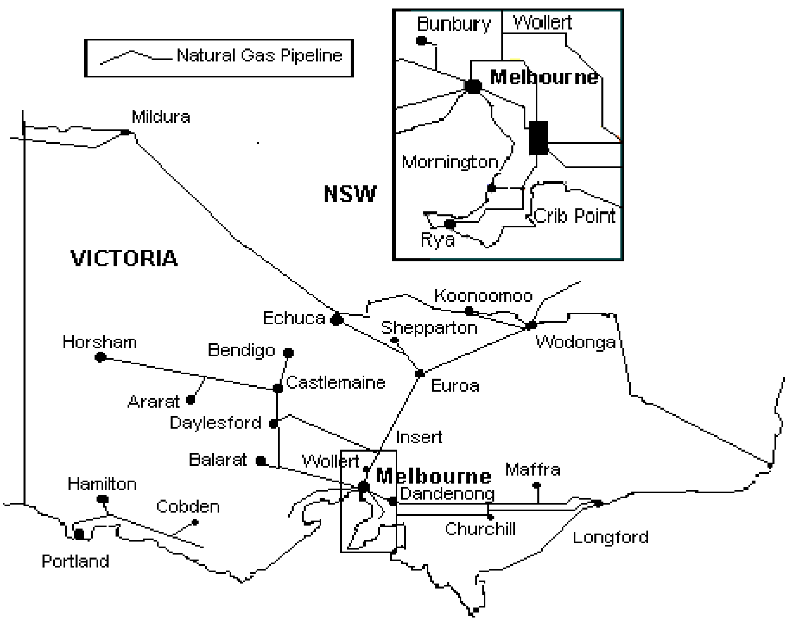

Figure 10: An indication of Victoria's major transmission pipelines prior to 2005

Distribution is currently carried out by four licence holders: Envestra, Multinet Gas (DB No's 1 and 2), Vic Gas Distribution and SPI Networks (Gas).

Figure 11 sets out the structure of ownership in the gas industry in Victoria.

6.3.5 Legal Responsibility for Planning and Management

Electricity

A number of bodies are charged with responsibilities and obligations in relation to the electricity market. This report notes that certain responsibilities that apply across multiple functions before considering the legal responsibilities specifically in relation to generation, transmission and distribution below.

NEMMCO has responsibilities and obligations including the following:

- NEMMCO is required to maintain power system security and to undertake the coordination of the planning of augmentations to the national electricity system by the National Electricity Law.
- NEMMCO is required to produce an indicative load forecast for each region for various periods up to 24 months in advance. This indicative load forecast is required, among other things, to take into account:

  'weather forecasts and the current and historic weather conditions and patterns' under the National Electricity Rules.

- Furthermore, NEMMCO is conferred with the power to direct registered participants to take certain actions if it considers such actions necessary in order to maintain power system security or for reasons of public safety by the National Electricity Law.

The Essential Services Commission has responsibilities and obligations including:

- an objective 'to promote a consistent regulatory approach between the gas industry and the electricity industry' under the *Gas Industry Act* 2001.

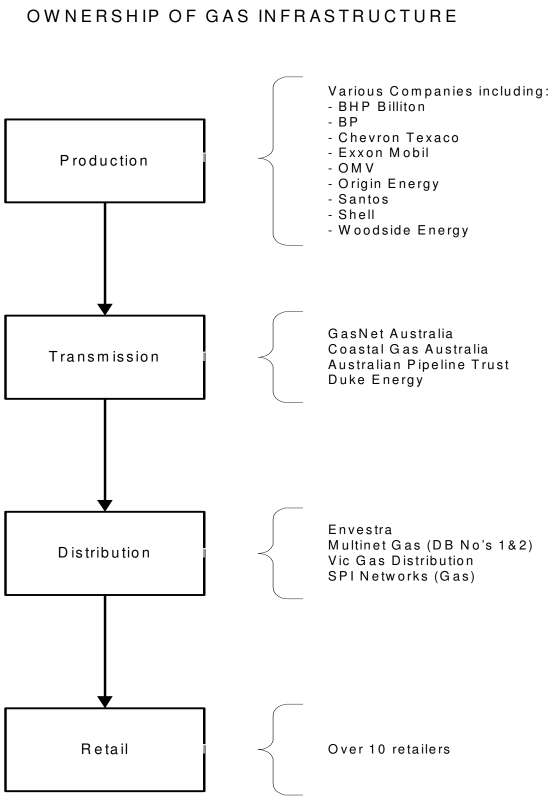

Figure 11: Ownership of Victoria's gas infrastructure

The Australian Energy Regulator has responsibilities and obligations including:

- The Australian Energy Regulator is conferred with power to monitor compliance with the National Electricity Law and the Rules by registered participants under the National Electricity Law.

The Australian Energy Market Commission has responsibilities and obligations including:

- The Australian Energy Market Commission is conferred with the power to make and amend the Rules and a power in respect of market development under the National Electricity Law. Furthermore, the AEMC is required to establish a 'Reliability Panel' to monitor, review and report on the safety, security and reliability of the national electricity system.

The National Electricity Law provides, in Part 9, that Registered participants will not incur any civil monetary liability for failure to supply electricity unless through bad faith or negligence. Furthermore, sections 84 and

99 of the *Electricity Industry Act* 2000 (Vic) provide immunity for persons acting in good faith in the execution of a direction under the load shedding provision contained in section 81 or a direction, proclamation or requisition under the emergency provisions contained in Part 6 of that Act respectively.

Electricity Generation

Generators are privately managed and any increase in cost as a result of climate change would be borne initially by the owner. However, such cost increase may affect the spot price of electricity through the bids submitted by the generator. In this respect, the generator may not be able to bid at all, or its bids may simply be altered (e.g. higher price for electricity supply). Thus, the overall effect of such increased cost to particular generators on the spot price is likely to depend upon the nature of that cost and the nature of competition in the supply market both before and after the cost occurs.

Electricity Transmission

Transmission lines are maintained by SPI PowerNet. Increased costs as a result of climate change, whether those costs are in the nature of capital costs or operating and maintenance expenses, would initially be borne by SPI PowerNet, although the regulator may allow these costs to be passed on at the next price review.

- The prices that SPI PowerNet may charge are regulated. The most recent price review was conducted by the ACCC in 2002 (for the period 2003-2007). However, it is likely that the next price review will be conducted by the AER.

The Victorian Department of Infrastructure website provides that 'VENCorp is responsible for planning for the Victorian electricity transmission system to ensure existing and expected demands are met. This excludes the transmission connection facilities that connect the distribution networks and the generators to the high voltage network. Proposals for the development of transmission connection facilities are typically undertaken by distribution companies and generators. (DoI, 2006b)

VENCorp is not responsible for commissioning or paying for any required enhancements to the transmission system.

Electricity Distribution

Distribution companies are responsible for the operation and maintenance of distribution lines. Consequently, increased costs as a result of climate change, whether in the nature of capital costs or operating and maintenance expenses, would initially be borne by the distribution companies, although the regulator may allow these costs to be passed on at the next price review.

Distribution licences may vary from one distributor to another. However, currently licences impose the following obligations on distributors:

- 'prepare and submit to the Commission a proposed default use of system agreement' (clause 5 of the Citipower licence); and
- 'the Licensee must participate to the extent specified by the Commission in the development, issue and review of any standards and procedures specified by the Commission' (clause 23 of the Citipower licence)

The prices that distributors may charge are regulated. The most recent price review was conducted by the Essential Services Commission in October 2005 (for the period 2006-2010). Whether increased costs incurred by a distributor may be passed on in the form of higher prices depends upon the regulator.

Natural Gas

A number of bodies are charged with responsibilities and obligations in relation to the natural gas market. We note certain responsibilities that apply across multiple functions before considering the legal responsibilities specifically in relation to production, transmission and distribution below.

VENCorp is conferred with power:

- in respect of the gas transmission system to specify security standards and to control the security and operation of the gas transmission system by virtue of section 160 of the *Gas Industry Act 2001* (Vic).
- to issue directions to market participants in various circumstances for the purpose of facilitating the security of the gas transmission system or the gas distribution system pursuant to section 186 of the *Gas Industry Act* 2001.
- to approve a proposed change to the Market and System Operations Rules by clause 8.4 of those rules.

The Essential Services Commission has responsibilities and obligations including the following:

- Section 18 of the *Gas Industry Act* 2001 provides that an objective of the Essential Services Commission is 'to the extent that it is efficient and practicable to do so, to promote a consistent regulatory approach between the gas industry and the electricity industry'.

Furthermore, the Essential Services Commission is conferred with a power to issue licenses to act as a distributor of natural gas pursuant to section 25 of the *Gas Industry Act* 2001.

Part 9 of the *Gas Industry Act* 2001 sets out gas supply emergency provisions and section 213 of this Act provides immunity from suit to a person acting in good faith in the execution of Part 9 or a direction, proclamation or requisition under Part 9.

Natural Gas Production

The production of natural gas is undertaken by private companies. Additional costs that are incurred as a result of climate change, whether in the nature of capital costs or operating and maintenance expenses, will initially be borne by those companies. However, such increases in costs may be passed on to retailers and eventually consumers.

Natural Gas Transmission

The transmission pipelines in Victoria are owned by private companies including GasNet Australia. Any increase in costs as a result of climate change, whether in the nature of capital costs or operating and maintenance expenses, is likely to be borne initially by the owner. This is the case despite the fact that VENCorp is responsible for the operation of these pipelines. However, an increase in costs may be passed on to consumers through increased prices.

Natural Gas Distribution

The distribution pipelines in Victoria are owned by private companies including Envestra, Multinet Gas (DB No's 1 and 2), Vic Gas Distribution and SPI Networks (Gas). Any increase in costs as a result of climate change, whether in the nature of capital costs or operating and maintenance expenses, is likely to be borne initially by the owner. However, the Essential Services Commission, as regulator of distribution tariffs, may allow distribution companies to pass through such increased costs.

6.3.6 Possible Claims in the Event of Failure

The risk analysis has identified a number of key risks to existing infrastructure. Each has the potential to generate a range of claims, as outlined in Section 4. Specific issues that will arise in the electricity and gas sectors are:

- Electricity and gas business' specific obligations and immunities under the relevant legislation
- Breaches of mandated service standards.
- Possibility of liability for policy and operational decisions, by virtue of private sector management.

6.3.7 Insurance

As noted in Section 4, while current insurance arrangement may respond to some of the likely losses identified here, there will be increasing pressure on the insurance industries' ability to meet growing claims. Also, where additional costs arise for maintenance activities (such as increased repairs for degraded wires as a result of increased intensity solar radiation) it is unlikely that existing insurance arrangements will respond. Beyond this, no electricity and gas sector specific insurance issues arise.

7.0 Telecommunications Infrastructure Risk Assessment

7.1 Introduction

Telecommunications infrastructure was assessed against climate change impacts to determine the risk to the assets and the services they provide. The telecommunications infrastructure services were divided into the following:

- Fixed Line Network - Trunk lines to exchange stations; and
- Mobile Network - Transmission towers.

A Telecommunications Infrastructure Risk Summary is provided in Section 7.2. The full comprehensive risk assessment of telecommunications infrastructure is located in Appendix E: Telecommunications Risk Assessment.

7.2 Telecommunications Infrastructure Risk Summary

Victoria's telecommunications infrastructure is at considerable risk from climate change impacts as indicated by Table 17. The main risks generally relate to:

a) Extreme Events

The predicted increased frequency and intensity of extreme wind, lightning and bushfire events may cause damage to above ground fixed line transmission infrastructure and therefore reductions in the level of service that they provide. Increased extreme rainfall events and storm surges have the potential to lead to the flooding of telecommunications exchange stations. The increase in storm activity may lead to increases in the cost of telecommunications supply due to an intensified infrastructure maintenance regime.

Additionally, the anticipated increased frequency and length of network outages would cause a disruption to communication services provided to the community, business and government, while potentially affecting emergency response and coordination efforts.

Mobile telecommunications towers may be adversely affected by an increase in wind events. Ultimately construction standards may need to be modified to address the predicted changes in climate variables.

b) Accelerated Degradation of Materials and Structures

Predicted climactic changes may lead to an acceleration of the decline in stability of telecommunications structures and foundations, through increased ground movement, changes in groundwater affecting the chemical structure of foundations and fatigue of structures from extreme storm events. Increased solar radiation in some areas of Victoria may also accelerate the degradation of transmission cables. This accelerated degradation would reduce the life expectancy of infrastructure, increase maintenance costs and potentially lead to structural failure during extreme events.

Table 17: Telecommunications Infrastructure Risk Summary

Network	Risk Scenario	Climate Variable	Risk Rating			
			2030		2070	
			Low	High	Low	High
Fixed line Network	Decline in stability of structures and foundations	• Decrease in available moisture • Increased variation in wet dry spells	Moderate	Moderate	Moderate	Moderate
	Degradation of cables	• Increased Solar radiation	Low	Low	Low	Low
	Storm damage to above ground transmission	• Increase in intensity of extreme wind • Increase in frequency and intensity of storms • Increased electrical storm activity	Low	Moderate	Moderate	High
	Exchange station flooding of exchanges, manholes and underground pits	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms • Sea-level rise	Moderate	High	High	High
Mobile Network	Wind damage to transmission towers	• Increase in intensity of wind	Low	Low	Low	Moderate

7.3 Governance

7.3.1 Summary

The majority of Victoria's telecommunications infrastructure is owned by Telstra, which has been partially privatised. The balance of telecommunications assets are split between private and public ownership. Some networks are used to offer retail services to a wide range of customers and are privately held. Private networks tend to be designed and owned by a specific entity with particular needs, which may be public or private in nature.

The primary statutory framework regulating telecommunications is the *Telecommunications Act* 1997. This imposes specific and general obligations relating to the market behaviour of telecommunications companies. An important obligation that is currently imposed on Telstra is the universal service obligation, which requires Telstra to guarantee a certain level of service to all Australian residents.

The obligations of asset owners are less defined through this statutory framework than is the case in many other infrastructure sectors. As a result, the terms of any contractual arrangements that market participants have entered into will often be paramount when considering liability for climate change related losses. Obligations are also imposed on asset managers to properly manage risks to third parties through the common law doctrine of negligence, as modified by the statutory framework. Where the private asset owners are public companies, a range of additional obligations may arise under the *Corporations Act* 2001 and elsewhere, particularly with respect to the company's dealings with its shareholders.

As a result of these obligations, failure to properly consider and address the information considered in this report may lead to liability where third parties suffer loss or damage as a result.

With regard to the costs of any necessary upgrades, improvements or repairs, these will primarily be borne by the infrastructure owner. The ability of asset owners to pass such costs on to their customers, will only be constrained by prevailing market conditions. The ability to recover unexpected replacement, maintenance and upgrade costs through insurance will depend on the coverage that each asset owner has in place.

7.3.2 Introduction

Telecommunication technologies cover both wired and wireless technology in local access networks and long distance backbone transmission networks in Australia. Wired technology includes the copper wire cables that connect customer premises to their local exchange, ISDN, optic fibre and hybrid coaxial cable. Wireless technology includes cellular mobile, microwave, broadband wireless and satellite.

7.3.3 Existing Legal Framework

The telecommunications industry is subject to two major regulators: the Australian Communications and Media Authority (ACMA) and the Australian Competition and Consumer Commission (ACCC). Technical regulation rests with the ACMA. The ACCC has the responsibility for the competition regulation of telecommunications.

Specifically, ACMA is responsible for issuing of carrier licenses, regulation of service providers, and ensuring that carriage service providers make plans to manage natural disasters

Three main types of industry operators are subject to regulation under the telecommunications framework. They are carriers, carriage service providers and content service providers (who fall outside the ambit of this report)

A carrier is a holder of a carrier licence granted by ACMA under the *Telecommunications Act* 1997. The owner of a network unit used to supply carriage services to the public must hold a carrier licence. The only exception to this is if responsibility for the unit is transferred from the owner to the carrier. Since 1 July 1997, there has been no limit on the number of carriers that can be licensed to operate in the Australian telecommunications industry.

A carriage service provider is a person who supplies, or proposes to supply, certain carriage services using network units. Internet service providers may be classed as carriage service providers. Carriers may also be carriage service providers.

Laws Applicable to the Installation of Telecommunications Facilities

The Australian Government is responsible for regulating telecommunications matters. Telecommunications facilities specified in the *Telecommunications Act* 1997 ('Telecommunications Act'), or in a ministerial determination made under the Act, are exempt from local planning laws and can be installed with authorisation under Commonwealth law. The types of facilities covered by the Act and the determination include smaller radio-communications antennas and dishes, and underground cabling.

Telecommunications facilities that are not covered by the Telecommunications Act or a determination are likely to require approval under state or territory law, usually at the local government level. The types of facilities that require local government planning approval include broadband overhead cable and all freestanding mobile phone towers.

Accordingly, telecommunications facilities are governed by legislation at the local, state and federal government levels, depending on the type of facility and the zoning of the site.

Low-impact Facilities

Licensed telecommunications carriers are authorised by the *Telecommunications Act* to install a limited range of facilities without seeking state, territory or local government planning approval. The most common of these are known as 'low-impact' facilities that are specified in the *Telecommunications (Low impact Facilities) Determination* 1997 and its amendment of 1999.

Low-impact facilities are generally small radio-communications antennae and dishes that are designed to be unobtrusive erected on existing towers or buildings. Other types of low-impact facility include underground cables, public telephones, telecommunications pits in footpaths and co-located facilities. The maximum height of a low-impact facility is 6.5 metres, but only when sited in a rural or industrial zone and the facility must have an omnidirectional antenna or an array of these. One commonly installed low-impact facility is 5.8 metres high. By contrast, mobile phone towers are generally 25 to 30 metres high.

The Low-impact Facilities Determination defines where these facilities may be installed based on zoning considerations. For example, a facility that is deemed low-impact in a rural or industrial zone may not be low-impact if it is installed in a residential area. A facility in an area of environmental significance, such as a World Heritage area or an area on the Register of the National Estate, cannot be designated a low-impact facility.

A carrier who complies with the Telecommunications Act when installing a low-impact facility is immune from some state and territory laws, including town planning, use of land, tenancy and commercial and domestic power supply laws. The Act also offers immunity from environmental assessment and protection laws, with the exception of laws pertaining to the protection of places or items of significance to the cultural heritage of Aboriginal persons or Torres Strait Islanders, for installation or maintenance of facilities.

As a consequence of these exemptions, efforts to manage of climate change risks through the introduction of specific planning controls may be ineffective for telecommunications infrastructure.

7.3.4 Current Ownership Structure

Telstra Corporation owns most of Australia's telecommunications infrastructure. 51% of Telstra Corporation is presently owned by the Australian government. The future level of government ownership in Telstra is uncertain.

Infrastructure includes the cables, or the radio or satellite connections in rural and remote Australia, that connect customer premises to their local exchange. This network is also known as the "local loop" or "the last mile".

The backbone, or trunk, network that connects exchanges within and between cities and states has a greater diversity in ownership. These may be copper wires, radio links, fibre optic cables, microwave or satellite links. Operators in Victoria include Telstra, Amcom, Nextgen, C&W Optus and PowerTel.

Additionally, Telstra and Optus rolled out fibre optic cable networks in the Melbourne, AAPT and C&W Optus have rolled out a wireless LMDS network in Melbourne and Neighbourhood Cable rolled out fibre optic cable in Ballarat. Significant State and Federal government support exists for extension of the fibre optic cable system.

There are also private networks that may also interconnect with the public network. These are usually dedicated or unswitched connections over private lines used by the public and private sectors using technologies that allow higher bandwidth than traditional copper wire.

7.3.5 Legal Responsibility for Planning and Management

The Telecommunications Division of the Department of Communications, Information Technology and the Arts (DCITA) provides advice on all regulatory policy aspects of the telecommunications, radio-communications and postal sectors.

Policy advice is provided in relation to the Telecommunications Act as well as price regulation, universal service, the role and functions of ACMA, consumer safeguards, carrier powers and immunities, public health issues and matters relating to the carriers network rollout.

Where the private asset owners are public companies, a range of additional obligations may arise under the *Corporations Act* 2001 and elsewhere, particularly with respect to the company's dealings with its shareholders. These obligations will influence the processes adopted by the private asset owners in respect of their planning and management of existing and new infrastructure. For example, a business plan to increase customers or offer new services will usually require investment in infrastructure and to the extent that such investments are not properly designed or costed, management may breach their obligations to shareholders.

7.3.6 Possible Claims in the Event of Failure

The risk analysis has identified a number of key risks to existing infrastructure. Each has the potential to generate a range of claims, as outlined in Section 4. Specific issues that will arise in the telecommunication sector are implications for Telstra of its Universal Service Obligation, breaches of service agreements within individual customers and the possibility of liability for policy and operational decisions, by virtue of private sector management. The Universal Service Obligation aims to ensure that all people in Australia, wherever they reside or carry on business, have reasonable access, on an equitable basis, to the standard telephone service and payphones. The level of obligation may increase as the telecommunications market matures and the public begin to require a higher level of service.

Where the private asset owners are public companies, a range of potential additional obligations may arise under the Corporations Act and elsewhere, particularly with respect to the company's dealings with its shareholders.

7.3.7 Insurance

As noted in Section 4, while current insurance arrangement will respond to most of the likely losses identified here, there will be increasing pressure on the insurance industries' ability to meet growing claims. There will also be an increasing need for companies to demonstrate controls or mitigation measures in place to reduce insured loss potential, such as a company climate change mitigation plan. Where additional costs arise for maintenance activities (such as increased repairs for degraded wires as a result of increased intensity solar radiation) it is unlikely that existing insurance arrangements will respond. Beyond this, no telecommunications specific insurance issues arise.

8.0 Transport Infrastructure Risk Assessment

8.1 Introduction

Transport infrastructure was assessed against climate change impacts to determine the risk to the assets and the services they provide. The transport infrastructure services were divided into the following:

- Roads - Main and municipal roads;
- Rail - All networks;
- Tunnels - All transport tunnels;
- Bridges - All transport bridges;
- Airports - All airports; and
- Ports - All jetties, piers and seawall protection.

A Transport Infrastructure Risk Summary is provided in Section 8.2. The full comprehensive risk assessment of transport infrastructure is located in Appendix F: Transport Risk Assessment.

8.1.1 Value of Assets

Victoria has a road network of approximately 197,000 km, and includes around 9,800 bridges. Although most of this road length consists of municipal roads, over 70% of road traffic travels on state arterial roads. The network is valued at approximately $32 billion, of which approximately $14 billion are the assets of Victoria's 79 councils, with the remaining $16 billion being the Freeway and Arterial Road network and $2 billion the assets of City Link.

Approximately eighteen per cent of the State Government's total investment in infrastructure (18% = over $600 million p.a.), is spent on construction, maintenance and upgrade of roads. 51% of local council assets are represented by roads.

Victoria's regional rail network consists of approximately 5000 km of operational track, and Melbourne's heavy rail system comprises 371 km (in 2004) of broad gauge track. Melbourne's light rail network has 242km (in 2004) of operational track (Engineers Australia, 2005).

8.2 Transport Infrastructure Risk Summary

The transport infrastructure in Victoria is at significant risk from climate change impacts as indicated by Table 18. The main risks relate to:

a) Extreme Events

The projected increase in the frequency and intensity of extreme rainfall events has the potential to cause significant flood damage to road, rail, bridge, airport, port and especially tunnel infrastructure. It is regarded that rail, bridges, airports and ports are more prone to extreme wind events whilst port and coastal infrastructure are particularly at risk when storm surges combine with sea level rise.

It is forecast that an increase in the number of lightning strikes will occur with climate change, potentially affecting rail operations. The projected increase in storm activity may increase the cost of transport infrastructure maintenance and replacement, and the disruption of transport services which may result could have significant economic impacts. It is also anticipated that airports may be affected by an increase in bushfire events, causing air traffic delays due to decreased visibility.

Further research is required to determine whether Victoria's major ports are vulnerable to closure during extreme weather conditions which prevail over extended periods of time i.e. two or more days .

b) Accelerated Degradation of Materials and Structures

An acceleration in the degradation of materials, structures and foundations of transport infrastructure may occur through increased ground movement, changes in groundwater affecting the chemical structure of foundations and fatigue of structures from extreme storm events.

Temperature and solar radiation increases forecast to occur with climate change have the potential to cause reductions in the life of asphalt on road surfaces and airport tarmacs. An increase in temperature may particularly stress the steel in bridges and rail tracks through expansion and increased movement. Increased temperature will also cause additional expansion of concrete joints, protective cladding, coatings and sealants on bridges and airport infrastructure. Increased solar radiation in some parts of Victoria may reduce the life of timber bridges.

Sea level rise may affect tunnels close to the coast through increased tidal and salt gradients, ground water pressure and corrosion of materials.

This accelerated degradation of transportation infrastructure has the potential to reduce its life expectancy, increase maintenance costs and lead to potential structural failure during extreme events.

Table 18: Transport Infrastructure Risk Summary

Transport	Risk Scenario	Climate Variable	Rating			
			2030		2070	
			Low	High	Low	High
Roads	Asphalt degradation	• Increased solar radiation • Increased temperature and heatwaves	Moderate	Moderate	Moderate	Moderate
	Road foundations degradation	• Increased variation in Wet/dry spells • Decrease in Available moisture	Moderate	Moderate	Moderate	High
	Flood damage to roads	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms	Moderate	Moderate	Moderate	Moderate
Rail	Rail track movement	• Increased temperature and heatwaves	Low	Moderate	Moderate	High
	Storm damage to rail	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms • Increased electrical storm activity	Moderate	Moderate	Moderate	Moderate
Bridges	Bridge structural material degradation	• Increased Temperature and Heatwaves • Increased Solar Radiation	Moderate	High	High	High
	Storm damage to bridges	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms • Increase in intensity of extreme wind	Moderate	Moderate	High	High
Tunnels	Tunnel flooding	• Increase in Extreme Daily Rainfall • Increase in frequency and intensity of storms	Moderate	Moderate	High	High
	Sea level rise impacts on tunnels in proximity of coast	• Sea Level Rise • Decrease in Rainfall	Moderate	Moderate	Moderate	High
Airports	Asphalt degradation	• Increased solar radiation • Increased temperature heatwaves	Low	Low	Low	Moderate
	Degradation of runway foundations	• Increased Variation in Wet Dry Spells • Decreased in Available Moisture	Low	Low	Low	Moderate
	Extreme event impacts to airport operations	• Increase in intensity of extreme wind • Increase in extreme daily rainfall • Increase in frequency and intensity of storms • Increased electrical storm activity • Increase in bushfires	Moderate	Moderate	Moderate	High
Ports	Storm impacts on ports and coastal infrastructure	• Increase in Intensity of Extreme Wind • Sea Level Rise • Increase in Frequency and Intensity of Storms • Increase in Extreme Daily Rainfall	Low	High	High	Extreme
	Sea level rise impacts on port infrastructure materials	• Sea level rise	Low	Moderate	Low	High

8.3 Governance

8.3.1 Summary

The majority of Victoria's transport infrastructure is in public ownership:

- The road network is managed by either VicRoads (arterial roads and freeways) or local government (local roads). The major exceptions are CityLink and the EastLink (under construction), which are owned and managed privately.

- The rail network is also predominantly in public ownership, with VicTrack owning most of Victoria's rail and tram fixed infrastructure. The major exceptions are the Spencer Street Station Precinct, privately owned sidings and certain tourist lines.
- Port ownership varies. Melbourne and Hastings are in public ownership (though Hastings is managed privately), while Geelong and Portland have been privatised. The waters of all ports (including channels) remain public.

The Road, Rail and Port infrastructure segments each operate under different legislative frameworks. These frameworks impose specific and general obligations relating to (relevantly):

- planning and development of the infrastructure segment; and
- the service levels and maintenance standards to be achieved by the infrastructure segment manager

In the case of rail and ports, significant contractual arrangements have been entered into that also impose obligations on asset owners and mangers. In addition to these statutory and contractual obligations, asset managers to properly manage risks to third parties through the common law doctrine of negligence, as modified by the statutory framework. Where the private asset owners or managers are public companies, a range of additional obligations may arise under the Corporations Act and elsewhere, particularly with respect to the company's dealings with its shareholders.

As a result of these obligations, failure to properly consider and address the information considered in this report may lead to liability where third parties suffer loss or damage as a result.

With regard to the costs of any necessary upgrades, improvements or repairs, these will primarily be borne by the infrastructure owner. The ability of asset owners to pass such costs on to their customers, will be constrained by the role of the Essential Services Commission in setting prices (on a five year cycle), and the prevailing conditions in the national electricity and gas markets. The ability to recover unexpected replacement, maintenance and upgrade costs through insurance will depend on the coverage that each asset owner has in place.

8.3.2 Introduction

There are three key elements to Victoria's transport infrastructure: road, rail; and ports.

Airports also form part of the picture, but have been excluded from this report because (from a legislative perspective) they are the primary responsibility of the Commonwealth.

8.3.3 Existing Legal Framework

Road

Most road infrastructure is owned either by VicRoads (arterial roads and freeways) or by local government (municipal roads), although two significant freeways are owned and are or will be operated by proprietary corporations.

The *Road Management Act 2004* (Road Management Act) establishes the statutory framework for road management in Victoria. The Road Management Act establishes a co-ordinated management system that is intended to promote safe and efficient roads and the responsible use of road reserves for other legitimate purposes.

The Road Management Act allocates responsibility for management of the road system between VicRoads, which is responsible for management of arterial roads and freeways; local governments, which are responsible for municipal roads; and other public bodies responsible for a relatively small number of State roads.

Two major roads are owned and managed by private companies under concession arrangements negotiated with the State: Citylink and Eastlink (under construction).

VicRoads' statutory functions, including maintaining and extending the State's declared road network are conferred under section 16(1) of the *Transport Act 1983* ('Transport Act'). Local governments' road management functions are conferred on them under the *Local Government Act 1989*.

Rail

The Transport Act and the *Rail Corporations Act 1996* ('Rail Corporations Act') establish the statutory framework for the management and ownership of rail infrastructure in Victoria (including trams). The Transport Act confers various functions on the Secretary to the Department of Infrastructure and the Director of Public Transport with respect to the provision and regulation of rail infrastructure and road operations. The RCA establishes VicTrack and certain passenger transport corporations to whom the operations and property of the former Public Transport Corporation were transferred prior to the privatisation of rail services in 1997.

Ports

The general legal framework for the management of Victoria's ports is set out in the *Port Services Act 1995* ('Port Services Act'). The Port Services Act provides for two types of ports in Victoria, commercial trading ports and local ports. The Port Services Act establishes a number of statutory corporations (Port of Melbourne Corporation, Port of Hastings Corporation and the Victorian Regional Channels Authority) to manage the commercial trading ports, and provides for the appointment of port managers to manage the local ports.

8.3.4 Current Ownership Structure

Road

The Road Management Act deals with the ownership and management of roads and the land on which they are built. It provides that the land on which freeways and arterial roads are located is owned by the Crown, while the materials from which those roads are built and other road infrastructure is owned by VicRoads. Both the land and infrastructure of municipal roads are generally the property of the local government within whose jurisdiction they are located.

The land on which Citylink (and EastLink) is built, together with the road infrastructure is held by the private owner (Transurban in the case of Citylink, Connect East in the case of EastLink) under lease arrangements. Ownership will revert to the State at the end of the concession period (in CityLink's case, after 37 years).

Rail

VicTrack currently owns most of Victoria's rail and tram fixed infrastructure (apart from the Spencer Street Station Precinct, privately owned sidings and certain tourist lines). Fixed infrastructure assets owned by VicTrack include all land and interests in land, track, signals and wiring, buildings and structures, power substation and communications infrastructure.

VicTrack leases the majority of the assets to the Director of Public Transport (Vic), who in turn sub-leases them to various transport operators and track access providers. Current leases are the metropolitan rail networks to Connex Ltd; the non metropolitan broad gauge network to Pacific National Ltd; the interstate standard gauge network to Australian Rail Tracks Corporation (ARTC) Ltd; and the metropolitan tram network to Yarra Trams.

Ports

Ownership arrangements for the land and landside assets of the commercial trading ports varies. For example, Port of Melbourne land is vested in Port of Melbourne Corporation (a state owned corporation); the Port of Geelong has been privatised and is owned and managed by Toll Holdings Pty Ltd; the Port of Hastings is owned by the Crown and is managed under an operating agreement between the State and Toll Western Port, a division of Toll Holdings Pty Ltd; and the Port of Portland is owned and operated by Port of Portland Pty Ltd.

Port waters (including channels) of the commercial ports remain in Crown ownership and are managed by the Victorian Regional Channels Authority. Generally, local ports are on Crown land reserved for port purposes under the *Crown Land (Reserves) Act* 1978, with the port manager acting as Committee of Management of the land.

8.3.5 Legal Responsibility for Planning and Management

Road

Planning

Local governments and VicRoads have a range of functions in relation to road system planning. VicRoads identifies future arterial road and freeway requirements. Corridors are protected through the reservations and zoning mechanisms in relevant planning schemes. Major projects generally require environmental approvals under State and Commonwealth impact assessment legislation. Local governments approve road proposals in subdivisions as planning authority under the *Planning and Environment Act 1987* (PE Act). VicRoads exercises control over proposals affecting the declared road network as a referral authority under the PE Act.

Management

Part 3 of the Road Management Act defines the road system in law and establishes a legal process for creating or discontinuing roads and the identification of those roads that road authorities must actively manage (generally referred to as 'public roads', including freeways, arterial and municipal roads).

Part 4 of the Road Management Act deals with the management of roads. It sets out the principal object of road management, which is to ensure that a safe and efficient road network is provided for use by members of the public and that road reserves are available for other appropriate uses. It also establishes principles that are to guide the management and co-ordination of works and infrastructure on roads by road authorities and other infrastructure managers.

Generally under the Road Management Act, local governments are responsible for the management of municipal roads, whilst VicRoads is responsible for the management of freeways and arterial roads. Section 15 of the Road Management Act enables road authorities to make arrangements to transfer road management functions as between themselves. Other statutory bodies can have responsibility for road management, either by appointment of the relevant Minister under the Road Management Act or under specific legislation like the *Melbourne City Link Act 1995*.

Part 4 of the Road Management Act deals with the development and making of codes of practice, which can provide practical guidance for road authorities, infrastructure managers and works managers in the performance of their road management functions. Codes must be developed through a process of consultation, including with utilities, and must be publicly available.

Part 4 of the Road Management Act also sets out the general functions and powers of road authorities. In doing so it distinguishes between co-ordinating road authorities, who are generally responsible for managing uses of roads (including: declaration, naming and discontinuance of roads, keeping a register of the roads each administers, and co-ordinating the installation of infrastructure and related works); and responsible road authorities, who are generally responsible for the operational aspects of road management, including construction and maintenance.

The Road Management Act sets out the matters that a road authority must have regard to when exercising its powers and functions, including the principal object of road management; the works and infrastructure management principles set out in Schedule 7 of the Road Management Act; the rights of roads users; the need to exercise the functions and powers within its overall policy and budgetary context; any relevant code of practice developed by the road authority; any other law affecting the management of roads; any roadside management plan developed to protect flora and fauna; policies and priorities in relation to transport, the environment and other matters determined by the Victorian Government; and any matters arising from consultation with the community, utilities and other stakeholders.

Road authorities are also generally required to make policies about how their road management functions are to be exercised (such as standards of construction or maintenance of a road) after considering social and community needs of the community and road users; any relevant environmental, economic, social or financial policies or objectives of the Government of Victoria; and the volume and nature of road usage; and manage the road network in cooperation with other road authorities, utilities, providers of public transport, government agencies, community organisations and private sector.

The Road Management Act also provides for the construction, inspection, maintenance and repair of public roads. In particular, it imposes a statutory duty to inspect, maintain and repair the public roads assigned to them; enables road authorities to set standards for these purposes having regard to policy and budgetary considerations; and where no standard has been made, the road authority will be under a duty to maintain the road to a reasonable standard having regard to the principles set out in the Road Management Act.

The Road Management Act also provides for the creation by a road authority of its most significant framework document, a 'road management plan' that enables road authorities to capture their policies relating to the performance of their road management functions. Through road management plans, individual road authorities may determine standards and policies for managing public roads under their control. The primary purpose of road management plans is to establish good asset management practices focused on delivering the optimal outcomes for the available resources and having regard to the policies and priorities determined by accountable bodies. The Road Management Act sets out a process for creating a road management plan, which among other things, requires it to publish the document and review it at regular intervals.

Rail

Planning

The legal responsibility for planning and managing the rail and tram network in Victoria generally resides with VicTrack. VicTrack is responsible for establishing, managing, maintaining the railways and rail infrastructure, as well as controlling access to the rail and tram infrastructure (s11 of the Rail Corporations Act). However, State-wide planning responsibilities are in practice exercised by the Department of Infrastructure.

Major rail developments are generally subject to State and Commonwealth environmental impact assessment legislation.

VicTrack is required by the Rail Corporations Act to create, with the approval of the relevant Minister, a corporate plan for each financial year, including a statement of corporate intent that must specify for the corporation in respect of the financial year to which it relates, and each of the two following financial years their business objectives, main undertakings, the nature and scope of the activities to be undertaken, accounting policies and performance targets.

The Rail Corporations Act requires VicTrack to follow its corporate plan unless approval is obtained by the Minister (s29 of the Rail Corporations Act). The Minister, with the approval of the Treasurer, can issue directions to VicTrack to perform non-commercial functions.

Management

The Transport Act imposes a series of responsibilities on the managers of rail infrastructure and operators of rolling stock. The *Rail Safety Act* 2006 imposes a new range of safety related duties on these entities with respect to the safety of rail infrastructure and rail operations. The duties will include ensuring that infrastructure provided for use in rail operations is safe.

Presently, and under the proposed new arrangements, managers of rail infrastructure are required to be accredited. Requirements of accreditation include obligations to inspect infrastructure periodically and to obtain the approval of the rail safety regulator where there is to be a 'material change' to that infrastructure.

Ports

The Port Services Act places the legal responsibility for the planning and management of ports with the statutory body created for the purpose, for example, the Port of Melbourne Corporation or the Port of Hastings Corporation (Part 2 of the PSA), or a body appointed by the Minister in relation to a local port (Part 2A of the Port Services Act).

Planning

Under the Port Services Act, port corporations are generally required to plan for the management and development of the relevant port or channel in a manner that is safe, environmentally sustainable and commercially sound manner.

The Port Services Act requires a port corporation to follow, develop and follow a corporate plan. Each port corporation is subject to the direction of the Minister and the Minister, with the approval of the Treasurer, may require a port corporation to perform non-commercial functions. The board of directors of port corporations are also required to provide reports to the Minister as required, as well as an annual report under the *Financial Management Act* 1994.

Port planning is the responsibility of the port corporation, although in practice the Department of Infrastructure plays a major role in the planning and development of major port infrastructure.

Development proposals are subject to approval processes under the *Coastal Management Act 1986* and under Commonwealth and State environmental impact assessment legislation.

Management

Part 2A of the Port Services Act provides for the Minister to appoint port managers for local ports. Port managers generally function to manage the operations of the local port, particularly with respect to shipping and boating activities of the port, providing and maintaining infrastructure at the port, as well as the operation of the port facilities (including charging for the use of port facilities).

Commercial ports are required to engage a harbour master to be responsible for direction and control of navigation and vessel operations within the port. This in part reflects the duty of a port authority at common law to ensure that the port is safe for navigation, a duty which extends to providing information about channel depths and hazards in the port. Harbour masters and port corporations therefore issue notices to mariners, provide meteorological, wave and tide information and navigation charts to assist the navigation of vessels using the ports. To the extent that climate change may effect the safe operation of the port, and the accuracy of information provided to port users, harbour masters will need to factor it in to their processes.

Draught restricted ports such as Melbourne and Geelong use information about environmental and meteorological conditions for decision-making about allowing large vessels to use channels and berths.

Part 6A of the Port Services Act requires port managers to prepare and have certified safety and environment management plans; and ensure that reasonable steps are taken to implement the measures or strategies in the plans.

The plans need to be certified, in the case of the safety management plan, by a person approved by the Minister, or in the case of the environment management plan: for a commercial trading port, an environmental auditor appointed under s 53S of the Environmental Protection Act 1970; or for a local port, a person approved by the Minister under the Port Services Act or a person appointed under s 53S of the *Environmental Protection Act* 1970.

Section 91D of the Port Services Act sets out in some detail what is required in these management plans - for example, they need to identify the nature and extent of environmental hazards, specify the measures and strategies to prevent the hazards, and set out how tenants, licensees and service providers will be involved in the implementation of the management plan.

Section 91F of the Port Services Act provides for regular audits of the managements plans to ensure they are still adequately covering the issues set out in section 91D, as well as compliance audits to see wether the port manager is adhering to the plans.

Importantly, the Minister can provide guidance on how the management plans should be developed, as well as the content and implementation of the plans. He or she can also direct the port managers on how to implement the plans, or any aspect of the plans, as well as direct the port manager to amend any plans.

8.3.6 Possible Claims in the Event of Failure

Roads

Part 6 of the Road Management Act deals with negligence claims relating to the performance of road management functions. This Part sets out the principles for a court to establish whether a road authority has a duty of care and, if so, the standard of care, in respect of the performance of a road management function. These principles are similar to those set out in the High Court decision in *Brodie v Singleton Shire Council* (2001) 206 CLR 512.

Part 6 of the Road Management Act also provides that a road authority is not liable for failure to remove or repair hazards or defects between inspections, unless it was actually aware of the hazard or defect. This does not take away from any liability for failing to inspect at appropriate intervals. Further, the Road Management Act establishes a 'policy' defence for road managers. In essence this means that where a road authority acts in accordance with established policy, they will not be liable for losses suffered by third parties as a result. However, this does not apply where the policy is completely unreasonable.

Thus, the Road Management Act provides a framework under which a road authority must respond to deterioration and damage to road infrastructure, whatever its cause.

Rail

As noted, rail infrastructure is made available for use by rail operators through a series of lease agreements between VicTrack, the Director of Public Transport and infrastructure managers and/or operators. Some infrastructure managers permit rail operators to use the infrastructure under various forms of access agreements.

Generally, those agreements provide guarantees of 'quiet enjoyment' (in the case of leases) or access subject only to operational constraints, so there is potential for conditions that prevent the infrastructure being used giving rise to various contract based claims (subject to possible exclusions for force majeure and the like).

Generally, the lease arrangements between Director of Public Transport and infrastructure managers (Pacific National, Connex, Yarra Trams and ARTC) require the infrastructure managers to maintain and repair the infrastructure, and allocate the attendant risks to them (subject to force majeure clauses).

Rail infrastructure managers are therefore likely to face claims based on tort (including negligence and breach of statutory duties) and under the various contractual arrangements in the event that persons suffer injury, loss or damage as a result of deterioration or change to the rail network.

Unlike under the Road Management Act, there is no statutory limitation and modifications of the potential liabilities of rail infrastructure managers.

Ports

Port operation, particularly in draught-restricted ports, are highly dependent on predictability of tide, wave and weather patterns. Changes to those patterns may affect the ability of ports and harbour masters to manage the port safely and efficiently.

Port authorities face exposure to liability in relation to future to take reasonable care to identify and warn port users of navigation hazards.

The Port Services Act also provides for port managers to recover damages where damage is caused to port land or port waters. If damage or loss to the port land or waters is caused by a vessel or person employed in or about the vessel, the owner, master, or agent of the vessel is liable whether or not he or she acted negligently or wrongfully (although the owner, master or agent can seek to recover from another party if that party's negligence contributed to the loss or damage). The liability regime under the Port Services Act covers both property and economic loss. Difficult questions about liability may arise in situations where damage is caused to Portland or waters by a third party relying on information support by the port manager that did not adequately address climate change.

8.3.7 Insurance

As noted in Section 4, while current insurance arrangement will respond to most of the likely losses identified here, there will be increasing pressure on the insurance industries' ability to meet growing claims. There will also be an increasing need for companies to demonstrate controls or mitigation measures in place to reduce insured loss potential, such as company climate change mitigation plans. Where additional costs arise for maintenance activities (such as increased repairs to degraded road pavement or rail tracks, or increased dredging of port channels) it is unlikely that existing insurance arrangements will respond. Beyond this, no transport specific insurance issues arise.

9.0 Buildings Infrastructure Risk Assessment

9.1 Introduction

Victorian buildings infrastructure was assessed against climate change impacts to determine the risk to the assets and the services they provide. Buildings infrastructure services were divided into the following:

- Buildings and Structures - All residential, commercial, industrial buildings and storage structures; and
- Urban Facilities - All recreational, parks, community and public space facilities.

A Buildings Infrastructure Risk Summary is provided in Section 9.2. The full comprehensive risk assessment of buildings infrastructure is located in Appendix G: Buildings Risk Assessment.

9.1.1 Value of assets

The value of residential houses and apartments in Victoria is estimated to be valued at around $350 billion based on Private Residential Valuation for Victoria 2001 figures (Department of Sustainability and Environment, 2005). The value of the commercial and government buildings and facilities in Victoria would also be significant.

9.2 Building Infrastructure Risk Summary

Buildings infrastructure in Victoria is at significant risk from climate change impacts as indicated by Table 19. The main risks generally relate to:

a) Extreme Events

An increase in the frequency and intensity of extreme rainfall, wind and lightning events may cause increased rates of damage to buildings and urban facilities. Buildings and facilities close to the coast are considered to be particularly at risk when storm surges are combined with sea level rise.

Increases in bushfire frequency and intensity have the potential to increase rates of damage to buildings, structures and other urban facilities. The majority of buildings are situated in urban areas and therefore less susceptible to bushfire risks.

The predicted increase in storm activity could increase the cost of public and private building maintenance and replacement and may have significant economic impacts.

b) Accelerated Degradation of Materials and Structures

Climate change projections indicate that the degradation of materials, structures and foundations of buildings and facilities may accelerate, mainly due to increased ground movement, changes in groundwater affecting the chemical structure of foundations and fatigue of structures from extreme storm events.

Increased temperature and solar radiation could reduce the life of building and facility elements due to temperature causing increased expansion and materials degradation of concrete joints, steel, asphalt, protective cladding, coatings, sealants, timber and masonry. Buildings in coastal zones could also be at risk from climate change impacts, due to increases in humidity in the coastal zone affecting the rate of corrosion and material degradation.

This accelerated degradation of materials has the potential to reduce the life expectancy of buildings, structures and facilities, also increasing maintenance costs and leading to potential structural failure during extreme events. Such degradation also increases the probability that extreme weather events will result in structural failure.

9.3 Building Infrastructure High Risk Summary

Table 19: Building Infrastructure

Buildings	Risk Scenario	Climate Variable	Rating			
			2030		2070	
			Low	High	Low	High
Buildings and Structures	Degradation and failure of foundations	• Increased Variation in Wet/Dry Spells • Decrease in Available Moisture	Moderate	High	High	High
	Degradation and failure of building materials	• Increased temperature and heatwaves	Moderate	Moderate	Moderate	Moderate
	Increased storm and flood damage	• Increase in Extreme Daily Rainfall • Increase in Intensity of Extreme Wind • Increase in Frequency and Intensity of Storms	Moderate	High	High	Extreme
	Coastal storm surge and flooding	• Increase in extreme daily rainfall • Sea level rise • Increase in Intensity of Extreme Wind • Increase in frequency and intensity of storms	Moderate	High	Moderate	Extreme
	Increased bushfire damage	• Increase in Bush fires	Moderate	High	High	Extreme
Urban Facilities	Degradation and failure of foundations	• Increased variations in wet/dry spells • Decrease in available moisture	Low	Low	Low	Moderate
	Degradation and failure of urban facilities' materials	• Increased temperature and heatwaves • Humidity • Increased solar radiations	Low	Low	Low	High
	Increased storm and flood damage	• Increase in extreme daily rainfall • Increase in frequency and intensity of storms • Increase in intensity in extreme wind	Moderate	Moderate	Moderate	High
	Coastal storm surge and flooding	• Increase in frequency and intensity of storms • Increase in extreme daily rainfall • Sea level rise	Low	Moderate	Moderate	High
	Increased bushfire damage	• Increase in Bushfires	Low	Moderate	Moderate	Moderate

9.4 Governance

9.4.1 Summary

The ownership of Victoria's building infrastructure (which here refers to structures not forming part of the infrastructure sectors previously dealt with) is broadly dispersed between individuals, corporations (private and public) and the government itself. Unlike all the other infrastructure sectors considered in this report, it does not have a specific regulatory framework, beyond that discussed in section 4.

Accordingly, the obligations of particular infrastructure owners will largely be as discussed in section 4, with additional obligations arising because of the nature of the owning entity, and any contractual arrangements that it may have entered into. Public companies, for instance, will have specific duties to shareholders as a result of the provisions of the Corporations Act.

These obligations mean that failure to properly consider and address the information considered in this report may lead to liability where third parties suffer loss or damage as a result.

The ability to recover unexpected replacement, maintenance and upgrade costs through insurance will depend on the coverage that each asset owner has in place.

9.4.2 Introduction

'Buildings' is a broad term that could be said to encompass much of the infrastructure elements dealt with in this report. Here it is being used to refer primarily to buildings other than those forming part of the infrastructure elements dealt with elsewhere in this report.

Victoria's buildings are owned and managed by a mixture of private and government interests. They have been established over a long period, in accordance with standards and management systems that have evolved with the process of development. Of all the infrastructure sectors dealt with in this report, it has the most diversity in ownership, the greater number of individual owners, and the greatest level of public participation in ownership. This presents challenges regarding communication of the risks to owners, and ensuring that the risks are incorporated into decision making.

The imposition of higher standards by government through the enactment of legislation and alterations to the Building code is one means of affecting behaviours.

9.4.3 Existing Legal Framework

The legal framework for built environment is essentially as described in Section 4. Unlike the position with the other infrastructure sectors, the building sector does not have its own specific legislative framework beyond that detailed earlier.

9.4.4 Current Ownership Structure

As noted above ownership is split between the private and public sectors and widely disbursed.

9.4.5 Legal Responsibility for Planning and Management

Fundamentally, the legal responsibility for the planning and management of building rests with the building owner. However, as outlined above, the final form of any given building project will be the result of a large number of decisions made by professionals and regulators, whose judgements will often be informed by the advice of the others. As a consequence, a wide range of people may be liable in the event of climate change related failures.

9.4.6 Possible Claims in the Event of Failure

The range of possible claims are as described in Section 4. The lack of a specific additional legislative framework for the building sector means that are no building specific litigation risks that need to be considered here.

9.4.7 Insurance

As noted in Section 4, while current insurance arrangements will respond to most of the likely losses identified here, there will be increasing pressure on the insurance industries ability to meet growing claims. There will also be an increasing need for companies to demonstrate controls or mitigation measures in place to reduce insured loss potential. Where additional costs arise for maintenance activities (such as accelerated degradation of footings) it is unlikely that existing insurance arrangements will respond. Beyond this, no building specific insurance issues arise.

It should be recognised that much of the public sector operates on a self-insurance basis. This will mean that government carries the direct risk of losses sustained as a result of climate change impacts. The government should consider appropriate mitigation strategies in the same way as would be required by insurers to minimise and manage the risks.

10.0 Climate Change Impacts on Infrastructure Adaptation Framework

There is general consensus in the scientific community that Australia's climate is changing partly due to the enhanced greenhouse effect. These changes will occur irrespective of efforts to reduce greenhouse gas emissions, although our success in achieving mitigation will determine the magnitude and possibly the nature of the changes to which we will need to adapt. Clearly, it is paramount that Australia continues efforts to reduce its emissions of greenhouse gases, but sitting alongside such strategies should also be effective, efficient and well communicated adaptation plans.

Although discussed theoretically since the 1980s, adaptation as an applied response to environmental change only gained practical support and acceptance following the Intergovernmental Panel on Climate Change's (IPCC) 3rd Assessment Report in 2001. Adaptation strategies aim to *increase the resilience* of human and natural systems to possible changes in climatic conditions, whilst taking account of the social dimensions of distributing losses. Such strategies should be frameworks for managing future climate risk, offering the potential to reduce future economic, social, and environmental costs.

The climate change adaptation framework for Victorian infrastructure would need to be inclusive of the key stakeholders in infrastructure policy, planning, investment, insurance, design, construction, management, operation and maintenance. The primary goal of the framework would be to reduce the significant risks that climate change poses to the cost, service and life of significant Victorian assets.

The long and short term benefits that this adaptation framework would generate are outlined below:

10.1.1 Short Term Benefits

- Investment decisions generating:
    - Reduced risk of significant losses or liability; and
    - Increased confidence in infrastructure projects due to climate change risk mitigation being integrated into project design.
- Improved planning for:
    - Residential and coastal developments; and
    - Transport, water, power, telecommunications facilities and structures.
- Enhanced reputation assisting to manage the public perception of:
    - Government;
    - Industry; and
    - Infrastructure assets.
- Insurance – possibility of reduced premiums for climate change assessed and risk mitigated infrastructure related projects

10.1.2 Long Term Benefits

- Improved resilience of infrastructure to climate change impacts;
- Reduced asset maintenance costs;
- Reduced disruption to services & productivity;
- Better informed emergency response and management, enhancing public perceptions;
- Proactive adaptation could reduce the risk of government, industry and/or community possessing no, or inadequate, insurance protection;
- Improved materials selection; and
- Increased potential of innovation of technology and cultural responses.

A climate change adaptation framework for Victorian Infrastructure needs to actively engage stakeholders to allow decision makers from government, business and the community, to make informed decisions about how to best prepare for climate change. Figure 12 below shows a potential framework for infrastructure stakeholder engagement relating to climate change impacts. It is provided to highlight the channels of communication between government, infrastructure sectors and other key stakeholders.

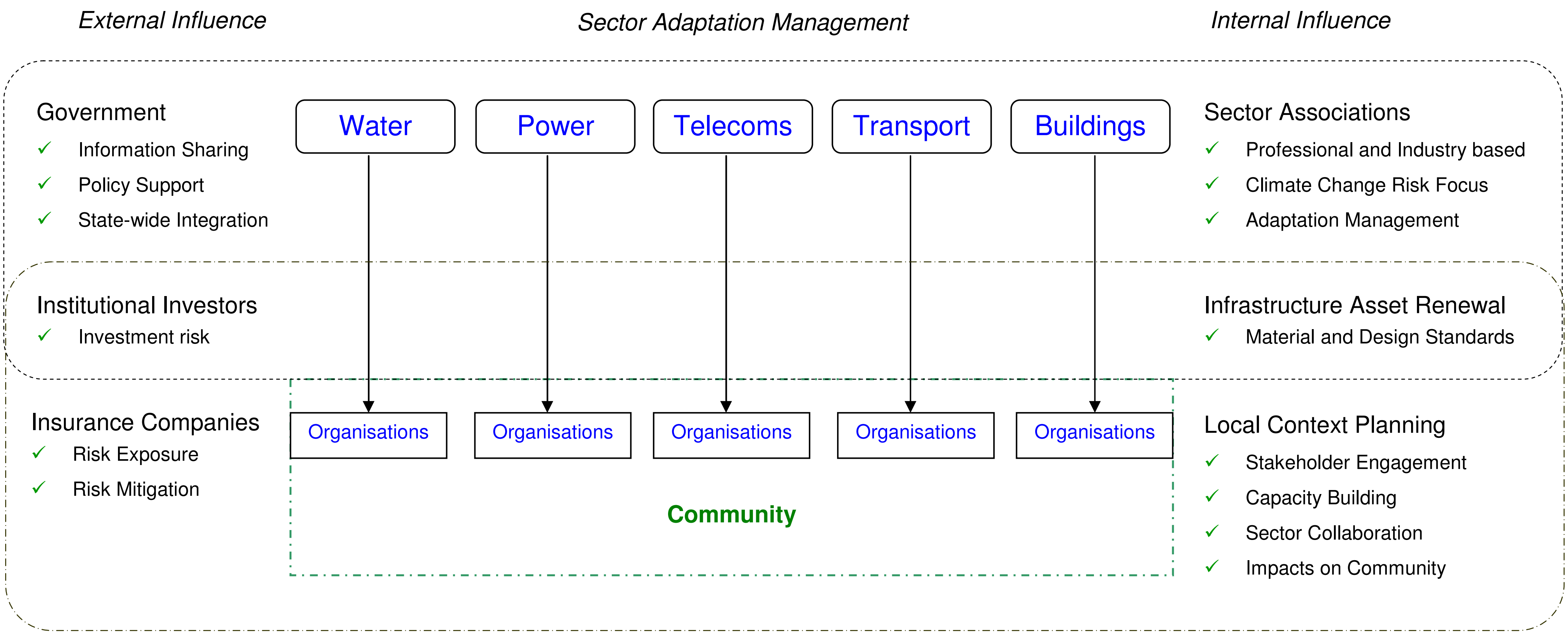

Figure 12: Suggested framework for infrastructure stakeholder engagement. Each of the infrastructure sectors is made up of individual organisations that are directly affected by insurance risk and specific issues, such as the way in which they engage with stakeholders, and their capacity to adapt.

10.2 Adaptation and Change Management

To affect a state wide adaptation response from key infrastructure stakeholders to control and mitigate the climate change risks, change management principles need to be applied. The change management is required to facilitate stakeholders to identify impacts, while aiming to empower stakeholders to deliver a mitigation response. Applied change management principles in this instance would include:

- Empowering and capacity building for the right stakeholders to lead adaptation;
- Identifying gaps in the level of understanding required by stakeholders;
- Understanding the cultural barriers to change i.e. lack of a clearly identified business case for change; the degree of resistance to commence and sustain a change process, and; lack of 'trusted others' in industry championing climate change adaptation (people listen to others that look and sound like themselves);
- Support mechanisms for change i.e. policy, incentives/disincentives, mentoring and education;
- Aim to turn climate change adaptation into a 'normal' mainstream industry response; and
- Early engagement, no surprises and plenty of warning for stakeholders.

Government leadership is required to support each infrastructure sector to build its capacity to assess the likely climate change impacts on their assets and to plan mitigation and adaptation responses to control any risks.

10.3 Adaptation Responses to Risk

Adaptation response will vary depending upon the level of risk exposure and must be prospective rather than reactionary across the industry. The adaptation response for any given location, region and infrastructure service will depend on the type and severity of the climate change impact to be avoided, mitigated or managed. The inherent climate and landscape characteristics of a location (i.e. marginal rainfall area, coastal, flood or wind prone) need to inform infrastructure planning, design and operation.

Several adaptation responses are considered below:

10.3.1 Change in Materials Selection

There will be a changing impact on building conditions as the climatic conditions change. For example, road surfaces in some areas will be exposed to increased solar radiation leading to accelerated degradation of the asphalt surface. Allowing for this increase in solar radiation in the design stage for a region will, for example, mean that the materials mix that is used in Yea will resemble the mix used for the current conditions of Mildura roads where radiation levels are already higher.

The same goes for infrastructure in close proximity to the sea such as wharfs, bridges and sea walls that will need to incorporate changes in the height of spray zones and corrosion resistance levels of materials to compensate for sea level rise. Material degradation in infrastructure may make the structure more prone to being impacted by extreme storm events.

A change in the selection of materials for infrastructure components that will be exposed to changed conditions will be an important initial step for most forms of infrastructure. The selection should be based on the desired life expectancy of the infrastructure and maintenance regime.

Any changes in materials should be linked to alterations in temperature, solar radiation, humidity, soil moisture levels, inundation and the frequency and intensity of extreme events.

10.3.2 Change in Design Standards

The design standards of particular components of infrastructure should allow for changes in the range of expected extreme events as well as accelerated degradation of certain materials and structures generated by climate change.

A review and adaptation of design standards for the majority of infrastructure is required to build the capacity of specific types of infrastructure to accommodate and withstand a wider range of extreme and changing conditions to address climate change impact risks.

10.3.3 Change in Maintenance Regime

The maintenance regime of assets over time will need to adapt to the acceleration in the degradation of materials and structures. Preventative maintenance regimes, such as, wetting dam walls during periods of low capacity and dry spells to ensure that the structure's integrity is maintained and does not get significantly affected by shrinkage and cracking. Environmental maintenance may also be required where increases in storm events lead to damage of trees and other surrounds.

10.3.4 Change in Technology

Due to expected changes in climate, it is likely that existing technology may not be able to deliver the services that the community expects. For example, technology used for maintaining water quality may need to be upgraded following a bush fire in a catchment.

Roofing technology used for housing may change to withstand greater wind velocities and storm-related damage such as water intrusion into eaves. Other forms of technology relating to stormwater collection systems and water reuse are already emerging.

10.3.5 Change in Culture

Cultural change mechanisms would need to be used as part of the risk mitigation solution. Increasing awareness of climate change impacts within the government, infrastructure, industry, community sectors will support cultural change transitions as required to more climate change friendly technologies, designs and operations of public and private infrastructure. Engaging with the various stakeholders needs to instil ownership of climate change adaptation, build the capacity to respond appropriately and support in the form of policy incentives, regulation, training and targeted programs.

10.3.6 Change in Planning

Planning considerations are vital to adaptation to climate change. For example:

- Zoning of residential, commercial and recreational areas may need to be adapted to meet changes in coastal, flood plain and rainfall conditions;
- Master and structure planning, development control plans and local environment plans may need to incorporate a strategic approach to climate change impacts in local government policy and growth area planning;
- Planning of regional essential services and community response to help build resilience to extreme weather events;
- Essential services planning may need to adapt to manage changed resource demand pressures. Two areas of focus could include:
    - capture and store stormwater locally to help supplement supply where reductions in rainfall and traditional reservoir supplies are projected; and
    - the creation of localised distributed power generation, particular from low-carbon or renewable sources, to reduce the vulnerability of the electricity system during heatwave and extreme storm events.
- Improving the energy efficiency of existing building stock as well as new buildings may be required to reduce the demand pressures on energy infrastructure and supply during heatwaves.

11.0 Selected Resources

Climate change – general

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Appendix A: IPCC Scenarios

The IPCC (2001) attributes most of the global warming observed over the last 50 years to greenhouse gases released by human activities. To estimate future climate change, the IPCC (SRES, 2000) prepared forty greenhouse gas and sulfate aerosol emission scenarios for the 21st century that combine a variety of assumptions about demographic, economic and technological driving forces likely to influence such emissions in the future. They do not include the effects of measures to reduce greenhouse gas emissions, such as the Kyoto Protocol.

Each scenario represents a variation within one of four 'storylines': A1, A2, B1 and B2. The experts who created the storylines (described below) were unable to arrive at a most likely scenario, and probabilities were not assigned to the storylines.

- The A1 storyline describes a world of very rapid economic growth in which the population peaks around 2050 and declines thereafter and there is rapid introduction of new and more efficient technologies. The three sub-groups of A1 are fossil fuel intensive (A1FI), non-fossil fuel using (A1T), and balanced across all energy sources (A1B).

- The A2 storyline depicts a world of regional self-reliance and preservation of local culture. In A2, fertility patterns across regions converge slowly, leading to a steadily increasing population and per capita economic growth and technological change is slower and more fragmented slower than for the other storylines.

- The B1 storyline describes a convergent world with the same population as in A1, but with an emphasis on global solutions to economic, social and environmental sustainability, including the introduction of clean, efficient technologies.

- The B2 storyline places emphasis on local solutions to economic, social and environmental sustainability. The population increases more slowly than that in A2. Compared with A1 and B1, economic development is intermediate and less rapid, and technological change is more diverse.

The projected carbon dioxide and sulfate aerosol emissions, and carbon dioxide concentrations, are shown in Figure 13 (a, b, c). Emissions of other gases and other aerosols were included in the scenarios but are not shown in the figure. By incorporating these scenarios into computer models of the climate system, the IPCC (2001) estimated a global-average warming of 0.54 to 1.24°C by the year 2030 and 1.17 to 3.77°C by the year 2070 (Figure 13d). The analysis allowed for both uncertainty in projecting future greenhouse gas and aerosol concentrations (behavioural uncertainty) and uncertainty due to differences between models in their response to atmospheric changes (scientific uncertainty). Projected sea-level rise is shown in Figure 13e.

The range of uncertainty in projections of global warming increases with time. Half of this range is due to uncertainty about human socio-economic behaviour, and consequent emissions of greenhouse gases and sulfate aerosols. The other half of the range is due to different climate model responses to these scenarios of greenhouse gases and sulfate aerosols. Each of the models is considered equally reliable.

Climate simulations indicate that warming will be greater near the poles and over the land, and that global-average rainfall will increase. More rainfall is likely nearer the poles and in the tropics, and less rainfall is expected in the middle latitudes such as southern Australia.

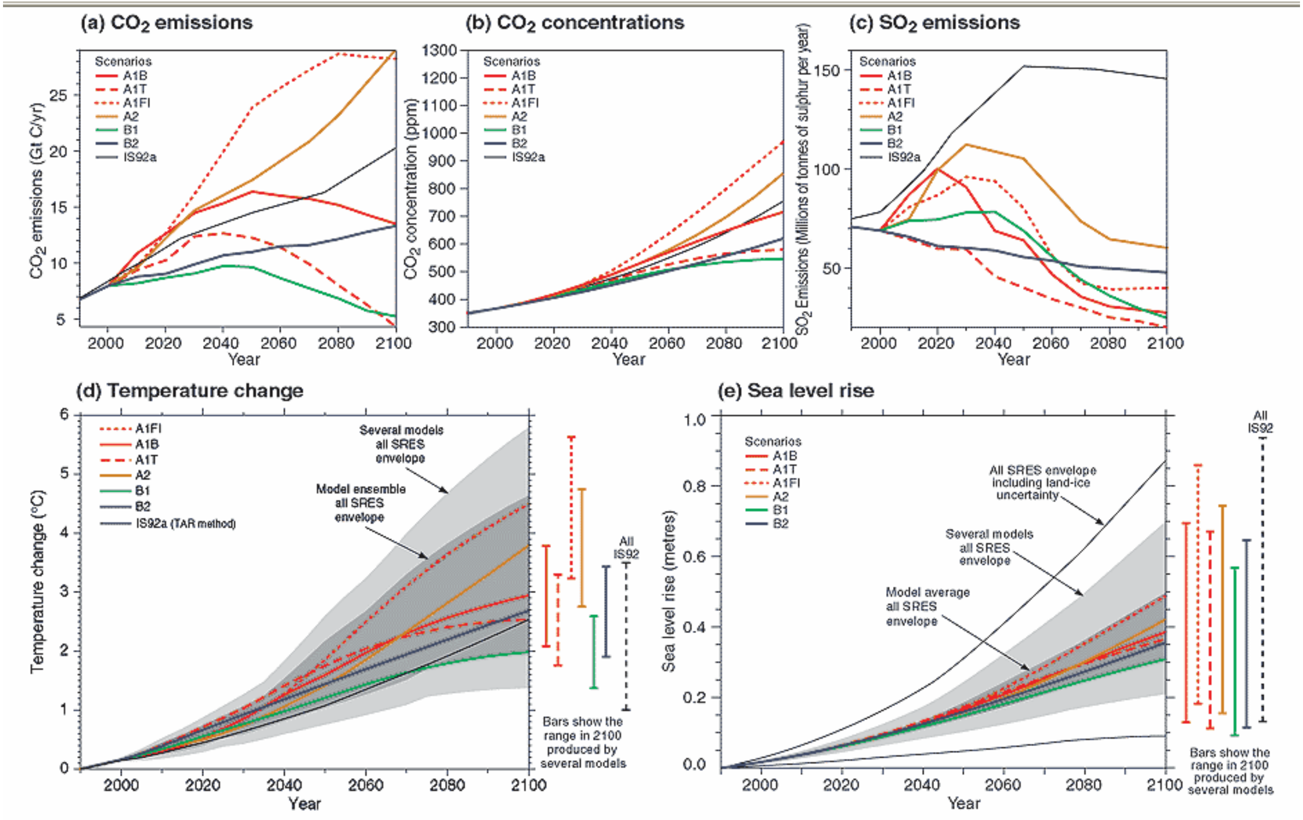


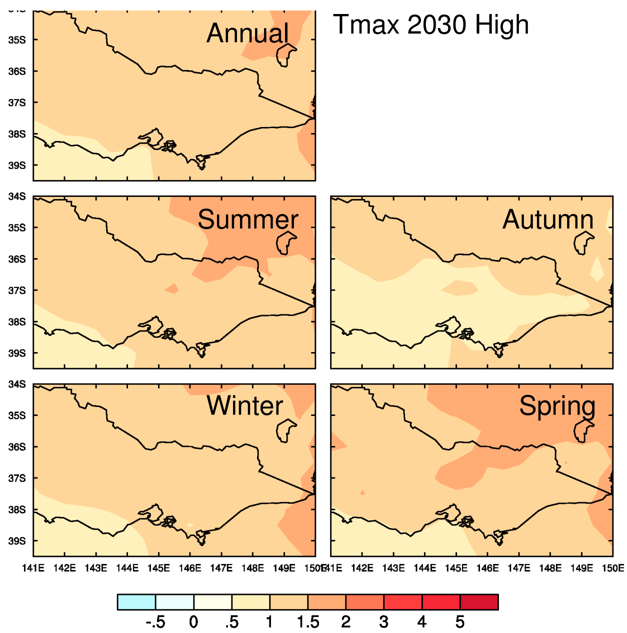
Figure 13: (a) carbon dioxide (CO_2) emissions for the six illustrative SRES (2000) scenarios, and the superseded IS92a scenario, (b) CO_2 concentrations, (c) anthropogenic sulfur dioxide (SO_2) emissions, (d) and (e) show the projected temperature and sea level responses, respectively. Source: IPCC(2001).

At present, it is not possible to assign probabilities to values within these ranges. However, the IPCC (2001) defined confidence levels that represent “the degree of belief among the authors in the validity of a conclusion, based on their collective expert judgment of observational evidence, modelling results and theory that they have examined”. The confidence levels are:

- Very high (95% or greater);
- High (67-94%);
- Medium (33-66%);
- Low (5-32%);
- Very low (4% or less).

For the global warming data in Figure 13, we have very high confidence that the lower warming limits will be exceeded and that the higher limits will not be exceeded.

Appendix B: Maps of Projected Changes



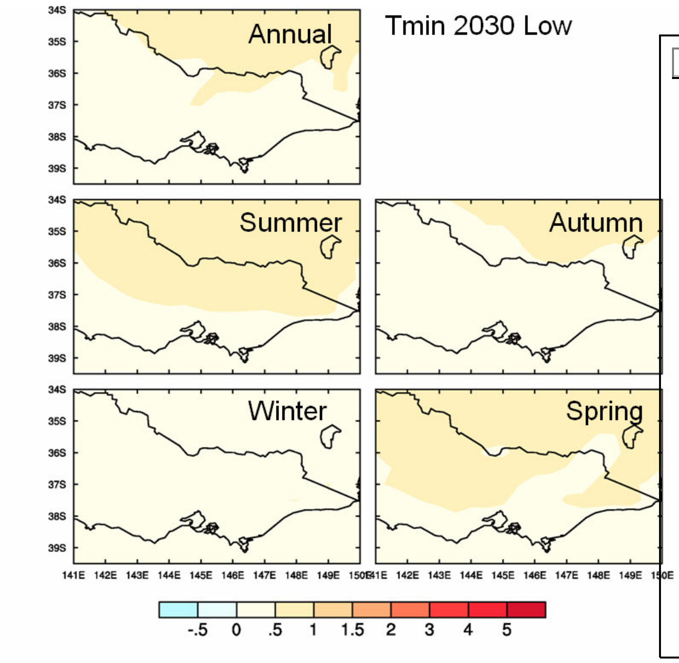


Figure 14: Average seasonal and annual changes (°C) in maximum temperature for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

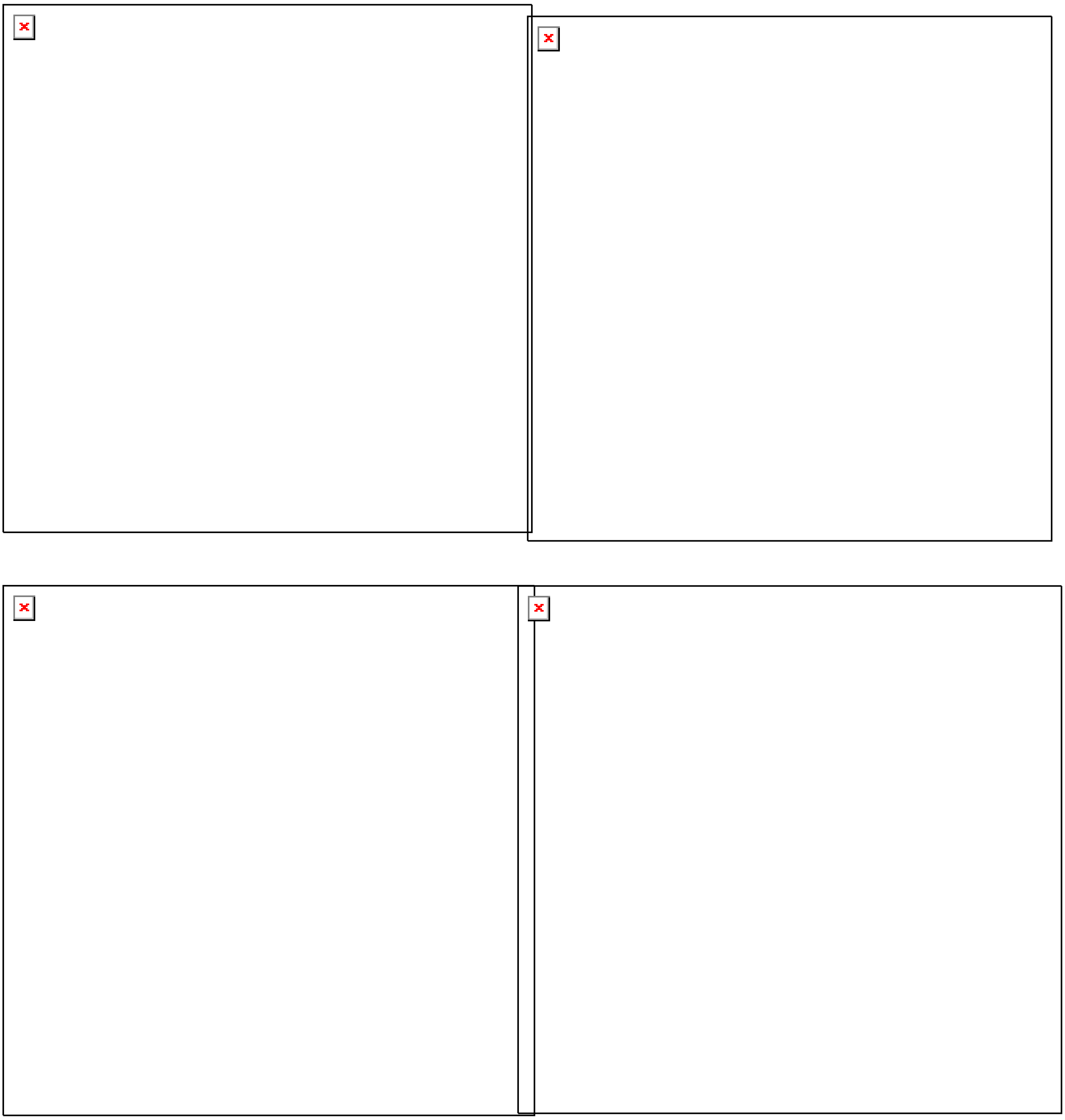


Figure 15: Average seasonal and annual changes (°C) in maximum temperature for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

Figure 16: Average seasonal and annual changes (°C) in minimum temperature for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

Figure 17: Average seasonal and annual changes (°C) in minimum temperature for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

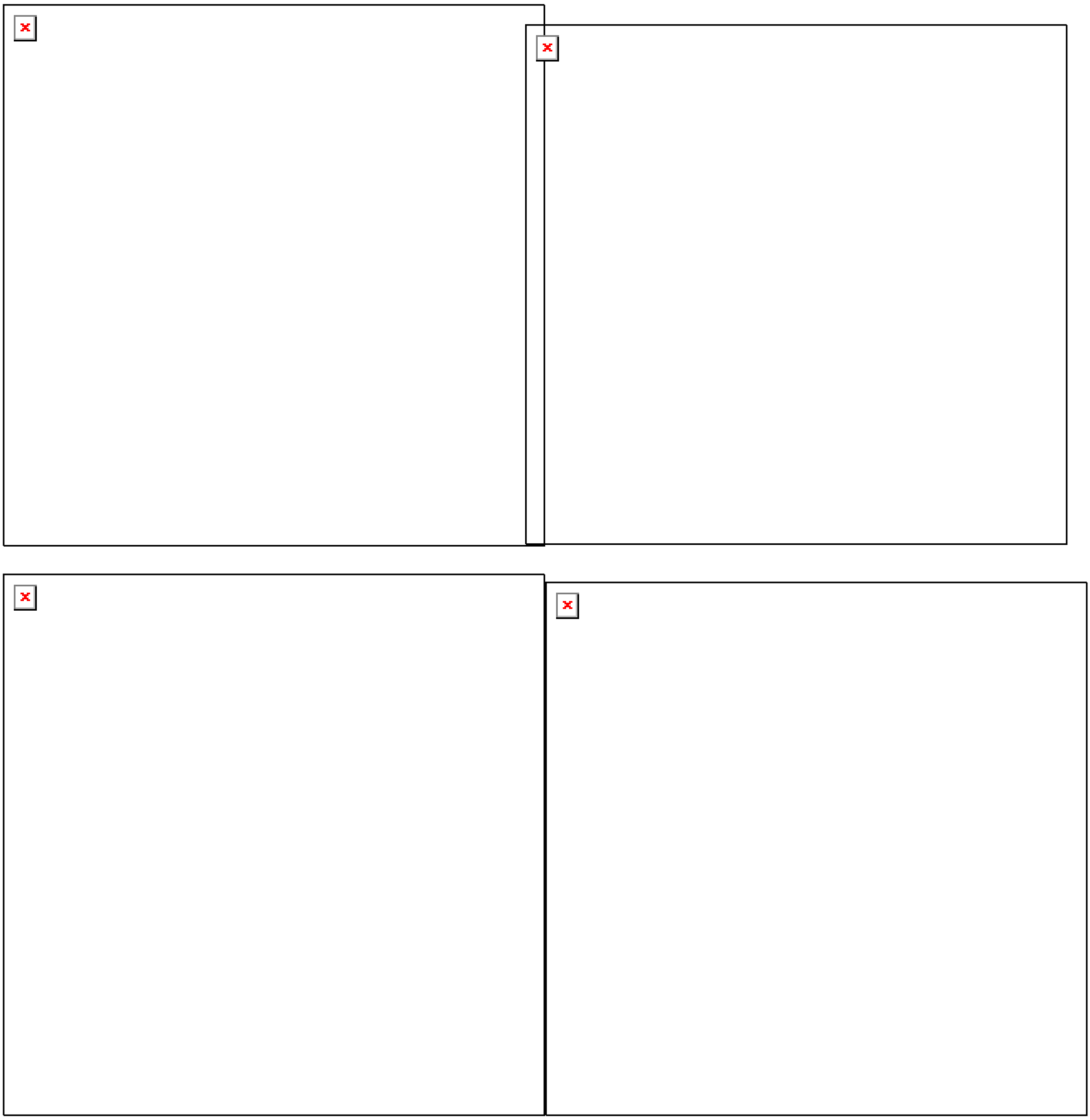


Figure 18: Average seasonal and annual changes (%) in rainfall for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

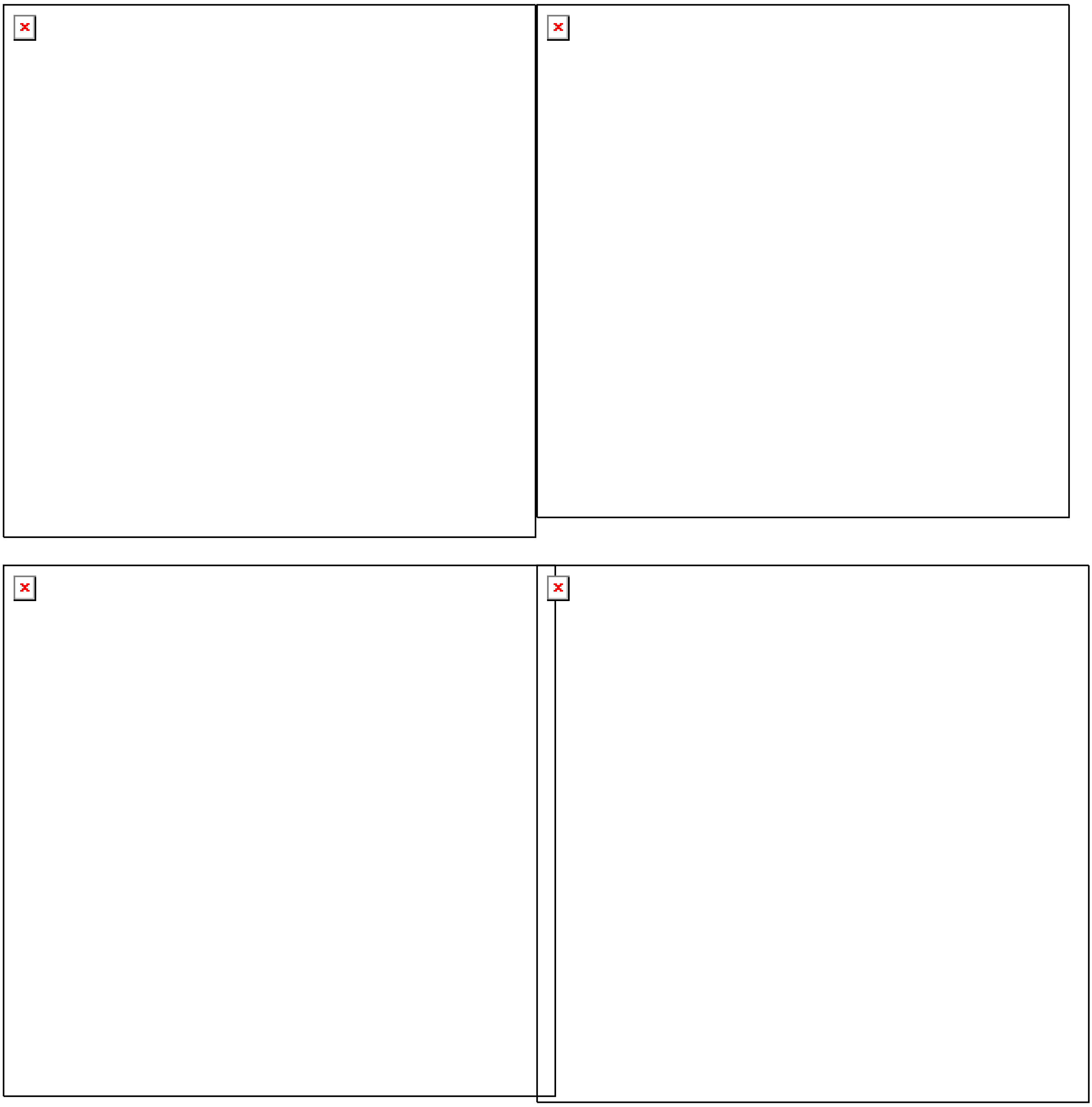


Figure 19: Average seasonal and annual changes (%) in rainfall for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

Figure 20: Average seasonal and annual changes (mm) in atmospheric moisture balance (rainfall minus potential evaporation) for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

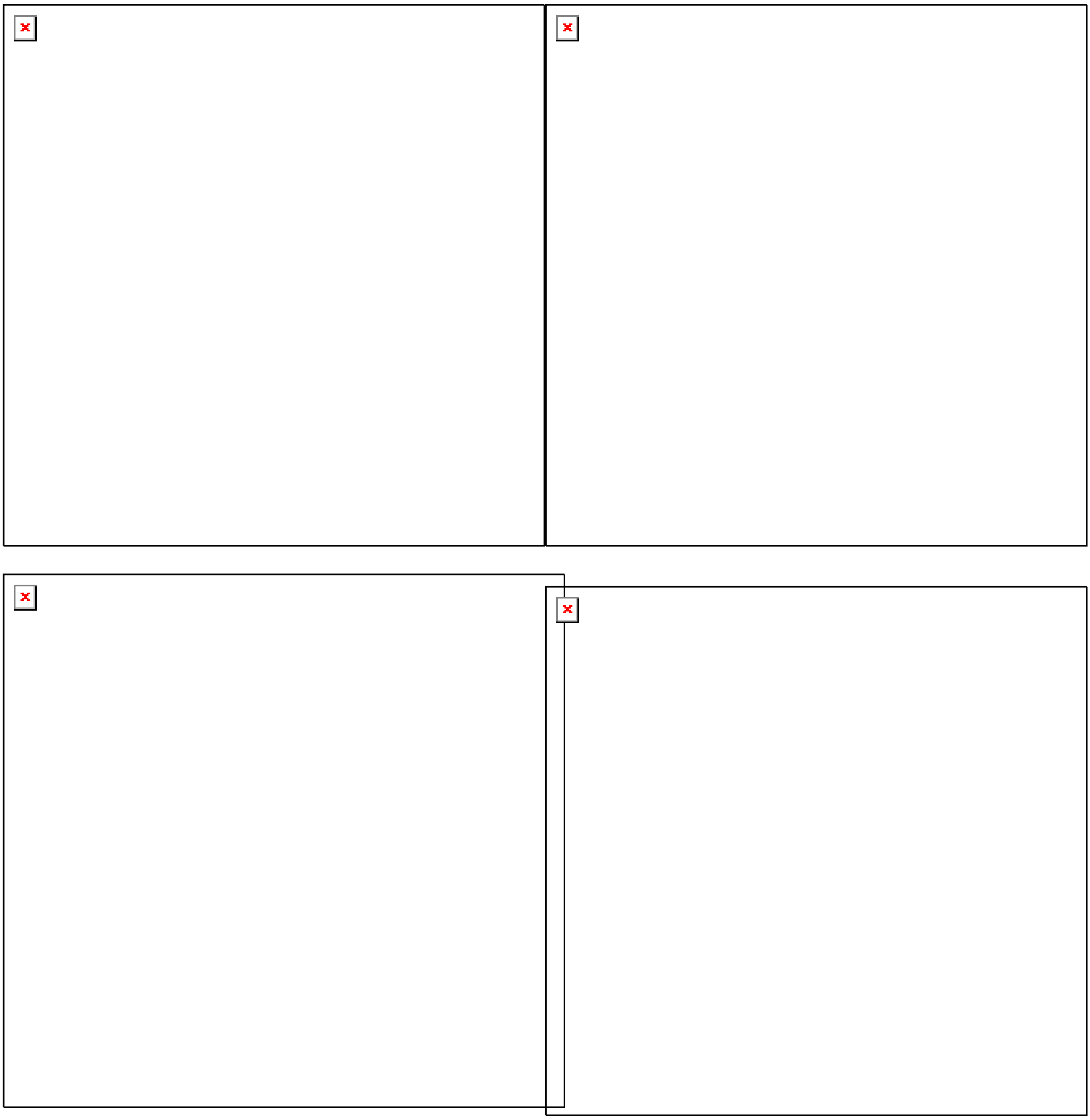


Figure 21: Average seasonal and annual changes (mm) in atmospheric moisture balance (rainfall minus potential evaporation) for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

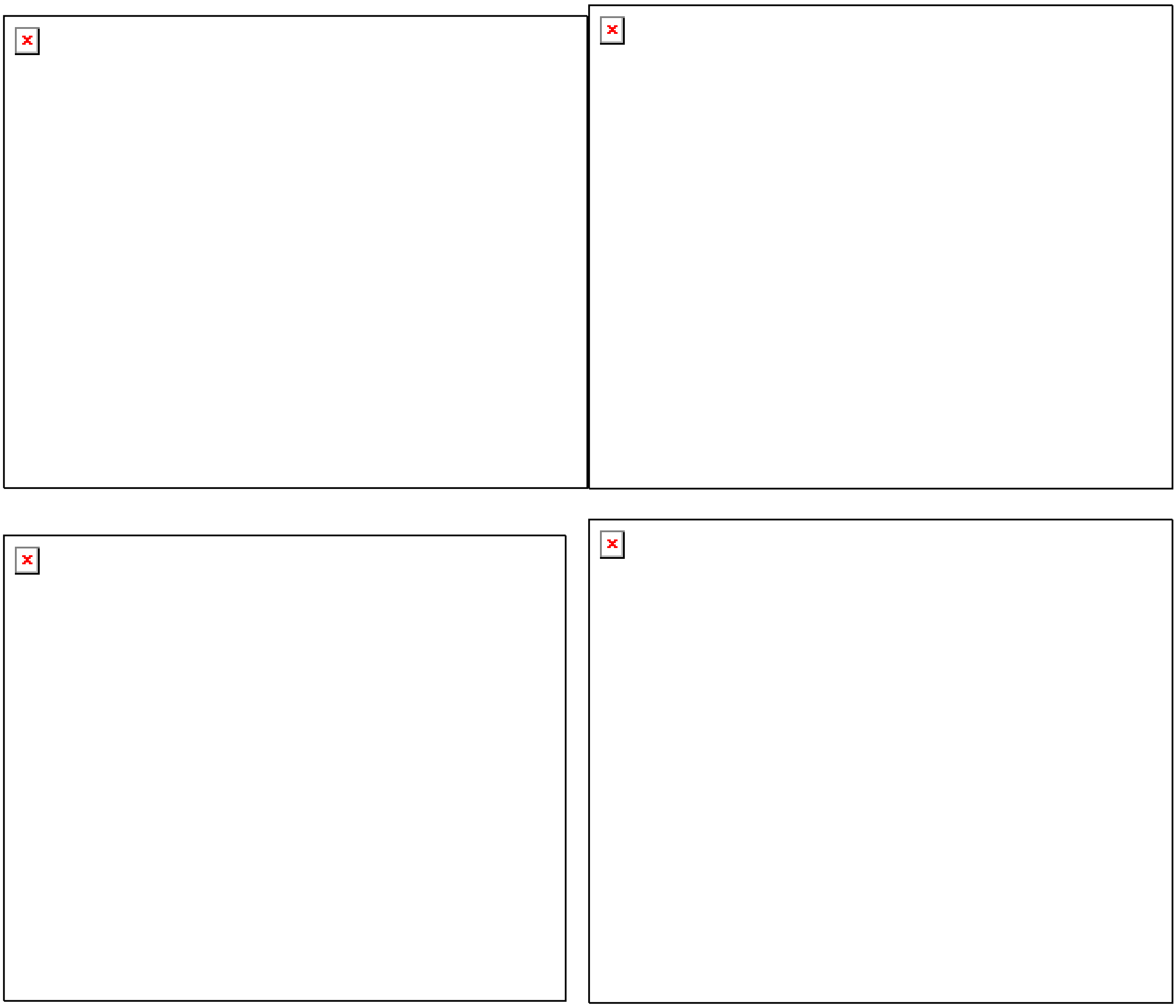


Figure 22: Average seasonal changes (%) in extreme daily wind-speed (99th percentile) for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

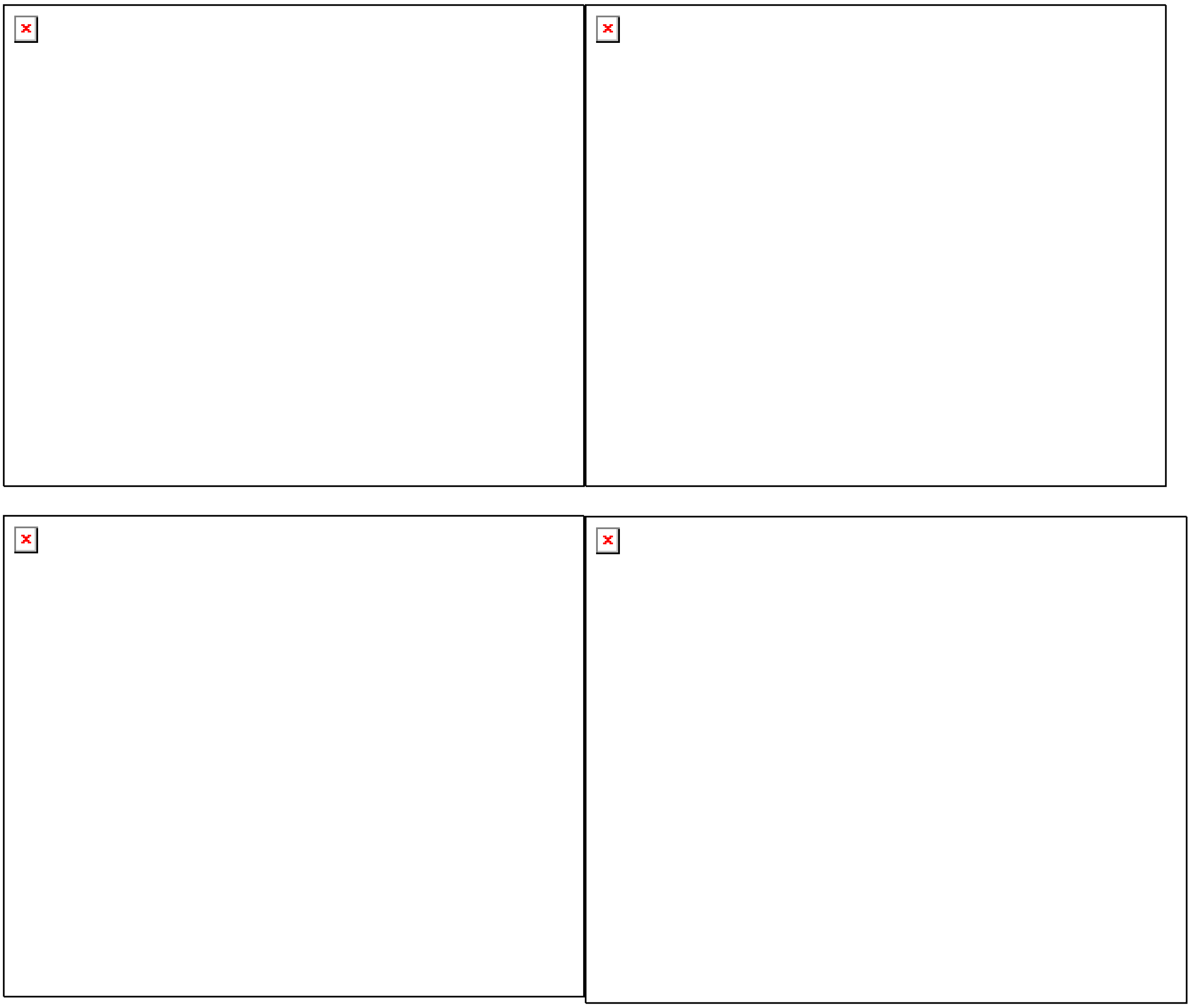


Figure 23: Average seasonal changes (%) in extreme daily wind-speed (99th percentile) for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

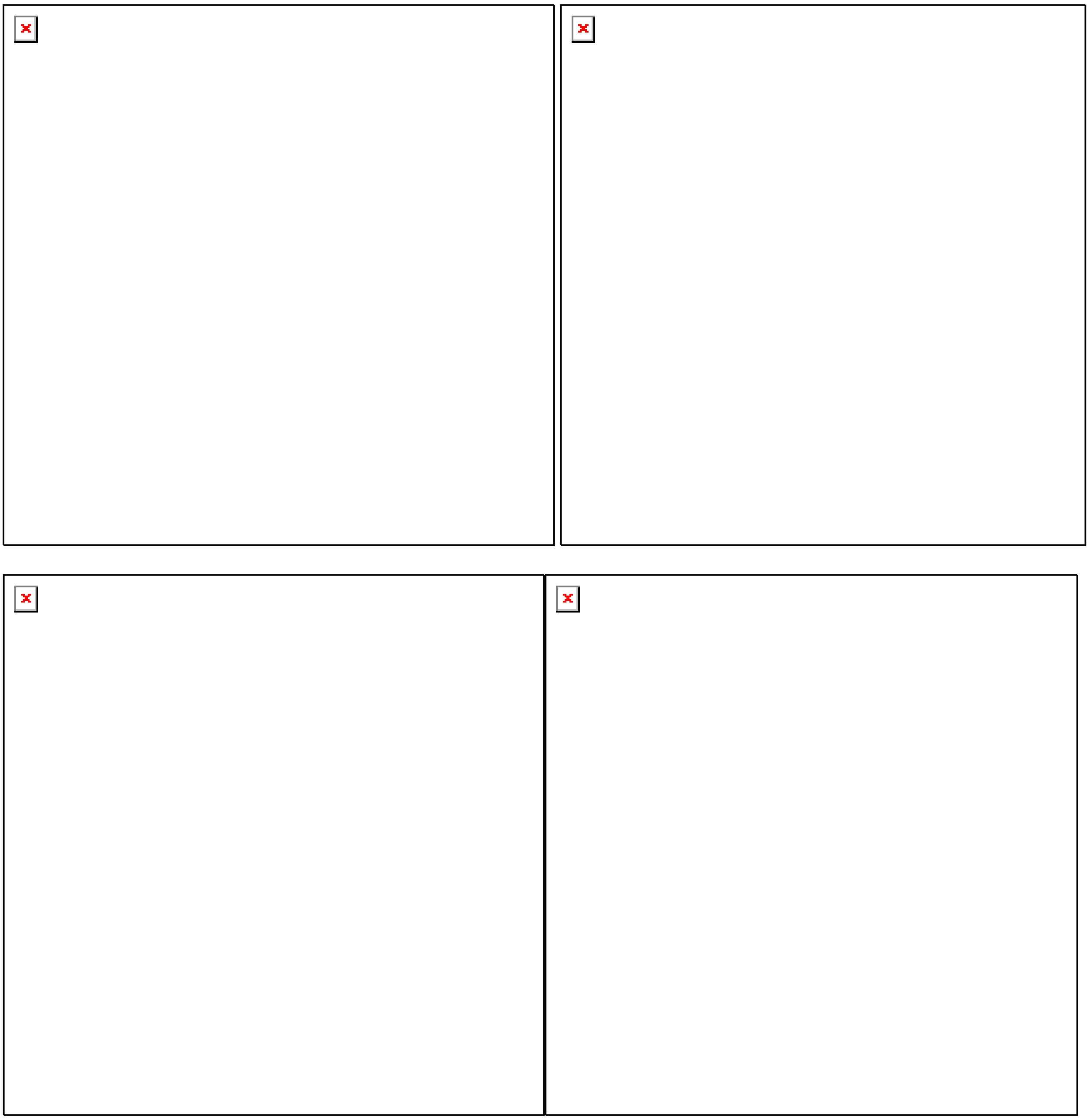


Figure 24: Average annual and seasonal changes (%) in relative humidity for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

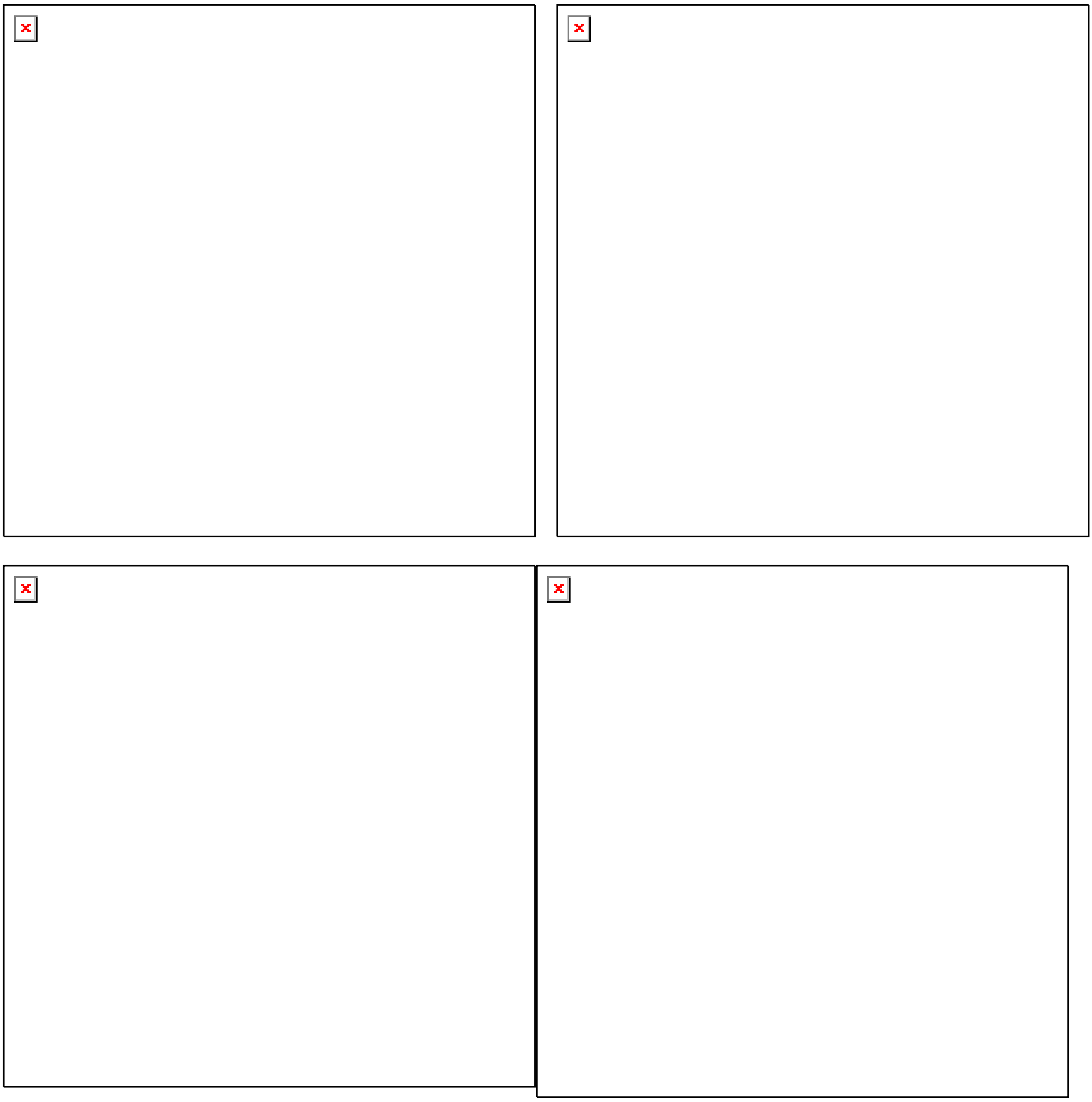


Figure 25: Average annual and seasonal changes (%) in relative humidity for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

Figure 26: Average annual and seasonal changes (%) in downward solar radiation for 2030 and 2070 relative to 1990, for the CCAM Mark 3 model.

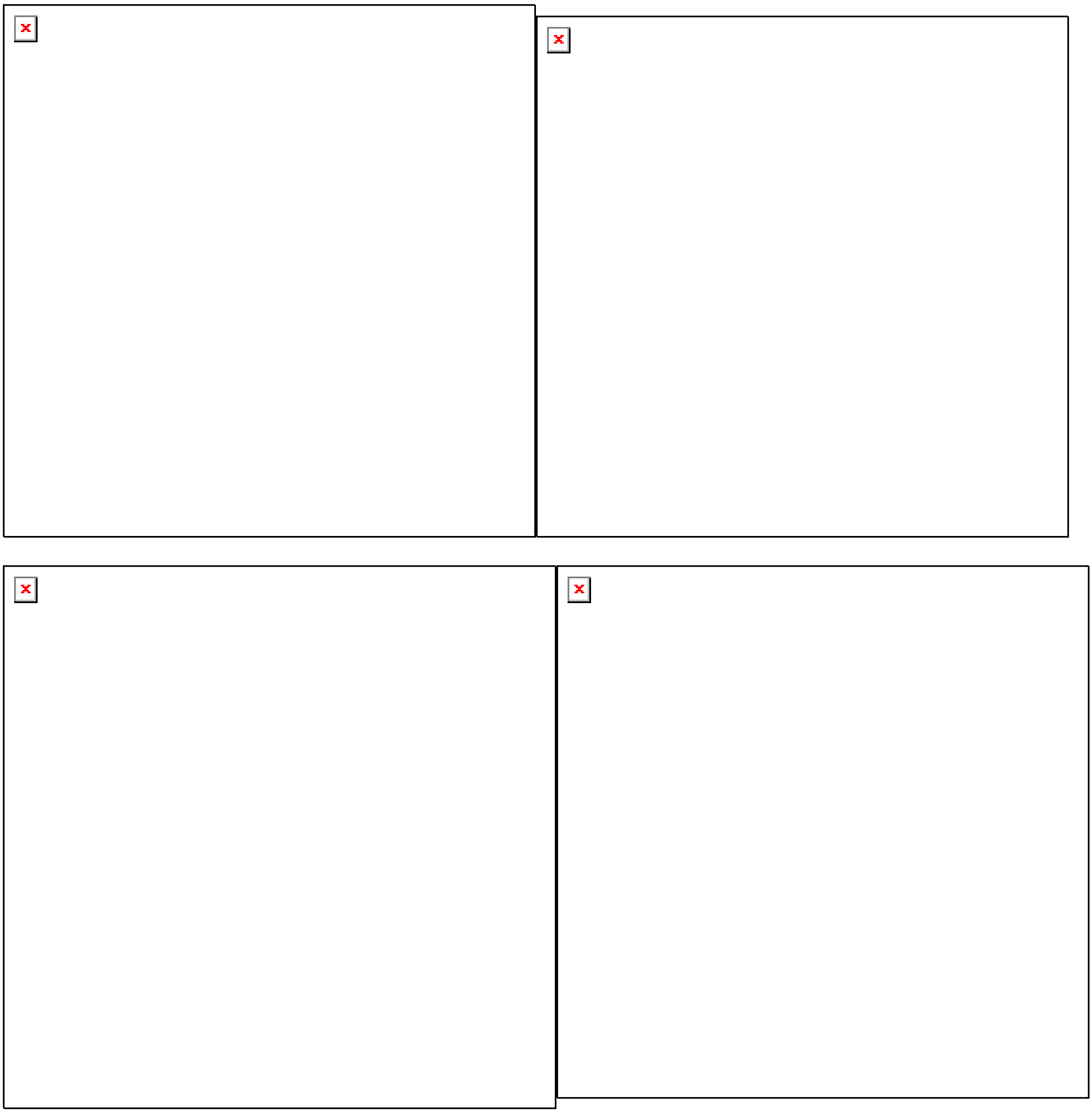


Figure 27: Average annual and seasonal changes (%) in downward solar radiation for 2030 and 2070 relative to 1990, for the CCAM Mark 2 model.

Appendix C: Water Risk Assessment

Water Risk Assessment 2030 Low

Water	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Impact for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
1.1 Water Storage and Supply	**1.1.1 Water Shortage**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Reduced capacity of the dams and reservoirs to capture and store water due to higher evaporation rates.	• Moderately likely seasonal loss of supply to localised regions. Impacts on irrigation dependent agriculture, water intensive business and residents. Financial impact to water dependent industries and water supply agencies. • Water supply shortage to sections of cities (regional and Melbourne). • Increase in water treatment costs due to lower water quality of catchment supply and potential health risks • Expensive transport of water and extraction from other water constrained areas. • Increase in water demand due to temperature increases and heat stress on humans, animals and vegetation. • Dry ground causing increased run-off and less filtration into ground water, therefore less water storage and reduced quality of water. Potentially leading to an increase to water treatment costs and the need for new forms of water storage. • Less regionally stored water in reservoirs. Under utilisation of irrigation and water storage infrastructure due to reduced rainfall and longer periods of low water storage levels. Irrigation infrastructure in some areas may be left stranded and unused due lack of water supply and viability.	**High**	**M (C3)**	**M (C3)**	**H (C4)**	**H (C4)**
		Decrease in Rainfall	**The majority of the state will have a 0-5% reduction in rainfall** Decrease in rainfall to refill storage. Increase in drought occurrence						
		Increased Temperature and Heatwaves	**0.5-1°C increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a..** Increased losses from storage facilities and increased demand for water due to heat stresses, greater water irrigation demand.						
	1.1.2 Degradation and Failure of Water Supply Piping	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater.	**Moderate**	**M (D4)**	**M (D4)**	**M (D4)**	**M (D4)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	• Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply service in some localities due to increases to maintenance regime to repair and replace piping. • Regional cost to councils and water authorities located in areas with moderate to highly expansive clays. For example the western basalt plains are characterised by their expansive clay soil, which expands and contracts greatly with changes in moisture content.					
	1.1.3 Bushfire Impacts on Catchment and Storage	**Increase in Bushfires**	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture as indicated above.	• Increase in bushfire within the main water catchment for cities and towns causing an immediate loss of water supply from ash, debris, sediments and fire fighting chemicals affecting the water quality of the dams and reservoirs. The Canberra Fires in 2004 are an example of this impact. • A financial cost impact resulting from a bushfire through key water harvesting catchments could also be the technology expenditure to utilise the water affected in the short term through, for example installation of cleaning or membrane filtration technology to treat water to meet quality standards. Such technology is not currently installed for any of the major Melbourne catchments. • Financial impact to water dependent industries and water supply agencies. • Significant community hardship and outrage. • Several years of reduced water yield from catchments due to increased water use during tree regrowth.	**Moderate**	**M (E4)**	**M (E5)**	**M (E4)**	**M (E4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Drier forest understorey and available fuel for fire.						
1.2 Sewer	**1.2.1 Degradation and Failure of Sewer Pipes**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of sewer piping and pipe structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Possible increased maintenance and replacement costs of sewer piping infrastructure. • Short term loss of sewer services for several localities due to increased service disruption due to increased maintenance regime. Unlikely and moderate health risks associated with increased leakages of sewer discharge. • Regional cost to councils and water authorities located on the western basalt plains.	**Moderate**	**L (D2)**	**M (D3)**	**L (D2)**	**M (D3)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.						

	1.2.2 Sewer Spills to Rivers and Bays	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Flood events overload the capacity of the sewer network resulting in overflow to drainage network. Generating an increase in the amount of environmental pollution in waterways and bays. • Trunk sewers located close to the existing sea level may be subject to increased tidal gradient, ground water infiltration and overload. Trunk sewer capacity would be reduced and more prone to environmental spills during high rainfall events or king tides. • The trunk sewer pipes are designed to accept stormwater and groundwater during extreme rainfall events and this can dramatically increase the volume of sewage that there is to treat, therefore increases in treatment costs.	**Low**	**L (D2)**	**L (D2)**	**L (E2)**	**L (D2)**
		Sea Level Rise	**Increase in sea level by 3 cm.**						
1.3 Storm Water and Drainage	**1.3.1 Storm Water Drainage and Flooding Damage**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Increases in the height of the 1 in 100 year flood. While the current flood height return frequency will be reduced.	• Increase in flood frequency and intensity may degrade stormwater, waterway and drainage infrastructure. The majority of older (inner city) drainage networks have been designed on historical climate regimes and may not cope with the intensity and frequency of events projected to occur as a result of climate change. • Potentially major regional to statewide damage to property, buildings and infrastructure with the potential for significant private and public costs associated with clean up, maintenance and early replacement of assets. • Potential for permanent physical injuries and fatalities directly or indirectly from flooding event. • Flooded areas near the sea that rely on tidal drainage may be inundated for longer due to sea level rise impacts on tidal gradient. • Negative media reports in state media impacting on governance.	**High**	**H (C4)**	**H (C4)**	**M (D3)**	**H (C4)**
		Decrease in Available Moisture	**The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Low soil moisture prior to flood event reduces the capacity of the soil to absorb water, therefore increasing run off and the intensity of the flood event.						
		Sea Level Rise	**Increase in sea level by 3 cm.**						
	1.3.2 Degradation and Failure of Drainage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%..**	• Moderately likely degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and	**Moderate**	**M (C3)**	**M (C3)**	**L (C2)**	**M (C3)**

	Infrastructure	**Increase in Frequency and Intensity of Storms**	**Increase in intensity and number of storm events.**	changes in groundwater. • Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply for several localities due to increased service disruption due to increased maintenance regime. • Moderate state-wide costs from increased flood damage to waterway structures including river and levee banks.					

Water Risk Assessment 2030 High

Water	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
2.1 Water Storage and Supply 2.2 Sewer	**2.1.1 Water Shortage**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Reduced capacity of the dams and reservoirs to capture and store water due to higher evaporation rates.	• Moderately likely seasonal loss of supply to localised regions. • Water supply shortage to sections of cities (regional and Melbourne). • Increase in water treatment costs due to lower water quality of catchment supply and potential health risks • Financial impact to water dependent industries and water supply agencies. • Increase in water demand due to temperature increases and heat stress on humans, animals and vegetation, potentially leading to fatalities. • Dry ground causing increased run-off and less filtration into ground water, therefore less water storage and reduced quality of water. More water storage facilities required and increases to water treatment costs. • Less regionally stored water in reservoirs. Under utilisation of irrigation and water storage infrastructure. Dams and channels. • Increased regional costs of establishing water collection, storage and reuse systems for communities, developers, investors, local government, water authorities and state government.	**High**	**H (C4)**	**H (C4)**	**H (C4)**	**H (C4)**
		Decrease in Rainfall	**The majority of the state will have a 5-10% reduction in rainfall** Decrease in rainfall to refill storage. Increase in drought occurrence						
		Increased Temperature and Heatwaves	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a..** Increased losses from storage facilities and increased demand for water due to heat stresses, greater water irrigation demand.						
	2.1.2 Degradation and Failure of Water Supply Piping	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater.	**Moderate**	**M (B3)**	**M (B3)**	**M (C3)**	**M (B3)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	• Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply service in some localities due to increases to maintenance regime to repair and replace piping. Regional cost to councils and water authorities located in areas with moderate to highly expansive clays. For example the western basalt plains are characterised by their expansive clay soil, which expands and contracts greatly with changes in moisture content.					
	2.1.3 Bushfire Impacts on Catchment and Storage	**Increase in Bushfires**	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture as indicated above.	• Increase in bushfire within the main water catchment for cities and towns causing an immediate loss of water supply from ash, debris, sediments and fire fighting chemicals affecting the water quality of the dams and reservoirs. The Canberra Fires in 2004 are an example of this impact. • A financial cost impact resulting from a bushfire through key water harvesting catchments could also be the technology expenditure to utilise the water affected in the short term through, for example installation of cleaning or membrane filtration technology to treat water to meet quality standards. Such technology is not currently installed for any of the major Melbourne catchments. • Financial impact to water dependent industries and water supply agencies. • Significant community hardship and outrage. • Expensive transport of water and extraction from other water constrained areas. • Several years of reduced water yield from catchments due to increased water use during tree regrowth.	**High**	**M (D4)**	**H (D5)**	**M (D4)**	**M (D4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Drier forest understorey and available fuel for fire.						
	2.2.1 Degradation and Failure of Sewer Pipes	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of sewer piping and pipe structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of sewer	**Moderate**	**M (C3)**	**M (C3)**	**L (D2)**	**M (C3)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	piping infrastructure. • Short term loss of sewer services in some localities due to increases to maintenance regime to repair and replace piping.Could potentially increase health risks associated with increased leakages of sewer discharge. • Regional cost to councils and water authorities located on the western basalt plains. These plains are characterised by their soil, which expands and contracts greatly with changes in moisture content.					
	2.2.2 Sewer Spills to Rivers and Bays	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Flood events overload the capacity of the sewer network resulting in overflow to drainage network. Generating an increase in the amount of environmental pollution in waterways and bays. • Trunk sewers located close to the existing sea level may be subject to increased tidal gradient, ground water infiltration and overload. Trunk sewer capacity would be reduced and more prone to environmental spills during high rainfall events or king tides. • Increased volume of sewage during extreme rainfall events due to seepage into sewer system needing to be treated, therefore increases in treatment costs.	**Moderate**	**L (D2)**	**M (C3)**	**L (D2)**	**L (D2)**
		Sea Level Rise	**Increase in sea level by 17 cm.**						
2.3 Storm Water and Drainage	**2.3.1 Storm Water Drainage and Flooding Damage**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Increases in the height of the 1 in 100 year flood. While the current flood height return frequency will be reduced.	• Increase in flood frequency and intensity may degrade stormwater, waterway and drainage infrastructure. The majority of older (inner city) drainage networks have been designed on historical climate regimes and may not cope with the intensity and frequency of events projected to occur as a result of climate change. • Potentially major regional to statewide damage to property, buildings and infrastructure with the potential for significant private and public costs associated with clean up, maintenance and early replacement of assets. • Potential for permanent physical injuries and fatalities directly or indirectly from flooding event. • Flooded areas near the sea that rely on tidal drainage may be inundated for longer due to sea level rise impacts on tidal gradient. • Negative media reports in state media impacting on governance.	**High**	**H (C4)**	**H (C4)**	**M (D3)**	**H (C4)**
		Decrease in Available Moisture	**The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Low soil moisture prior to flood event reduces the capacity of the soil to absorb water, therefore increasing run off and the intensity of the flood event.						
		Sea Level Rise	**Increase in sea level by 17 cm.**						

	2.3.2 Degradation and Failure of Drainage Infrastructure	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Likely degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater. • Increased maintenance and replacement costs of water supply and waterway infrastructure. • Moderate state wide costs from increased flood damage to waterway structures including river and levee banks.	**Moderate**	**M (B3)**	**M (B3)**	**M (B2)**	**M (B3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						

Water Risk Assessment 2070 Low

Water	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating	Infrastructure Service	Social	Governance	Finance
3.1 Water Storage and Supply	**3.1.1 Water Shortage**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Reduced capacity of the dams and reservoirs to capture and store water due to higher evaporation and water losses rates.	• Moderately likely to have seasonal loss of supply to localised regions. • Water supply shortage to sections of cities (regional and Melbourne). • Increase in water treatment costs due to lower water quality of catchment supply and potential health risks • Financial impact to water dependent industries and water supply agencies. • Expensive transport of water and extraction from other water constrained areas. • Increase in water demand due to temperature increases and heat stress on humans, animals and vegetation potentially leading to fatalities. • Dry ground causing increased run-off and less filtration into ground water, therefore less water storage and reduced quality of water. More water storage facilities required and increases to water treatment costs. • Less regionally stored water in reservoirs leading to under utilisation of irrigation and water storage infrastructure. • Increased regional costs due to greater need for establishing water collection, storage and reuse systems for communities, developers, investors, local government and water authorities.	**High**	**H (C4)**	**H (C4)**	**H (C4)**	**H (C4)**
		Decrease in Rainfall	**The majority of the state will have a 5-10% reduction in rainfall.** Decrease in rainfall to refill storage. Increase in drought occurrence						
		Increased Temperature and Heatwaves	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.** Increased losses from storage facilities and increased demand for water due to heat stresses, greater water irrigation demand.						
	3.1.2 Degradation and Failure of Water Supply Piping	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater.	**Moderate**	**M (B3)**	**M (B3)**	**M (C3)**	**M (B3)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	• Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply service in some localities due to increases to maintenance regime to repair and replace piping. Regional cost to councils and water authorities located in areas with moderate to highly expansive clays. For example the western basalt plains are characterised by their expansive clay soil, which expands and contracts greatly with changes in moisture content.					
	3.1.3 Bushfire Impacts on Catchment and Storage	**Increase in Bushfires**	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture as indicated above.	• Increase in bushfire within the main water catchment for cities and towns causing an immediate loss of water supply from ash, debris, sediments and fire fighting chemicals affecting the water quality of the dams and reservoirs. The Canberra Fires in 2004 are an example of this impact. • A financial cost impact resulting from a bushfire through key water harvesting catchments could also be the technology expenditure to utilise the water affected in the short term through, for example installation of cleaning or membrane filtration technology to treat water to meet quality standards. Such technology is not currently installed for any of the major Melbourne catchments. • Financial impact to water dependent industries and water supply agencies. • Significant community hardship and outrage. • Expensive transport of water and extraction from other water constrained areas. • Several years of reduced water yield from catchments due to increased water use during tree regrowth.	**High**	**M (D4)**	**H (D5)**	**M (D4)**	**M (D4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Drier forest understorey and available fuel for fire.						
3.2 Sewer	**3.2.1 Degradation and Failure of Sewer Pipes**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of sewer piping and pipe structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of sewer	**Moderate**	**M (C3)**	**M (C3)**	**L (D2)**	**M (C3)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	piping infrastructure. • Short term loss of sewer services in some localities due to increases to maintenance regime to repair and replace piping. • Could potentially increase health risks associated with increased leakages of sewer discharge. Regional cost to councils and water authorities located in areas with moderate to highly expansive clays. For example the western basalt plains are characterised by their expansive clay soil, which expands and contracts greatly with changes in moisture content.					
	3.2.2 Sewer Spills to Rivers and Bays	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Flood events overload the capacity of the sewer network resulting in overflow to drainage network. Generating an increase in the amount of environmental pollution in waterways and bays. • Trunk sewers located close to the existing sea level may be subject to increased tidal gradient, ground water infiltration and overload. Trunk sewer capacity would be reduced and more prone to environmental spills during high rainfall events or king tides. • Increase in volume of sewage to treat, therefore increases in treatment costs.	**Moderate**	**M (C2)**	**M (C3)**	**M (D3)**	**M (C2)**
		Sea Level Rise	**Increase in sea level by 7 cm.**						
3.3 Storm Water and Drainage	**3.3.1 Storm Water Drainage and Flooding Damage**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Increases in the height of the 1 in 100 year flood. While the current flood height return frequency will be reduced.	• Increase in flood frequency and intensity will degrade stormwater, waterway and drainage infrastructure. The majority of older (inner city) drainage networks have inadequate capacity to deal with extreme rainfall events due to historical design standards being lower and subsequent build up of hard surfaces since original establishment of infrastructure to handle storm water drainage. • Potentially catastrophic regional to statewide damage to property, buildings and infrastructure. Significant private and public costs associated with clean up, maintenance and replacement of assets across the state. • Potential for permanent physical injuries and fatalities directly or indirectly from flooding event. • Flooded areas near the sea that rely on tidal drainage may be inundated for longer due to sea level rise impacts on tidal gradient. • Negative media reports in national and international media.	**Extreme**	**E (C5)**	**E (C5)**	**H (C4)**	**E (C5)**
		Decrease in Available Moisture	**The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Low soil moisture prior to flood event reduces the capacity of the soil to absorb water, therefore increasing run off and the intensity of the flood event.						
		Sea Level Rise	**Increase in sea level by 7 cm.**						

	3.3.2 Degradation and Failure of Drainage Infrastructure	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Likely Degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater. • Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply for several localities due to increased service disruption due to increased maintenance regime. • Moderate state-wide costs from increased flood damage to waterway structures including river and levee banks.	**Moderate**	**M (B3)**	**M (B3)**	**M (B2)**	**M (B3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						

Water Risk Assessment 2070 High

Water	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
4.1 Water Storage and Supply	**4.1.1 Water Shortage**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Reduced capacity of the dams and reservoirs to capture and store water due to higher evaporation rates.	• Likely seasonal loss of supply to localised regions. • Water supply shortage to sections of cities (regional and Melbourne). • Increase in water treatment costs due to lower water quality of catchment supply and potential health risks • Financial impact to water dependent industries and water supply agencies. Expensive transport of water and extraction from other water constrained areas. • Increase in water demand due to temperature increases and heat stress on humans, animals and vegetation potentially causing fatalities. • Dry ground causing increased run-off and less filtration into ground water, therefore less water storage and reduced quality of water. More water storage facilities required and increases to water treatment costs. • Less regionally stored water in reservoirs leading to under utilisation of irrigation and water storage infrastructure. • Increased regional costs due to greater need for establishing water collection, storage and reuse systems for communities, developers, investors, local government and water authorities.	**Extreme**	**H (B4)**	**E (B5)**	**E (B5)**	**H (B4)**
		Decrease in Rainfall	**The majority of the state will have a 10-30% reduction in rainfall, with some areas having a reduction of up to 40%.** Decrease in rainfall to refill storage. Increase in drought occurrence						
		Increased Temperature and Heatwaves	**3-5°C increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30°C by 4 (Melbourne) to 19 (Rutherglen) p.a.** Increased losses from storage facilities and increased demand for water due to heat stresses, greater water irrigation demand.						
	4.1.2 Degradation and Failure of Water Supply Piping	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater.	**High**	**H (A3)**	**M (B3)**	**M (C3)**	**H (A3)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	• Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply service in some localities due to increases to maintenance regime to repair and replace piping. • Regional cost to councils and water authorities located in areas with moderate to highly expansive clays. For example the western basalt plains are characterised by their expansive clay soil, which expands and contracts greatly with changes in moisture content.					
	4.1.3 Bushfire Impacts on Catchment and Storage	**Increase in Bushfires**	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture as indicated above.	• Increase in bushfire within the main water catchment for cities and towns causing an immediate loss of water supply from ash, debris, sediments and fire fighting chemicals affecting the water quality of the dams and reservoirs. The Canberra Fires in 2004 are an example of this impact. • A financial cost impact resulting from a bushfire through key water harvesting catchments could also be the technology expenditure to utilise the water affected in the short term through, for example installation of cleaning or membrane filtration technology to treat water to meet quality standards. Such technology is not currently installed for any of the major Melbourne catchments. • Financial impact to water dependent industries and water supply agencies. • Significant community hardship and outrage. • Expensive transport of water and extraction from other water constrained areas. • Several years of reduced water yield from catchments due to increased water use during tree regrowth.	**Extreme**	**H (C4)**	**E (C5)**	**H (C4)**	**H (C4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Drier forest understorey and available fuel for fire.						
4.2 Sewer	**4.2.1 Degradation and Failure of Sewer Pipes**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of sewer piping and pipe structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of sewer piping	**High**	**H (B4)**	**M (B3)**	**L (D2)**	**H (B4)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Soil movement generated in prone soils. Dry ground causing increased run-off and greater flood and flash flood potential.	infrastructure. • Short term loss of sewer services in some localities due to increases to maintenance regime to repair and replace piping. • Could potentially increase health risks associated with increased leakages of sewer discharge. Regional cost to councils and water authorities located in areas with moderate to highly expansive clays. For example the western basalt plains are characterised by their expansive clay soil, which expands and contracts greatly with changes in moisture content.					
	4.2.2 Sewer Spills to Rivers and Bays	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Flood events overload the capacity of the sewer network resulting in overflow to drainage network. Generating an increase in the amount of environmental pollution in waterways and bays. • Trunk sewers located close to the existing sea level may be subject to increased tidal gradient, ground water infiltration and overload. Trunk sewer capacity would be reduced and more prone to environmental spills during high rainfall events or king tides. • Increase in volume of sewage to treat, therefore increases in treatment costs.	**High**	**M (C3)**	**H (C4)**	**M (C3)**	**M (C3)**
		Sea Level Rise	**Increase in sea level by 52 cm.**						
4.3 Storm Water and Drainage	**4.3.1 Storm Water Drainage and Flooding Damage**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Increases in the height of the 1 in 100 year flood. While the current flood height return frequency will be reduced.	• Increase in flood frequency and intensity will degrade stormwater, waterway and drainage infrastructure. The majority of older (inner city) drainage networks have inadequate capacity to deal with extreme rainfall events due to historical design standards being lower and subsequent build up of hard surfaces since original establishment of infrastructure to handle storm water drainage. • Potentially catastrophic regional to statewide damage to property, buildings and infrastructure. Significant private and public costs associated with clean up, maintenance and replacement of assets across the state. • Potential for permanent physical injuries and fatalities directly or indirectly from flooding event. • Flooded areas near the sea that rely on tidal drainage may be inundated for longer due to sea level rise impacts on tidal gradient. • Negative media reports in national and international media.	**Extreme**	**E (C5)**	**E (C5)**	**H (C4)**	**E (C5)**
		Decrease in Available Moisture	**The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Low soil moisture prior to flood event reduces the capacity of the soil to absorb water, therefore increasing run off and the intensity of the flood event.						
		Sea Level Rise	**Increase in sea level by 52 cm.**						

	4.3.2 Degradation and Failure of Drainage Infrastructure	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Likely degradation, failure and replacement of pipe and waterway structures due to increases in ground and foundation movement and shrinkage, flooding events and changes in groundwater. • Increased maintenance and replacement costs of water supply and waterway infrastructure. • Short term loss of water supply for several localities due to increased service disruption due to increased maintenance regime. • Major state-wide costs from increased flood damage to waterway structures including river and levee banks.	**High**	**H (B4)**	**M (B3)**	**M (B2)**	**H (B4)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						

Appendix D: Power Risk Assessment

Power Risk Assessment 2030 Low

Electricity	Risk Scenario	Climate Variable (Cause)	Climate Change	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
1.1 Electricity Generation, Transmission and Demand	**1.1.1 Increase in Demand Pressure Blackouts**	**Increased Temperature and heatwaves**	**0.5-1 °C increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a.** As ambient temperature rises, the efficiency of power lines will decrease. Peak demand for electricity will increase due to increased air conditioner use.	• Peak demand requirements increase while the distribution efficiency is reduced due to ambient air temperature. This combined stress will cause minor brownouts and blackouts and less reliable electricity supply. • Short term shut down of some industrial and commercial enterprises. Short term loss of electricity supply to residential areas. • Increase in potential heat wave deaths in elderly and young to loss of relief from heat stress. • Moderate negative publicity and public perception of service.	**Moderate**	**M (B2)**	**M (B3)**	**M (B3)**	**M (B2)**
	1.1.2 Decline in Stability of Structures and Foundations	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Less moisture for the preservation of dam walls and foundations of transmission towers.	• Degradation, failure and replacement of foundations of power transmission line structures and generation structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for moderate financial impact across state over time. • Impacts on residents, industry, state government and energy utilities. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**Moderate**	**L (D2)**	**M (E4)**	**M (E4)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						

	1.1.3 Damage to Above Ground Transmission	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** Wind blows objects, trees and structures over overhead transmission lines and other structures.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of above ground transmission infrastructure.	**Low**	**L (E2)**	**L (E2)**	**L (E2)**	**L (E2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events cause power surges, faults and blackouts.						
	1.1.4 Increased Bushfire Damage	**Increased Electrical Storm Activity**	**Increase in lightning strikes.** Lightning events cause more bushfires to be started.	• Loss of supply and infrastructure for potentially extended periods of time to local and regional areas. • Increase in repair and replacement costs of above ground transmission infrastructure. • Potential fo significant financial impact across the State over time.	**Moderate**	**M (D3)**	**M (D3)**	**L (D1)**	**M (D3)**
		Increased Bushfires	**Increase in severity and number of Bushfires.**						
		Increased Temperature and Heatwaves	**0.5-1℃ increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a.**						
	1.1.5 Substation Flooding	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Floods become more frequent.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Unlikely relocation of coastal power supply infrastructure.	**Moderate**	**M (D3)**	**M (D3)**	**L (D1)**	**M (D3)**
		Sea-Level Rise	**Increase in sea level by 3 cm.** Land that is used by a substation to be flooded by the ocean.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						
	1.1.6 Arcing Faults of	**Decrease in Rainfall**	**The majority of the state will have a 0-5% reduction in rainfall.** Less rainfall to wash the dust off the insulators.	• Increase in transmission faults and blackouts, less reliable electricity supply.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**	**L (D2)**

	Transmission Lines	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Longer dry periods allow a build up of dust on the substation insulators.	• Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Cost to utilities due to loss of electricity supply.					
	1.1.7 Reduction of Hydroelectricity Generation	**Decrease in Rainfall**	**The majority of the state will have a 0-5% reduction in rainfall.** Less water to use in the production of hydroelectricity.	• Potential lack of available water storage to supply hydro electricity generation plants. • Potential increased cost of production of hydroelectricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**	**L (D2)**
	1.1.8 Reduction of Coal Electricity Generation	**Decrease in Rainfall**	**The majority of the state will have a 0-5% reduction in rainfall.** Less available water storage to supply coal electricity generation plants for steam generation and power station cooling systems.	• Potential minor increase in the cost of production of coal electricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**	**L (D2)**
	1.1.9 Wind Power Inhibited	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** Extreme wind events inhibit wind power generation during these periods. Electricity generation needs to stop during extreme wind due to stresses on wind turbines.	• Potential minor increase in cost of production of wind electricity per KW.	**Low**	**L (D1)**	**L (D1)**	**L (D1)**	**L (D1)**
1.2 Oil and Gas Extraction, Refining and Distribution	**1.2.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Less moisture for the foundations of refinery infrastructure and pipelines..	• Degradation, failure and replacement of foundations of on-shore oil and gas extraction, refinery and pipeline structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Unlikely potential for human injury and fatalities. Potential for negative local media.	**Moderate**	**M (D3)**	**M (E4)**	**M (E4)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						

	1.2.2 Offshore Infrastructure Storm Damage	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** Extreme wind events increase wave energy and increase potential shutdown periods of oil and gas platforms and floating production. The production is shut down at high risk periods as extreme events may damage structures. Increased surface wave activity, increases the disturbance on sea bed pipelines, leading to direct movement of the pipes, exposure and/or burial.	• Degradation, failure and replacement of offshore oil and gas extraction and pipeline structures due to increases in extreme wind, storm and wave events. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**Moderate**	**M (D3)**	**M (E4)**	**M (E4)**	**M (D3)**
		Sea-Level Rise	**Increase in sea level by 3 cm.** Increase in ocean swells, wave energy and the height at which the wave force is exerted on the structures. .Platforms and associated structures are designed for specific force scenarios, change in height of these forces can make these structure vulnerable to damage and failure.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Increased wave energy and fatigue of structures will be caused by more extreme storms.						
	1.2.3 Inundation of Refineries	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Floods become more frequent.	• Shutdown of the refinery and impacts on supply due to flooding. • Minor local impacts on business operations. • Increase maintenance and operational costs. • Unlikely loss of oil and chemicals from site, impacting on the surrounding environment. • Unlikely potential injuries and negative reports in media.	**Low**	**L (D2)**	**L (D2)**	**L (E1)**	**L (D2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						

Power Risk Assessment 2030 High

Electricity	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
2.1 Electricity Generation, Transmission and Demand	**2.1.1 Increase in Demand Pressure Blackouts**	**Increased Temperature and Heatwaves**	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** As ambient temperature rises, the efficiency of power lines will decrease. Peak demand for electricity will increase due to increased air conditioner use.	• Peak demand requirements increase while the distribution efficiency is reduced due to ambient air temperature. This combined stress will cause minor brownouts and blackouts and less reliable electricity supply. • Short term shut down of some industrial and commercial enterprises. Short term loss of electricity supply to residential areas. • Increase in potential heat wave deaths in elderly and young to loss of relief from heat stress. • Moderate negative publicity and public perception of service.	**High**	**M (A2)**	**H (A3)**	**H (A3)**	**H (A3)**
	2.1.2 Decline in Stability of Structures and Foundations	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Less moisture for the preservation of dam walls and foundations of transmission towers.	• Degradation, failure and replacement of foundations of power transmission line structures and generation structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for moderate financial impact across state over time. • Impacts on residents, industry, state government and energy utilities. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**Moderate**	**M (D3)**	**M (E4)**	**M (E4)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						

	2.1.3 Storm Damage to Above Ground Transmission	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Wind blow objects, trees and structures over overhead transmission lines and other structures.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of above ground transmission infrastructure.	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur.					
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events cause power surges, faults and blackouts.					
	2.1.4 Increased Bushfire Damage	**Increased Electrical Storm Activity**	**Increase in lightning strikes.** Lightning events cause more bushfires to be started.	• Loss of supply and infrastructure for potentially extended periods of time to local and regional areas. • Increase in repair and replacement costs of above ground transmission infrastructure. • Potential fo significant financial impact across the State over time.	**Moderate**	**M (D3)**	**M (D3)**	**L (D1)**
		Increased Bushfires	**Increase in severity and number of Bushfires.**					
		Increased Temperature and Heatwaves	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.**					
	2.1.5 Substation Flooding	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Floods become more frequent.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Unlikely potential relocation of coastal power supply infrastructure.	**High**	**H (C4)**	**M (C3)**	**M (C3)**
		Sea-Level Rise	**Increase in sea level by 17 cm.** Land that is used by a substation to be flooded by the ocean.					
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms					
	2.1.6 Arcing Faults of Transmissio	**Decrease in rainfall**	**The majority of the state will have a 5-10% reduction in rainfall.** Less rainfall to wash the dust off the insulators	• Increase in transmission faults and blackouts, less reliable electricity supply.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**

2.1.3 Storm Damage to Above Ground Transmission	**M (D3)**	
2.1.4 Increased Bushfire Damage	**M (D3)**	
2.1.5 Substation Flooding	**M (C3)**	
2.1.6 Arcing Faults of Transmissio	**L (D2)**	

	n Lines	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Longer dry periods allow a build up of dust on the substation insulators.	• Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Cost to utilities due to loss of electricity supply.					
	2.1.7 Reduction of Hydroelectricity Supply	**Decrease in Rainfall**	**The majority of the state will have a 5-10% reduction in rainfall.** Less water to use in the production of hydroelectricity.	• Potential lack of available water storage to supply hydro electricity generation plants. • Potential increased cost of production of hydroelectricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**Moderate**	**M (B3)**	**M (B2)**	**L (B1)**	**M (B3)**
	2.1.8 Reduction of Coal Electricity Generation	**Decrease in Rainfall**	**The majority of the state will have a 5-10% reduction in rainfall.** Less available water storage to supply coal electricity generation plants for steam generation and power station cooling systems.	• Potential minor increase in the cost of production of coal electricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**Moderate**	**M (D3)**	**L (D2)**	**L (D2)**	**M (D3)**
	2.1.9 Wind Power Inhibited	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Extreme wind events inhibit wind power generation during these periods. Electricity generation needs to stop during extreme wind due to stresses on wind turbines.	• Potential minor increase in cost of production of wind electricity per KW.	**Low**	**L (C1)**	**L (C1)**	**L (C1)**	**L (C1)**
2.2 Oil and Gas Extraction, Refining and Distribution	**2.2.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Less moisture for the foundations of refinery infrastructure and pipelines..	• Degradation, failure and replacement of foundations of on-shore oil and gas extraction, refinery and pipeline structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Unlikely potential for human injury and fatalities. Potential for negative local media.	**Moderate**	**M (C3)**	**M (E4)**	**M (E4)**	**M (C3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						

	2.2.2 Offshore Infrastructure Storm Damage	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Extreme wind events increase wave energy and increase potential shutdown periods of oil and gas platforms and floating production. The production is shut down at high risk periods as extreme events may damage structures. Increased surface wave activity, increases the disturbance on sea bed pipelines, leading to direct movement of the pipes, exposure and/or burial.	• Degradation, failure and replacement of offshore oil and gas extraction and pipeline structures due to increases in extreme wind, storm and wave events. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**Moderate**	**M (C3)**	**M (E4)**	**M (E4)**	**M (C3)**
		Sea-Level Rise	**Increase in sea level by 17 cm.** Increase in ocean swells, wave energy and the height at which the wave force is exerted on the structures. .Platforms and associated structures are designed for specific force scenarios, change in height of these forces can make these structure vulnerable to damage and failure.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Increased wave energy and fatigue of structures will be caused by more extreme storms.						
	2.2.3 Inundation of Refineries	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Floods become more frequent.	• Shutdown of the refinery and impacts on supply due to flooding. • Minor local impacts on business operations. • Increase maintenance and operational costs. • Unlikely loss of oil and chemicals from site, impacting on the surrounding environment. • Unlikely potential injuries and negative reports in media.	**Low**	**L (D2)**	**L (D2)**	**L (E1)**	**L (D2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						

Power Risk Assessment 2070 Low

Electricity	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
3.1 Electricity Generation, Transmission and Demand	**3.1.1 Increase in Demand Pressure Blackouts**	**Increased Temperature and Heatwaves**	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.** As ambient temperature rises, the efficiency of power lines will decrease. Peak demand for electricity will increase due to increased air conditioner use.	• Peak demand requirements increase while the distribution efficiency is reduced due to ambient air temperature. This combined stress will cause minor brownouts and blackouts and less reliable electricity supply. • Short term shut down of some industrial and commercial enterprises. Short term loss of electricity supply to residential areas. • Increase in potential heat wave deaths in elderly and young to loss of relief from heat stress. • Moderate negative publicity and public perception of service.	**High**	**M (A2)**	**H (A3)**	**H (A3)**	**H (A3)**
	3.1.2 Decline in Stability of Structures and Foundations	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Less moisture for the preservation of dam walls and foundations of transmission towers.	• Degradation, failure and replacement of foundations of power transmission line structures and generation structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for moderate financial impact across state over time. • Impacts on residents, industry, state government and energy utilities. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**Moderate**	**M (D3)**	**M (E4)**	**M (E4)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						

	3.1.3 Storm Damage to Above Ground transmissio n	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Wind blow objects, trees and structures over overhead transmission lines and other structures.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of above ground transmission infrastructure.	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur.						
		Increased electrical storm activity	**Increase in lightning strikes.** Lightning events cause power surges, faults and blackouts.						
	3.1.4 Increased Bushfire Damage	**Increased Electrical Storm Activity**	**Increase in lightning strikes.** Lightning events cause more bushfires to be started.	• Loss of supply and infrastructure for potentially extended periods of time to local and regional areas. • Increase in repair and replacement costs of above ground transmission infrastructure. • Potential fo significant financial impact across the State over time.	**Moderate**	**M (D3)**	**M (D3)**	**L (D1)**	**M (D3)**
		Increased Bushfires	**Increase in severity and number of Bushfires.**						
		Increased Temperature and Heatwaves	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.**						
	3.1.5 Substation Flooding	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Floods become more frequent	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Unlikely relocation of coastal power supply infrastructure.	**High**	**H (C4)**	**M (C3)**	**M (C3)**	**M (C3)**
		Sea-Level Rise	**Increase in sea level by 7 cm.** Land that is used by a substation to be flooded by the ocean.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms						
	3.1.6 Arcing Faults of Transmissio	**Decrease in Rainfall**	**The majority of the state will have a 5-10% reduction in rainfall.** Less rainfall to wash the dust off the insulators	• Increase in transmission faults and blackouts, less reliable electricity supply.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**	**L (D2)**

	n Lines	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Longer dry periods allow a build up of dust on the substation insulators.	• Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Cost to utilities due to loss of electricity supply.					
	3.1.7 Reduction of Hydroelectricity Supply	**Decrease in Rainfall**	**The majority of the state will have a 5-10% reduction in rainfall.** Less water to use in the production of hydro electricity	• Potential lack of available water storage to supply hydro electricity generation plants. • Potential increased cost of production of hydroelectricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**Moderate**	**M (B3)**	**M (B2)**	**L (B1)**	**M (B3)**
	3.1.8 Reduction of Coal Electricity Generation	**Decrease in Rainfall**	**The majority of the state will have a 5-10% reduction in rainfall.** Less available water storage to supply coal electricity generation plants for steam generation and power station cooling systems.	• Potential minor increase in the cost of production of coal electricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**M**	**M (D3)**	**L (D2)**	**L (D2)**	**M (D3)**
	3.1.9 Wind Power Inhibited	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Extreme wind events inhibit wind power generation during these periods. Electricity generation needs to stop during extreme wind due to stresses on wind turbines.	• Potential minor increase in cost of production of wind electricity per KW.	**Low**	**L (C1)**	**L (C1)**	**L (C1)**	**L (C1)**
3.2 Oil and Gas Extraction, Refining and Distribution	**3.2.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Less moisture for the foundations of refinery infrastructure and pipelines..	• Degradation, failure and replacement of foundations of on-shore oil and gas extraction, refinery and pipeline structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Unlikely potential for human injury and fatalities. Potential for negative local media.	**Moderate**	**M (C3)**	**M (E4)**	**M (E4)**	**M (C3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						

	3.2.2 Offshore Infrastructure Storm Damage	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Extreme wind events increase wave energy and increase potential shutdown periods of oil and gas platforms and floating production. The production is shut down at high risk periods as extreme events may damage structures. Increased surface wave activity, increases the disturbance on sea bed pipelines, leading to direct movement of the pipes, exposure and/or burial.	• Degradation, failure and replacement of offshore oil and gas extraction and pipeline structures due to increases in extreme wind, storm and wave events. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**Moderate**	**M (D3)**	**M (E4)**	**M (E4)**	**M (D3)**
		Sea-Level Rise	**Increase in sea level by 7 cm.** Increase in ocean swells, wave energy and the height at which the wave force is exerted on the structures. .Platforms and associated structures are designed for specific force scenarios, change in height of these forces can make these structure vulnerable to damage and failure.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Increased wave energy and fatigue of structures will be caused by more extreme storms.						
	3.2.3 Inundation of Refineries	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Floods become more frequent.	• Shutdown of the refinery and impacts on supply due to flooding. • Minor local impacts on business operations. • Increase maintenance and operational costs. • Unlikely loss of oil and chemicals from site, impacting on the surrounding environment. • Unlikely potential injuries and negative reports in media.	**Moderate**	**M (D3)**	**M (D3)**	**L (E2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						

Power Risk Assessment 2070 High

Power	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
4.1 Electricity Generation, Transmission and Demand	**4.1.1 Increase in Demand Pressure Blackouts**	**Increased Temperature and Heatwaves**	**3-5℃ increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30℃ by 4 (Melbourne) to 19 (Rutherglen) p.a.** As ambient temperature rises, the efficiency of power lines will decrease. Peak demand for electricity will increase due to increased air conditioner use.	• Peak demand requirements increase while the distribution efficiency is reduced due to ambient air temperature. This combined stress will cause major brownouts and blackouts and less reliable electricity supply. • Short term shut down of some industrial and commercial enterprises. Short term loss of electricity supply to residential areas. • Increase in potential heat wave deaths in elderly and young to loss of relief from heat stress. • Major negative publicity and public perception of service.	**Extreme**	**M (A2)**	**E (A4)**	**H (B4)**	**E (A4)**
	4.1.2 Decline in Stability of Structures and Foundations	**Decrease in Available Moisture**	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Less moisture for the preservation of dam walls and foundations of transmission towers.	• Degradation, failure and replacement of foundations of power transmission line structures and generation structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for moderate financial impact	**Moderate**	**M (C3)**	**M (D4)**	**M (D4)**	**M (C3)**

		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.	across state over time. • Impacts on residents, industry, state government and energy utilities. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.					
	4.1.3 Storm Damage to Above Ground Transmission	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.** Wind blows objects, trees and structures over overhead transmission lines and other structures.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of above ground transmission infrastructure.	**High**	**H (C4)**	**H (C4)**	**M (C3)**	**H (C4)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events cause power surges, faults and blackouts.						
	4.1.4 Increased Bushfire Damage	**Increased Electrical Storm Activity**	**Increase in lightning strikes.** Lightning events cause more bushfires to be started.	• Loss of supply and infrastructure for potentially extended periods of time to local and regional areas. • Increase in repair and replacement costs of above ground transmission infrastructure. • Potential fo significant financial impact across the State over time.	**Moderate**	**M (D3)**	**M (D3)**	**L (D1)**	**M (D3)**
		Increased Bushfires	**Increase in severity and number of Bushfires.**						
		Increased Temperature and Heatwaves	**3-5°C increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30°C by 4 (Melbourne) to 19 (Rutherglen) p.a.**						
	4.1.5 Substation Flooding	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Flooding of substations becomes more frequent.	• Blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises.	**High**	**H (B4)**	**M (B3)**	**M (B3)**	**H (B4)**

		Sea-Level Rise	**Increase in sea level by 52 cm**. Land that is used by a substation to be flooded by the ocean.	• Increase in repair and replacement costs of electricity infrastructure. • Potential relocation of coastal power supply infrastructure.					
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms						
	4.1.6 Arcing Faults of Transmission Lines	**Decrease in Rainfall**	**The majority of the state will have a 10-30% reduction in rainfall, with some areas having a reduction of up to 40%.** Less rainfall to wash the dust off the insulators	• Increase in transmission faults and blackouts, less reliable electricity supply. • Shut down of industrial and commercial enterprises. • Increase in repair and replacement costs of electricity infrastructure. • Cost to utilities due to loss of electricity supply.	**Moderate**	**M (C3)**	**L (C2)**	**L (C2)**	**L (C2)**
		Increased Variation in Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Longer dry periods allow a build up of dust on the substation insulators.						
	4.1.7 Reduction of Hydroelectricity Supply	**Decrease in Rainfall**	**The majority of the state will have a 10-30% reduction in rainfall, with some areas having a reduction of up to 40%.** Less water to use in the production of hydro electricity	• Potential lack of available water storage to supply hydro electricity generation plants. • Potential increased cost of production of hydroelectricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**High**	**H (B4)**	**M (B2)**	**L (B1)**	**H (B4)**
	4.1.8 Reduction of Coal Electricity Generation	**Decrease in Rainfall**	**The majority of the state will have a 10-30% reduction in rainfall, with some areas having a reduction of up to 40%.** Less available water storage to supply coal electricity generation plants for steam generation and power station cooling systems.	• Potential minor increase in the cost of production of coal electricity per KW. • Brownouts and blackouts, less reliable electricity supply.	**High**	**H (C4)**	**L (C2)**	**L (C2)**	**H (C4)**
	4.1.9 Wind Power Inhibited	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.** Extreme wind events inhibit wind power generation during these periods. Electricity generation needs to stop during extreme wind due to stresses on wind turbines.	• Potential minor increase in cost of production of wind electricity per KW.	**Moderate**	**L (D2)**	**L (C2)**	**L (D2)**	**M (D3)**

4.2 Oil and Gas Extraction, Refining and Distribution	**4.2.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Much less moisture for the foundations of refinery infrastructure and pipelines..	• Degradation, failure and replacement of foundations of on-shore oil and gas extraction, refinery and pipeline structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Unlikely potential for human injury and fatalities. Potential for negative local media.	**Moderate**	**M (C3)**	**M (D4)**	**M (D4)**	**M (C3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause an increase in variations in groundwater, soil moisture and the chemical structure of foundations, causing movement and weakening of foundations.						
	4.2.2 Offshore Infrastructure Storm Damage	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.** Extreme wind events increase wave energy and increase potential shutdown periods of oil and gas platforms and floating production. The production is shut down at high risk periods as extreme events may damage structures. Increased surface wave activity, increases the disturbance on sea bed pipelines, leading to direct movement of the pipes, exposure and/or burial.	• Degradation, failure and replacement of offshore oil and gas extraction and pipeline structures due to increases in extreme wind, storm and wave events. • Increased vulnerability to structural failures and increased maintenance costs. • Potential for weakening of structures to make it prone to failure and even collapse in an extreme storm event. • Potential for human injury and fatalities. Negative local media.	**High**	**H (C4)**	**M (D4)**	**M (D4)**	**H (C4)**
		Sea-Level Rise	**Increase in sea level by 52 cm**. Increase in ocean swells, wave energy and the height at which the wave force is exerted on the structures. .Platforms and associated structures are designed for specific force scenarios, change in height of these forces can make these structure vulnerable to damage and failure.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Increased wave energy and fatigue of structures will be caused by more extreme storms.						

	4.2.3 Inundation of Refineries	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Floods become more frequent.	• Shutdown of the refinery and impacts on supply due to flooding. • Minor local impacts on business operations. • Increase maintenance and operational costs. • Unlikely loss of oil and chemicals from site, impacting on the surrounding environment. • Unlikely potential injuries and negative reports in media.	**Moderate**	**M (D3)**	**M (D3)**	**L (E2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						

Appendix E: Telecommunications Risk Assessment

Telecommunications Risk Assessment 2030 Low

Tele-communications	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
1.1 Fixed Line Network	**1.1.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Less moisture for the preservation of dam walls and foundations.	• Degradation, failure and replacement of foundations of telecommunications structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Potentially increased maintenance costs. • Vulnerability of structures to collapse during extreme storm events.	**Moderate**	**L (D2)**	**L (E2)**	**L (E2)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause variations in soil moisture, causing cracks in foundations.						
	1.1.2 Degradation of Cables	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 0.5-2%.** Solar radiation degrades the cable coverings.	• Increased maintenance and replacement costs. • Outages and service interruptions during replacement.	**Low**	**L (E2)**	**L (E2)**	**L (E1)**	**L (E2)**
	1.1.3 Storm Damage to Above Ground Transmission	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** More wind which has the ability to damage and blow over overhead transmission lines and other structures.	• Increase in repair and replacement costs of above ground transmission infrastructure during wind, lightning and storm events. • Loss of communication service in emergency situations generated by extreme weather events. • Loss of above ground infrastructure due to increases in number and severity of bushfires. • Potential increase to the cost of the telecommunications service. • Potential disruption of telecommunications	**Low**	**L (E3)**	**L (E2)**	**L (E2)**	**L (E3)**
		Increase in Frequency and Intensity of Storms	**% increase in storm events and increase in intensity.** More opportunity for damage to occur.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events disrupt the network exchange service. Lightning events also cause more bushfires to be started.						

		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.	services impacting on community, business and government communications activities.				
	1.1.4 Exchange Station Flooding of Exchanges, Manholes and Underground Pits	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Flash floods become more intensive, and cause localised damage.	• Potential increase in repair and replacement costs of telecommunications infrastructure. • Relocation of telecommunications infrastructure. • Disruption of telecommunications services.	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						
		Sea-Level Rise	**Increase in sea level by 3 cm.** Land that is used by a substation to be flooded by the ocean.						
1.2 Mobile Network	**1.2.1 Wind Damage to Transmission Towers**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** More wind which has the ability to damage through airborne debris and potential blow over transmission tower structures.	• Potential increase in repair and replacement costs of transmission tower infrastructure. • Potential network outages.	**Low**	**L (E2)**	**L (E2)**	**L (E2)**	**L (E2)**

Telecommunications Risk Assessment 2030 High

Telecommunications	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
2.1 Fixed Line Network	2.1.1 Decline in Stability of Structures and Foundations	Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Less moisture for the preservation of dam walls and foundations.	• Degradation, failure and replacement of foundations of telecommunications structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Potentially increased maintenance costs. • Vulnerability of structures to collapse during extreme storm events.	Moderate	L (D2)	L (E3)	L (E2)	M (D3)
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause variations in soil moisture, causing cracks in foundations.						
	2.1.2 Degradation of Cables	Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Solar radiation degrades the cable coverings.	• Increased maintenance and replacement costs. • Outages and service interruptions during replacement.	Low	L (D2)	L (E2)	L (E1)	L (D2)
	2.1.3 Storm Damage to Above Ground Transmission	Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** More wind which has the ability to damage and blow over overhead transmission lines and other structures	• Increase in repair and replacement costs of above ground transmission infrastructure during wind, lightning and storm events. • Loss of communication service in emergency situations generated by extreme weather events. • Loss of above ground infrastructure due to increases in number and severity of bushfires. • Potential increase to the cost of the telecommunications service.	Moderate	M (D4)	M (D3)	L (D2)	M (D3)
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events disrupt the network exchange service. Lightning events also cause more bushfires to be started.						

		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.	• Potential disruption of telecommunications services impacting on community, business and government communications activities.					
	2.1.4 Exchange Station Flooding of Exchanges, Manholes and Underground Pits	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Flash floods become more intensive, and cause localised damage.	• Potential increase in repair and replacement costs of telecommunications infrastructure. • Relocation of telecommunications infrastructure. • Disruption of telecommunications services.	**High**	**H (C4)**	**L (C2)**	**L (C2)**	**M (C3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						
		Sea-Level Rise	**Increase in sea level by 17 cm.** Land that is used by a substation to be flooded by the ocean.						
2.2 Mobile Network	**2.2.1 Wind Damage to Transmission Towers**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** More wind which has the ability to damage through airborne debris and potential blow over transmission tower structures.	• Potential increase in repair and replacement costs of transmission tower infrastructure. • Potential network outages.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**	**L (D2)**

Telecommunications Risk Assessment 2070 Low

Telecommunications	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
3.1 Fixed Line Network	**3.1.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Less moisture for the preservation of dam walls and foundations.	• Degradation, failure and replacement of foundations of telecommunications structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Potentially increased maintenance costs. • Vulnerability of structures to collapse during extreme storm events.	**Moderate**	**L (D2)**	**L (E3)**	**L (E2)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause variations in soil moisture, causing cracks in foundations						
	3.1.2 Degradation of Cables	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 2-4%.** Solar radiation degrades the cable coverings.	• Increased maintenance and replacement costs. • Outages and service interruptions during replacement.	**Low**	**L (D2)**	**L (E2)**	**L (E1)**	**L (D2)**
	3.1.3 Storm Damage to Above Ground Transmission	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** More wind which has the ability to damage and blow over overhead transmission lines and other structures	• Increase in repair and replacement costs of above ground transmission infrastructure during wind, lightning and storm events. • Loss of communication service in emergency situations generated by extreme weather events. • Loss of above ground infrastructure due to increases in number and severity of bushfires. • Potential increase to the cost of the telecommunications service. Potential disruption of	**Moderate**	**M (D4)**	**M (D3)**	**L (D2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events disrupt the network exchange service. Lightning events also cause more bushfires to be started.						

		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.	telecommunications services impacting on community, business and government communications activities.					
	3.1.4 Exchange Station Flooding of Exchanges, Manholes and Underground Pits	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Flash floods become more intensive, and cause localised damage	• Potential increase in repair and replacement costs of telecommunications infrastructure. • Relocation of telecommunications infrastructure. • Disruption of telecommunications services.	**High**	**H (C4)**	**L (C2)**	**L (C2)**	**M (C3)**
		Sea-Level Rise	**Increase in sea level by 7 cm.** Land that is used by a substation to be flooded by the ocean.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms						
3.2 Mobile Network	**3.2.1 Wind Damage to Transmission Towers**	**Increase in Intensity of Extreme wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** More wind which has the ability to damage through airborne debris and potential blow over transmission tower structures.	• Potential increase in repair and replacement costs of transmission tower infrastructure. • Potential network outages.	**Low**	**L (D2)**	**L (D2)**	**L (D2)**	**L (D2)**

Telecommunications Risk Assessment 2070 High

Telecommunications	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
4.1 Fixed Line Network	**4.1.1 Decline in Stability of Structures and Foundations**	**Decrease in Available Moisture**	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Less moisture for the preservation of dam walls and foundations.	• Degradation, failure and replacement of foundations of telecommunications structures due to increases in ground and foundation movement and shrinkage and changes in groundwater. • Potentially increased maintenance costs. • Vulnerability of structures to collapse during extreme storm events.	**Moderate**	**M (D3)**	**M (D2)**	**M (D2)**	**M (D3)**
		Increased Variation of Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Large fluctuations cause variations in soil moisture, causing cracks in foundations.						
	4.1.2 Degradation of Cables	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 4-8%, with some areas experiencing up to a 12% increase.** Solar radiation degrades the cable coverings.	• Increased maintenance and replacement costs. • Outages and service interruptions during replacement.	**Low**	**L (D2)**	**L (D2)**	**L (D1)**	**L (D2)**
	4.1.3 Storm Damage to Above Ground Transmission	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase**. More wind which has the ability to damage and blow over overhead transmission lines and other structures.	• Increase in repair and replacement costs of above ground transmission infrastructure during wind, lightning and storm events. • Loss of communication service in emergency situations generated by extreme weather events. • Potential disruption of telecommunications services impacting on community, business and government communications activities. • Loss of above ground infrastructure due to increases in number and severity of bushfires. • Potential increase to the cost of the telecommunications service.	**High**	**H (C4)**	**M (C3)**	**M (C3)**	**M (C3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** More opportunity for damage to occur.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events disrupt the network exchange service. Lightning events also cause more bushfires to be started.						
		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.						

Telecommunications	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
	4.1.4 Exchange Station Flooding of Exchanges, Manholes and Underground Pits	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.** Flash floods become more intensive, and cause localised damage.	• Potentially significant increase in repair and replacement costs of telecommunications infrastructure. • Relocation of telecommunications infrastructure. • Disruption of telecommunications services.	**High**	**H (C4)**	**M (C3)**	**M (C3)**	**M (C3)**
		Increase in Frequency and Intensity of storms	**Increase in intensity and number of storm events.** More flooding will be caused by more extreme storms.						
		Sea-Level Rise	**Increase in sea level by 52 cm**. Land that is used by a substation to be flooded by the ocean.						
4.2 Mobile Network	**4.2.1 Wind Damage to Transmission Towers**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase**. More wind which has the ability to damage through airborne debris and potential blow over transmission tower structures.	• Potential increase in repair and replacement costs of transmission tower infrastructure. • Potential network outages.	**Moderate**	**M (C3)**	**L (C2)**	**L (C2)**	**M (C3)**

Appendix F: Transport Risk Assessment

Transport Risk Assessment 2030 Low

Transport	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
1.1 Roads	1.1.1 Asphalt Degradation	Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 0.5-2%.** Increased rate of degrading the asphalt and road surface. Materials breakdown and dispersion	• Increased maintenance and renewal of road and pavement surfaces in localised regions. • Increase in short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) during repair and replacement. • Increase in road replacement costs due to greater rate of degradation. • Likely financial impact to local councils, Vic Roads.	Moderate	M (B2)	M (B2)	L (B1)	M (B2)
		Increased Temperature and Heatwaves	**0.5-1°C increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a..** Increased rate of degradation to asphalt and road surface integrity.						
	1.1.2 Road Foundations Degradation	Increased Variation in Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of road structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.	Moderate	M (B2)	M (B2)	L (B1)	M (B3)
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	1.1.3 Flood Damage to Roads	Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of road structures due to increased damage from flooding, inundation of foundations and changes in	Moderate	M (D3)	M (D3)	L (D2)	M (D3)

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.					
1.2 Rail	**1.2.1 Rail Track Movement**	**Increased Temperature and Heatwaves**	**0.5-1℃ increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a.** Stress on rail track integrity due to continuous welded line expansion under high temperatures.	• Degradation, failure and replacement of rail structures due to increases in movement. • Increased maintenance and replacement costs of rail infrastructure. • Localised minor costs for public transport corporations and State Government.	**Low**	**L (C2)**	**L (C2)**	**L (C1)**	**L (C2)**
	1.2.2 Storm Damage to Rail	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of rail structures due to increase in damage from flooding, debris, fallen trees and landslides in rail cuttings. • Unlikely increased maintenance and replacement costs of rail infrastructure. • Short term loss of public transport service and increased congestion to sections of road transport (regional and Melbourne). • Increased cost to public transport corporations and State Government.	**Moderate**	**M (D3)**	**L (D2)**	**L (D2)**	**L (D2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increased Electrical Storm Activity	**Increase in lightning strikes**						
1.3 Bridges	**1.3.1 Bridge Structural Material Degradation**	**Increased Temperature and Heatwaves**	**0.5-1℃ increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a..** Stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of bridge structures due to increases in frequency and size of movement and material breakdown. • Unlikely increased maintenance and replacement costs of bridge infrastructure. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**Moderate**	**L (D2)**	**M (D4)**	**M (D3)**	**M (D3)**
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 0.5-2%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						

	1.3.2 Storm Damage to Bridges	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%..**	• Degradation, failure and replacement of bridge structures due to increases in frequency and intensity of high stress events on structural integrity. • Extreme wind events are of particular significance to incidents of bridge failure and the safety of vehicles and people crossing bridges during these events. • Damage to bridges during flood events is widespread with potential loss of structures. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage sustained. • Increased maintenance and replacement costs of bridge infrastructure. • Short to medium term loss of bridge service and increased congestion to surrounding transport access. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**Moderate**	**L (D2)**	**M (D4)**	**M (D3)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.**						
1.4 Tunnels	**1.4.1 Tunnel Flooding**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of tunnel structures due to increases in frequency and intensity of high rainfall and flood events on foundation, structural and materials integrity. • Damage to tunnels during flood events is widespread with potential failure of sections of structures at a later stage. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage and weakening sustained. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. • Localised costs for councils, Vic Roads, private transport companies and State Government.	**Moderate**	**L (D2)**	**M (D4)**	**M (D3)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events**						

	1.4.2 Sea Level Rise Impacts on Tunnels in Proximity of the Coast	**Sea Level Rise**	**Increase in sea level by 3 cm Impacting on salt gradient, and groundwater levels and water drainage capacity.**	• Very unlikely degradation, failure and replacement of tunnel structures over time due to increases in groundwater level and pressure, salt concentration of water and subsequent corrosion of steels and accelerated damage to concrete and masonry through chemical reaction. Potential for weakening of tunnel structure faster than expected overtime and prone to collapse. • The increase in salt gradient would be enhanced by the decrease of annual rainfall reducing the net fresh water run-off pressure in groundwater. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. • Localised costs for councils, Vic Roads, private transport companies and State Government.	**Moderate**	**L (E3)**	**M (E4)**	**L (E3)**	**L (E3)**
		Decrease in Rainfall	**The majority of the state will have a 0-5% reduction in rainfall**						
1.5 Airports	**1.5.1 Asphalt Degradation**	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 0.5-2%**Increased rate of degrading the asphalt and runway surface. Materials breakdown and dispersion	• Moderately likely increased maintenance and renewal of runway surfaces to localised regions. • Increase in short term loss of access or increased congestion on other runways during repair and replacement. • Increase in runway upgrade costs due to greater rate of degradation. • Financial impact to airport authorities.	**Low**	**L (C2)**	**L (D2)**	**L (E1)**	**L (D2)**
		Increased Temperature and Heatwaves	**0.5-1°C increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a.** Increased rate of degradation to asphalt and runway surface integrity.						
	1.5.2 Degradation of Runway Foundations	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of runway structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of	**Low**	**L (D2)**	**L (D2)**	**L (E1)**	**L (D2)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.	runway infrastructure. • Short term loss of access or increased congestion to runways due to increase maintenance and replacement regime. • Additional cost to airport authorities.					
	1.5.3 Extreme Event Impacts to Airport Operations	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** Extreme wind events create conditions unacceptable for takeoff and landing of aircraft	• Increase in delays for air passengers in leaving and increase in landing delays and diversions to other airports. • Increased costs in flight rescheduling and delays. • Unlikely increased maintenance and repair costs from wind, rain and lightning storm damage. • Lower visibility during bushfire events for air safety. • Potential accidents causing injuries and fatalities. • Cost impacts to airport authorities, business and community.	**Moderate**	**M (D3)**	**M (E4)**	**L (E3)**	**M (D3)**
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%.**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Severe storms will create unsafe conditions for aircraft takeoff and landing.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events may disrupt the radar and communications equipment for traffic control. Lightning events also cause more bushfires to be started.						
		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.						
1.6 Ports	**1.6.1 Storm Impacts on Ports and Coastal Infrastructure**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events..**	• Degradation, failure and replacement of port, coastal and sea platform structures due to increase in power and reach of storm surge, coastal flooding, spray zone and erosion patterns. • Increase in magnitude and duration of storm currents and increase in the incidents of water over sea wall structures and low land flooding. • Reducing the capacity of natural systems to recover from storm erosion including permanent loss of sand offshore and degradation of structures. Retreat of	**Moderate**	**M (D4)**	**M (D3)**	**L (D2)**	**M (D4)**
		Sea Level Rise	**Increase in sea level by 3 cm** Increasing the vulnerability and magnitude of impacts to infrastructure from storm surge, wind, erosion and coastal flooding events						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						

		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%..** Reduced drainage capacity of coastal floodplains and flat low lying coastal regions. Because of the minimum gradient of these areas and use of tidal drainage, coastal infrastructure in certain tidal conditions can be prone to flooding and drainage backup.	coast landscapes. • The magnitude of the power of wave forces are increased while the height at which this power is concentrated on structures also increases. Water based infrastructure is designed for stress conditions on a specific area of the structure and as those conditions intensify and are focused higher on the structure, the vulnerability of the structure increases. • Unlikely increased maintenance and replacement costs of port, coastal and sea platform infrastructure. • Short term loss of port access. Increased service disruption due to increased maintenance regime. Back up of goods at the container terminals during closure generating a financial burden on businesses. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc.					
	1.6.2 Sea Level Rise Impacts on Port Infrastructure Materials	**Sea Level Rise**	**Increase in sea level by 3 cm** Increasing power and reach of storm surge, coastal flooding, spray zone and erosion patterns.	• Degradation over time of materials specifically designed for a particular range of sea level conditions due to a change in conditions. • Redevelopment of wharf fender arrangements (to barrier ships at dock). • Raising of the high risk exposure category of the water level, will increase exposure of decks of wharfs and jetties and accelerate corrosion levels to decks.	**Low**	**L (E3)**	**L (E2)**	**L (E1)**	**L (E3)**

Transport Risk Assessment 2030 High

Transport	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
2.1 Roads	**2.1.1 Asphalt Degradation**	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt and road surface. Materials breakdown and dispersion	• Increased maintenance and renewal of road and pavement surfaces in localised regions. • Increase in short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) during repair and replacement. • Increase in road replacement costs due to greater rate of degradation. • Likely financial impact to local councils, Vic Roads.	**Moderate**	**M (B2)**	**M (B2)**	**L (B1)**	**M (B2)**
		Increased Temperature and Heatwaves	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** Increased rate of degradation to asphalt and road surface integrity.						
	2.1.2 Road Foundations Degradation	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of road structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.	**Moderate**	**M (B3)**	**M (B2)**	**M (B2)**	**M (B3)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	2.1.3 Flood Damage to Roads	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of road structures due to increased damage from flooding, inundation of foundations and changes in	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**	**M (D3)**

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.					
2.2 Rail	**2.2.1 Rail Track Movement**	**Increased Temperature and Heatwaves**	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** Stress on rail track integrity due to continuous welded line expansion under high temperatures.	• Degradation, failure and replacement of rail structures due to increases in movement. • Increased maintenance and replacement costs of rail infrastructure. • Localised minor costs for public transport corporations and State Government.	**Moderate**	**L (C2)**	**M (C3)**	**L (C2)**	**L (C2)**
	2.2.2 Storm Damage to Rail	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of rail structures due to increase in damage from flooding, debris, fallen trees and landslides in rail cuttings. • Unlikely increased maintenance and replacement costs of rail infrastructure. • Short term loss of public transport service and increased congestion to sections of road transport (regional and Melbourne). • Increased cost to public transport corporations and State Government.	**Moderate**	**M (D3)**	**L (D2)**	**L (D2)**	**L (D2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increased Electrical Storm Activity	**Increase in lightning strikes.**						
2.3 Bridges	**2.3.1 Bridge Structural Material Degradation**	**Increased Temperature and Heatwaves**	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** Stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of bridge structures due to increases in frequency and size of movement and material breakdown. • Moderately likely increased maintenance and replacement costs of bridge infrastructure. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**High**	**L (C2)**	**H (C4)**	**M (C3)**	**M (C3)**

		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	2.3.2 Storm Damage to Bridges	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of bridge structures due to increases in frequency and intensity of high stress events on structural integrity. • Extreme wind events are of particular significance to incidents of bridge failure and the safety of vehicles and people crossing bridges during these events. • Damage to bridges during flood events is widespread with potential loss of structures. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage sustained. • Increased maintenance and replacement costs of bridge infrastructure. • Short to medium term loss of bridge service and increased congestion to surrounding transport access. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**Moderate**	**L (D2)**	**M (D4)**	**M (D3)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.**						
2.4 Tunnels	**2.4.1 Tunnel Flooding**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation, failure and replacement of tunnel structures due to increases in frequency and intensity of high rainfall and flood events on foundation,	**Moderate**	**L (D2)**	**M (D4)**	**M (D3)**	**M (D3)**

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	structural and materials integrity. • Damage to tunnels during flood events is widespread with potential failure of sections of structures at a later stage. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage and weakening sustained. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. • Localised costs for councils, Vic Roads, private transport companies and State Government.					
	2.4.2 Sea Level Rise Impacts on Tunnels in Proximity of the Coast	**Sea Level Rise** **Decrease in Rainfall**	**Increase in sea level by 17 cm** **The majority of the state will have a 5-10% reduction in rainfall**	• Unlikely degradation, failure and replacement of tunnel structures over time due to increases in groundwater level and pressure, salt concentration of water and subsequent corrosion of steels and accelerate damage to concrete and masonry through chemical reaction. Potential for weakening of tunnel structure faster than expected overtime and prone to collapse. • The increase in salt gradient would be enhanced by the decrease of annual rainfall reducing the net fresh water run-off pressure in groundwater. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. • Localised costs for councils, Vic Roads, private transport companies and State Government.	**Moderate**	**M (D3)**	**M (D4)**	**M (D3)**	**M (D3)**
2.5 Airports	**2.5.1 Asphalt Degradation**	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt and runway surface. Materials breakdown and dispersion	• Moderately likely increased maintenance and renewal of runway surfaces to localised regions. • Increase in short term loss of access or increased	**Low**	**L (C2)**	**L (C2)**	**L (E1)**	**L (C2)**

		Increased Temperature and Heatwaves	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** Increased rate of degradation to asphalt and runway surface integrity.	congestion on other runways during repair and replacement. • Increase in runway upgrade costs due to greater rate of degradation. • Financial impact to airport authorities.					
	2.5.2 Degradation of Runway Foundations	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of runway structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of runway infrastructure. • Short term loss of access or increased congestion to runways due to increase maintenance and replacement regime. • Additional cost to airport authorities	**Low**	**L (C2)**	**L (D2)**	**L (E1)**	**L (C2)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	2.5.3 Extreme Event Impacts to Airport Operations	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.** Extreme wind events create conditions unacceptable for takeoff and landing of aircraft	• Increase in delays for air passengers in leaving and increase in landing delays and diversions to other airports. • Increased costs in flight rescheduling and delays. • Unlikely increased maintenance and repair costs from wind, rain and lightning storm damage. • Lower visibility during bushfire events for air safety. • Potential accidents causing injuries and fatalities. • Cost impacts to airport authorities, business and community.	**Moderate**	**M (D3)**	**M (D4)**	**M (D3)**	**M (D3)**
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%.**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Severe storms will create unsafe conditions for aircraft takeoff and landing.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events may disrupt the radar and communications equipment for traffic control. Lightning events also cause more bushfires to be started.						

		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.						
2.6 Ports	**2.6.1 Storm Impacts on Ports and Coastal Infrastructure**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.**	• Degradation, failure and replacement of port, coastal and sea platform structures due to increase in power and reach of storm surge, coastal flooding, spray zone and erosion patterns. • Increase in magnitude and duration of storm currents and increase in the incidents of water over sea wall structures and low land flooding. • Reducing the capacity of natural systems to recover from storm erosion including permanent loss of sand offshore and degradation of structures. Retreat of coast landscapes. • The magnitude of the power of wave forces are increased while the height at which this power is concentrated on structures also increases. Water based infrastructure is designed for stress conditions on a specific area of the structure and as those conditions intensify and are focused higher on the structure, the vulnerability of the structure increases. • Moderately likely increased maintenance and replacement costs of port, coastal and sea platform infrastructure. • Short term loss of port access. Increased service disruption due to increased maintenance regime. Back up of goods at the container terminals during closure generating a financial burden on businesses. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc.	**High**	**H (C4)**	**M (C3)**	**L (C2)**	**H (C4)**
		Sea Level Rise	**Increase in sea level by 17 cm** Increasing the vulnerability and magnitude of impacts to infrastructure from storm surge, wind, erosion and coastal flooding events						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%.** Reduced drainage capacity of coastal floodplains and flat low lying coastal regions. Because of the minimum gradient of these areas and use of tidal drainage, coastal infrastructure in certain tidal conditions can be prone to flooding and drainage backup.						

	2.6.2 Sea Level Rise Impacts on Port Infrastructure Materials	**Sea Level Rise**	**Increase in sea level by 17 cm** Increasing power and reach of storm surge, coastal flooding, spray zone and erosion patterns.	• Degradation over time of materials specifically designed for a particular range of sea level conditions due to a change in conditions. • Redevelopment of wharf fender arrangements (to barrier ships at dock). • Raising of the high risk exposure category of the water level, will increase exposure of decks of wharfs and jetties and accelerate corrosion levels to decks. • Unlikely, moderate increase in maintenance and replacement costs of port, coastal and sea platform infrastructure. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc. • Loss of viable residential land use where impacted by increased storm surge activity and intrusion.	**Moderate**	**M (D3)**	**L (D2)**	**L (D1)**	**M (D3)**

Transport Risk Assessment 2070 Low

Transport	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
3.1 Roads	**3.1.1 Asphalt Degradation**	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt and road surface. Materials breakdown and dispersion	• Increased maintenance and renewal of road and pavement surfaces in localised regions. • Increase in short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) during repair and replacement. • Increase in road replacement costs due to greater rate of degradation. • Likely financial impact to local councils, Vic Roads.	**Moderate**	**M (B2)**	**M (B2)**	**L (B1)**	**M (B2)**
		Increased Temperature and Heatwaves	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a..** Increased rate of degradation to asphalt and road surface integrity.						
	3.1.2 Road Foundations Degradation	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of road structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.	**Moderate**	**M (B3)**	**M (B2)**	**M (B2)**	**M (B3)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	3.1.3 Flood Damage to Roads	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement road structures due to increase damage from flooding, inundation of foundations and changes in groundwater.	**Moderate**	**M (C3)**	**M (C3)**	**L (C2)**	**M (C3)**

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	• Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.					
3.2 Rail	**3.2.1 Rail Track Movement**	**Increased Temperature and Heatwaves**	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.** Stress on rail track integrity due to continuous welded line expansion under high temperatures.	• Degradation, failure and replacement of rail structures due to increases in movement. • Increased maintenance and replacement costs of rail infrastructure. • Localised minor costs for public transport corporations and State Government.	**Moderate**	**L (C2)**	**M (C3)**	**L (C2)**	**L (C2)**
	3.2.2 Storm Damage to Rail	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement rail structures due to increase damage from flooding, debris, fallen trees and landslides in rail cuttings. • Moderately likely increased maintenance and replacement costs of rail infrastructure. • Short term loss of public transport service and increased congestion to sections of road transport (regional and Melbourne). • Increased cost to public transport corporations and State Government.	**Moderate**	**M (C3)**	**L (C2)**	**L (C2)**	**L (C2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increased Electrical Storm Activity	**Increase in lightning strikes.**						
3.3 Bridges	**3.3.1 Bridge Structural Material Degradation**	**Increased Temperature and Heatwaves**	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a..** Stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of bridge structures due to increases in frequency and size of movement and material breakdown. • Moderately likely increased maintenance and replacement costs of bridge infrastructure. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**High**	**L (C2)**	**H (C4)**	**M (C3)**	**M (C3)**
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						

	3.3.2 Storm Damage to Bridges	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement of bridge structures due to increases in frequency and intensity of high stress events on structural integrity. • Extreme wind events are of particular significance to incidents of bridge failure and the safety of vehicles and people crossing bridges during these events. • Damage to bridges during flood events is widespread with potential loss of structures. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage sustained. • Increased maintenance and replacement costs of bridge infrastructure. • Short to medium term loss of bridge service and increased congestion to surrounding transport access. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**High**	**L (C2)**	**H (C4)**	**M (C3)**	**M (C3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.**						
3.4 Tunnels	**3.4.1 Tunnel Flooding**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement of tunnel structures due to increases in frequency and intensity of high rainfall and flood events on foundation, structural and materials integrity. • Damage to tunnels during flood events is widespread with potential failure of sections of structures at a later stage. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage and weakening sustained. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. Localised costs for councils, Vic Roads, private transport companies and State Government.	**High**	**L (C2)**	**H (C4)**	**M (C3)**	**M (C3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						

	3.4.2 Sea Level Rise Impacts on Tunnels in Proximity of the Coast	**Sea Level Rise**	**Increase in sea level by 7 cm**	• Very unlikely degradation, failure and replacement of tunnel structures over time due to increases in groundwater level and pressure, salt concentration of water and subsequent corrosion of steels and accelerated damage to concrete and masonry through chemical reaction. Potential for weakening of tunnel structure faster than expected overtime and prone to collapse. • The increase in salt gradient would be enhanced by the decrease of annual rainfall reducing the net fresh water run-off pressure in groundwater. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. Localised costs for councils, Vic Roads, private transport companies and State Government.	**Moderate**	**L (E3)**	**M (E4)**	**L (E3)**	**L (E3)**
		Decrease in Rainfall	**The majority of the state will have a 5-10% reduction in rainfall**						
3.5 Airports	**3.5.1 Asphalt Degradation**	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 2-4%** Increased rate of degrading the asphalt and runway surface. Materials breakdown and dispersion	• Moderately likely increased maintenance and renewal of runway surfaces to localised regions. • Increase in short term loss of access or increased congestion on other runways during repair and replacement. • Increase in runway upgrade costs due to greater rate of degradation. • Financial impact to airport authorities.	**Low**	**L (C2)**	**L (C2)**	**L (E1)**	**L (C2)**
		Increased Temperature and Heatwaves	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.** Increased rate of degradation to asphalt and runway surface integrity.						
	3.5.2 Degradation of Runway Foundations	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of runway structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of	**Low**	**L (C2)**	**L (D2)**	**L (E1)**	**L (C2)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.	runway infrastructure. • Short term loss of access or increased congestion to runways due to increase maintenance and replacement regime. • Additional cost to airport authorities.					
	3.5.3 Extreme Event Impacts to Airport Operations	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase. Ex**treme wind events create conditions unacceptable for takeoff and landing of aircraft	• Increase in delays for air passengers in leaving and increase in landing delays and diversions to other airports. • Increased costs in flight rescheduling and delays. • Unlikely increased maintenance and repair costs from wind, rain and lightning storm damage. • Lower visibility during bushfire events for air safety. • Potential accidents causing injuries and fatalities. • Cost impacts to airport authorities, business and community.	**Moderate**	**M (D3)**	**M (D4)**	**M (D3)**	**M (D3)**
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 40%.**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Severe storms will create unsafe conditions for aircraft takeoff and landing.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events may disrupt the radar and communications equipment for traffic control. Lightning events also cause more bushfires to be started.						
		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.						
3.6 Ports	**3.6.1 Storm Impacts on Ports and Coastal Infrastructure**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase.**	• Degradation, failure and replacement of port, coastal and sea platform structures due to increase in power and reach of storm surge, coastal flooding, spray zone and erosion patterns. • Increase in magnitude and duration of storm currents and increase in the incidents of water over sea wall structures and low land flooding. • Reducing the capacity of natural systems to recover from storm erosion including permanent loss of sand offshore and degradation of structures. Retreat of	**High**	**H (C4)**	**M (C3)**	**L (C2)**	**H (C4)**
		Sea Level Rise	**Increase in sea level by 7 cm** Increasing the vulnerability and magnitude of impacts to infrastructure from storm surge, wind, erosion and coastal flooding events						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						

		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 40%.** Reduced drainage capacity of coastal floodplains and flat low lying coastal regions. Because of the minimum gradient of these areas and use of tidal drainage, coastal infrastructure in certain tidal conditions can be prone to flooding and drainage backup.	coast landscapes. • The magnitude of the power of wave forces are increased while the height at which this power is concentrated on structures also increases. Water based infrastructure is designed for stress conditions on a specific area of the structure and as those conditions intensify and are focused higher on the structure, the vulnerability of the structure increases. • Moderately likely increased maintenance and replacement costs of port, coastal and sea platform infrastructure. • Short term loss of port access. Increased service disruption due to increased maintenance regime. Back up of goods at the container terminals during closure generating a financial burden on businesses. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc.					
	3.6.2 Sea Level Rise Impacts on Port Infrastructure Materials	**Sea Level Rise**	**Increase in sea level by 7 cm** Increasing power and reach of storm surge, coastal flooding, spray zone and erosion patterns.	• Degradation over time of materials specifically designed for a particular range of sea level conditions due to a change in conditions. • Redevelopment of wharf fender arrangements (to barrier ships at dock). • Raising of the high risk exposure category of the water level, will increase exposure of decks of wharfs and jetties and accelerate corrosion levels to decks. • Very unlikely, moderate increased maintenance and replacement costs of port, coastal and sea platform infrastructure. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc. • Loss of viable residential land use where impacted by increased storm surge activity and intrusion.	**Low**	**L (E3)**	**L (E2)**	**L (E1)**	**L (E3)**

Transport Risk Assessment 2070 High

Transport	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
4.1 Roads	4.1.1 Asphalt Degradation	Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 4-8%, with some areas experiencing up to a 12% increase.** Increased rate of degrading the asphalt and road surface. Materials breakdown and dispersion	• Increased maintenance and renewal of road and pavement surfaces in localised regions. • Increase in short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) during repair and replacement. • Increase in road replacement costs due to greater rate of degradation. • Almost certain financial impact to local councils, Vic Roads.	Moderate	M (A2)	M (A2)	L (A1)	M (A2)
		Increased Temperature and Heatwaves	**3-5°C increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30°C by 4 (Melbourne) to 19 (Rutherglen) p.a.** Increased rate of degradation to asphalt and road surface integrity.						
	4.1.2 Road Foundations Degradation	Increased Variation in Wet/Dry Spells	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of road structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.	High	H (A3)	M (A2)	M (A2)	H (A3)
		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	4.1.3 Flood Damage to Roads	Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement of road structures due to increased damage from flooding, inundation of foundations and changes in	Moderate	M (C3)	M (C3)	L (C2)	M (C3)

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	groundwater. • Increased maintenance and replacement costs of road infrastructure. • Short term loss of public access or increased congestion to sections of road and highway (regional and Melbourne) due to increase maintenance and replacement regime. • Regional cost to councils and VicRoads.					
4.2 Rail	**4.2.1 Rail Track Movement**	**Increased Temperature and Heatwaves**	**3-5°C increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30°C by 4 (Melbourne) to 19 (Rutherglen) p.a.** Stress on rail track integrity due to continuous welded line expansion under high temperatures.	• Degradation, failure and replacement of rail structures due to increases in movement. • Increased maintenance and replacement costs of rail infrastructure. • Localised moderate costs for public transport corporations and State Government.	**High**	**M (B3)**	**H (B4)**	**M (C3)**	**M (B3)**
	4.2.2 Storm Damage to Rail	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement of rail structures due to increase in damage from flooding, debris, fallen trees and landslides in rail cuttings. • Moderately likely increased maintenance and replacement costs of rail infrastructure. • Short term loss of public transport service and increased congestion to sections of road transport (regional and Melbourne). • Increased cost to public transport corporations and State Government.	**Moderate**	**M (C3)**	**L (C2)**	**L (C2)**	**L (C2)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increased Electrical Storm Activity	**Increase in electrical storms and lightning strikes impacting rail signals, substations and power supply**						
4.3 Bridges	**4.3.1 Bridge Structural Material Degradation**	**Increased Temperature and Heatwaves**	**3-5°C increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30°C by 4 (Melbourne) to 19 (Rutherglen) p.a.** Stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of bridge structures due to increases in frequency and size of movement and material breakdown. • Likely increased maintenance and replacement costs of bridge infrastructure. • Increased risk of bridge failure and associated risks to loss of life. • Localised costs for councils and State Government.	**High**	**M (B2)**	**H (B4)**	**M (B3)**	**M (B3)**

		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 4-8%, with some areas experiencing up to a 12% increase.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	4.3.2 Storm Damage to Bridges	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement of bridge structures due to increases in frequency and intensity of high stress events on structural integrity. • Extreme wind events are of particular significance to incidents of bridge failure and the safety of vehicles and people crossing bridges during these events. • Damage to bridges during flood events is widespread with potential loss of structures. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage sustained. • Increased maintenance and replacement costs of bridge infrastructure. • Short to medium term loss of bridge service and increased congestion to surrounding transport access. • Increased risk of bridge failure and associated risks to loss of life. Localised costs for councils and State Government.	**High**	**M (B2)**	**H (B4)**	**M (B3)**	**M (B3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.**						
4.4 Tunnels	**4.4.1 Tunnel Flooding**	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation, failure and replacement of tunnel structures due to increases in frequency and intensity of high rainfall and flood events on foundation,	**High**	**L (C2)**	**H (C4)**	**M (C3)**	**M (C3)**

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	structural and materials integrity. • Damage to tunnels during flood events is widespread with potential failure of sections of structures at a later stage. Increased frequency of storm events reduces the capacity to repair damage before subsequent storm events compound structural damage and weakening sustained. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. Localised costs for councils, Vic Roads, private transport companies and State Government.					
	4.4.2 Sea Level Rise Impacts on Tunnels in Proximity of the Coast	**Sea Level Rise** **Decrease in Rainfall**	**Increase in sea level by 52 cm Impacting on salt gradient, and groundwater levels and water drainage capacity.** **The majority of the state will have a 10-30% reduction in rainfall, with some areas having a reduction of up to 40%.**	• Likely degradation, failure and replacement of tunnel structures over time due to increases in groundwater level and pressure, salt concentration of water and subsequent corrosion of steels and accelerate damage to concrete and masonry through chemical reaction. Potential for weakening of tunnel structure faster than expected overtime and prone to collapse. • The increase in salt gradient would be enhanced by the decrease of annual rainfall reducing the net fresh water run-off pressure in groundwater. • Increased maintenance and replacement costs of tunnel infrastructure. • Short to medium term loss of tunnel service and increased congestion to surrounding transport access. • Increased risk of tunnel failure and associated risks to loss of life. Localised costs for councils, Vic Roads, private transport companies and State Government.	**High**	**H (B4)**	**H (B4)**	**H (B4)**	**H (B4)**
4.5 Airports	**4.5.1 Asphalt Degradation**	**Increased Solar Radiation**	**Majority of Victoria experiences an increase in radiation by 4-8%, with some areas experiencing up to a 12% increase..** Increased rate of degrading the asphalt and runway surface. Materials breakdown and dispersion	• Almost certain increased maintenance and renewal of runway surfaces to localised regions. • Increase in short term loss of access or increased congestion on other runways during repair and replacement.	**Moderate**	**M (A2)**	**M (A2)**	**L (E1)**	**M (A2)**

		Increased Temperature and Heatwaves	**3-5°C increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30°C by 4 (Melbourne) to 19 (Rutherglen) p.a.** Increased rate of degradation to asphalt and runway surface integrity.	• Increase in runway upgrade costs due to greater rate of degradation. • Financial impact to airport authorities.					
	4.5.2 Degradation of Runway Foundations	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of runway structures due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Increased maintenance and replacement costs of runway infrastructure. • Short term loss of access or increased congestion to runways due to increase maintenance and replacement regime. • Additional cost to airport authorities.	**Moderate**	**M (C3)**	**M (D3)**	**L (D2)**	**M (C3)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	4.5.3 Extreme Event Impacts to Airport Operations	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase..** Extreme wind events create conditions unacceptable for takeoff and landing of aircraft	• Increase in delays for air passengers in leaving and increase in landing delays and diversions to other airports. • Increased costs in flight rescheduling and delays. • Moderately likely increased maintenance and repair costs from wind, rain and lightning storm damage. • Lower visibility during bushfire events for air safety. • Potential accidents causing injuries and fatalities. • Cost impacts to airport authorities, business and community.	**High**	**M (C3)**	**H (C4)**	**M (C3)**	**M (C3)**
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 40%..**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.** Severe storms will create unsafe conditions for aircraft takeoff and landing.						
		Increased Electrical Storm Activity	**Increase in lightning strikes.** Lightning events may disrupt the radar and communications equipment for traffic control. Lightning events also cause more bushfires to be started.						
		Increase in Bushfires	**Increase in severity and number of Bushfires.** Increase in frequency and intensity of bushfires due to increases in wind events, increases in temperature and increases in number of days of fire danger p.a. In addition to this the decease in available moisture.						

4.6 Ports	**4.6.1 Storm Impacts on Ports and Coastal Infrastructure**	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.**	• Degradation, failure and replacement of port, coastal and sea platform structures due to increase in power and reach of storm surge, coastal flooding, spray zone and erosion patterns. • Increase in magnitude and duration of storm currents and increase in the incidents of water over sea wall structures and low land flooding. • Reducing the capacity of natural systems to recover from storm erosion including permanent loss of sand offshore and degradation of structures. Retreat of coast landscapes. • The magnitude of the power of wave forces are increased while the height at which this power is concentrated on structures also increases. Water based infrastructure is designed for stress conditions on a specific area of the structure and as those conditions intensify and are focused higher on the structure, the vulnerability of the structure increases. • Almost certain increased maintenance and replacement costs of port, coastal and sea platform infrastructure. • Short term loss of port access. Increased service disruption due to increased maintenance regime. Back up of goods at the container terminals during closure generating a financial burden on businesses. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc.	**Extreme**	**E (A4)**	**H (A3)**	**M (A2)**	**E (A4)**
		Sea Level Rise	**Increase in sea level by 52 cm** Increasing the vulnerability and magnitude of impacts to infrastructure from storm surge, wind, erosion and coastal flooding events						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events..**						
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 40%..** Reduced drainage capacity of coastal floodplains and flat low lying coastal regions. Because of the minimum gradient of these areas and use of tidal drainage, coastal infrastructure in certain tidal conditions can be prone to flooding and drainage backup.						

	4.6.2 Sea Level Rise Impacts on Port Infrastructure Materials	**Sea Level Rise**	**Increase in sea level by 52 cm** Increasing power and reach of storm surge, coastal flooding, spray zone and erosion patterns.	• Degradation over time of materials specifically designed for a particular range of sea level conditions due to a change in conditions. • Redevelopment of wharf fender arrangements (to barrier ships at dock). • Raising of the high risk exposure category of the water level, will increase exposure of decks of wharfs and jetties and accelerate corrosion levels to decks. • Likely, major increased maintenance and replacement costs of port, coastal and sea platform infrastructure. • State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc. • Loss of viable residential land use where impacted by increased storm surge activity and intrusion.	**High**	**H (B4)**	**H (B4)**	**H (B4)**	**H (B4)**

Appendix G: Buildings Risk Assessment

Buildings Risk Assessment 2030 Low

Building Classification	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
1. Buildings and Structures	**1.1.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of building foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potentially increased maintenance and replacement costs of building foundations. Increased vulnerability to structural failures. May affect the serviceability of a building or structure. • Short term loss of public use due to increase maintenance and replacement regime. • Unlikely but significant increase cost to residential and commercial building owners, investors and developers. • Significant financial impact across state over time. • Community outrage over building standards and property losses. • Negative national media.	**Moderate**	**M (D3)**	**M (D4)**	**M (D3)**	**M (D4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	1.1.2 Degradation and failure of Building Materials	**Increased Temperature and Heatwaves**	**0.5-1℃ increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of building materials due to increases in frequency and size of movement and material breakdown. • Potentially increased maintenance and replacement costs of building infrastructure. Significant financial impact across state over time. • Short term loss of use due to increase in maintenance and replacement regime.	**Moderate**	**M (D3)**	**M (D3)**	**M (D3)**	**M (D3)**

		Humidity	**Annual increases by up to 1% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, most of the state increases in relative humidity by up to 1%.** Humidity increases the rate of corrosion and material degradation.	• Moderate increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative state media.					
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 0.5-2%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	1.1.3 Increased Storm and Flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.** Flash flooding and water levels exceeding the 1 in 100 year flood level.	• Degradation and replacement of buildings due to increase damage from flooding, debris, fallen trees and landslides. • Potentially increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building. • Potentially increase cost to residential and commercial building owners, investors and developers. • Unlikely, but significant financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.	**Moderate**	**M (D4)**	**M (D4)**	**L (D2)**	**M (D4)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.** Damage to roofs, walls, sheds and fences from wind and airborne objects. Extreme wind aids rain penetration into building areas not designed to be wet.						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
	1.1.4 Coastal Storm Surge and Flooding	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Damage to buildings from coastal storm surge and flooding. Degradation, failure and replacement of building and structure materials. • Permanent flooding of coastal buildings and therefore making them uninhabitable. • Potentially increased maintenance and replacement	**Moderate**	**M (D3)**	**M (E4)**	**L (E3)**	**M (D3)**
		Sea Level Rise	**Increase in sea level by 3 cm.**						

		Increase in Frequency and Intensity of storms	**Increase in intensity and number of storm events.**	costs of building infrastructure. • Short term loss of use of building. • Potential increase cost to residential and commercial building owners, investors and developers. • Potentially significant financial impact to coastal councils and state governments over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.					
	1.1.5 Increased Bushfire Damage	**Increase in Bush fires**	**Increase in severity and number of Bushfires.**	• Buildings and structures damaged or destroyed in bush areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of building. • Potential increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative national media.	**Moderate**	**M (D3)**	**M (E4)**	**L (E3)**	**M (D3)**
1.2 Urban Facilities	**1.2.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures.	• Degradation, failure and replacement of facilities foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potential increased maintenance and replacement costs of facilities foundations. • Localised loss of public use due to increase maintenance and replacement regime. • Increased vulnerability of facility structures, i.e. street light poles. • Minor regional financial impact on local government. • Negative local media.	**Low**	**L (C2)**	**L (C2)**	**L (D2)**	**L (D2)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with the exception of the Great Dividing Range. The annual reduction in the moisture balance for majority of Vic is between -50 and -100mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						

	1.2.2 Degradation and Failure of Urban Facilities' Materials	**Increased Temperature and Heatwaves**	**0.5-1°C increase in temp over majority of the state and increase of 1 (Melbourne) to 4 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 0.5 (Melbourne) to 2 (Rutherglen) p.a.** Stress on facilities integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of facilities materials due to increases in frequency and size of movement and material breakdown. • Potential increased maintenance and replacement costs of facilities infrastructure. • Short term loss of use due to increase in maintenance and replacement regime. • Potential increase cost to councils and state government. • Degradation, failure and replacement of facilities materials. • Minor financial impact across state over time. • Negative local media.	**Low**	**L (C2)**	**L (C2)**	**L (D2)**	**L (D2)**
		Humidity	**Annual increases by up to 1% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, most of the state increases in relative humidity by up to 1%.**						
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 0.5-2%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	1.2.3 Increased Storm and Flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation and replacement of facilities due to increase damage from flooding, debris, fallen trees and landslides. • Increased maintenance and replacement costs of facilities infrastructure. • Potential short term loss of use of facilities. • Potential increase cost to residential and commercial building owners, investors and developers. • Unlikely, moderate financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Negative reports in state media.	**Moderate**	**M (D3)**	**M (D4)**	**L (E2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 0-3% increases in intensity of extreme wind events.**						
	1.2.3 Coastal Storm Surge and Flooding	**Increase in Frequency and Intensity of Storms**	**Increase in intensity and number of storm events.**	• Damage to facilities from coastal storm surge and flooding. • Permanent flooding of coastal facilities and therefore reduced usability. • Potential increased maintenance and replacement costs of facilities infrastructure. • Very unlikely short term loss of use of facilities. • Increase cost to coastal councils and state governments.	**Low**	**L (E3)**	**L (E3)**	**L (E2)**	**L (E3)**
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%.**						

		Sea Level Rise	**Increase in sea level by 3 cm.**	• Permanent physical injuries and fatalities from storm event. • Will potentially result in local community outrage loss of facilities. • Negative state media.					
	1.2.4 Increased Bushfire Damage	**Increase in Bush fires**	**Increase in severity and number of Bushfires.**	• Facilities and structures damaged or destroyed in bush or park areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. Increase cost to local government, communities and state government. • Very unlikely short to medium term loss of use of facilities. • Negative state media.	**Low**	**L (E3)**	**L (E3)**	**L (E2)**	**L (E3)**

Buildings Risk Assessment 2030 High

Building Classification	**Risk Scenario**	**Climate Variable (Cause)**	**Climate Change Impact**	**Risk Description for Multiple Causes**	**Risk Rating (likelihood x consequence)**				
					Risk Rating	**Infrastructure Service**	**Social**	**Governance**	**Finance**
2.1 Buildings and Structures	**2.1.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures.	• Degradation, failure and replacement of building foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater.	**High**	**M (C3)**	**H (C4)**	**M (C3)**	**H (C4)**

		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.	• Potentially increased maintenance and replacement costs of building foundations. Increased vulnerability to structural failures. May affect the serviceability of a building or structure. • Short term loss of public use due to increase maintenance and replacement regime. • Unlikely but significant increase cost to residential and commercial building owners, investors and developers. • Significant financial impact across state over time. • Community outrage over building standards and property losses. • Negative national media.					
	2.1.2 Degradation and Failure of Building Materials	**Increased Temperature and Heatwaves**	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of building materials due to increases in frequency and size of movement and material breakdown. • Potentially increased maintenance and replacement costs of building infrastructure. Significant financial impact across state over time. • Short term loss of use due to increase in maintenance and replacement regime. • Moderate increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative state media.	**Moderate**	**M (C3)**	**M (C3)**	**M (C3)**	**M (C3)**
		Humidity	**Annual increases by up to 1% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, Summer and Spring the coastal areas increases in relative humidity by up to 3%. In Autumn, most of the state increases in relative humidity by up to 1%.**						
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	2.1.3 Increased Storm and Flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation and replacement of buildings due to increase damage from flooding, debris, fallen trees and landslides. • Potentially increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building.	**High**	**H (C4)**	**H (C4)**	**L (C2)**	**H (C4)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**						

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	• Potentially increase cost to residential and commercial building owners, investors and developers. • Unlikely, but significant financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.					
	2.1.4 Coastal Storm Surge and Flooding	**Increase in Extreme daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Damage to buildings from coastal storm surge and flooding. Degradation, failure and replacement of building and structure materials. • Permanent flooding of coastal buildings and therefore making them uninhabitable. • Potentially increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building. • Potential increase cost to residential and commercial building owners, investors and developers. • Potentially significant financial impact to coastal councils and state governments over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.	**High**	**H (C4)**	**M (D4)**	**M (D3)**	**H (C4)**
		Sea Level Rise	**Increase in sea level by 17 cm.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
	2.1.5 Increased Bushfire Damage	**Increase in Bush fires**	**Increase in severity and number of Bushfires.**	• Buildings and structures damaged or destroyed in bush areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of building. • Potential increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative national media. .	**High**	**H (C4)**	**M (D4)**	**M (D3)**	**H (C4)**

2. 2 Urban Facilities	**2.2.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of facilities foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potential increased maintenance and replacement costs of facilities foundations. • Localised loss of public use due to increase maintenance and replacement regime. • Increased vulnerability of facility structures, i.e. street light poles. • Minor regional financial impact on local government. • Negative local media	**Low**	**L (C2)**	**L (C2)**	**L (D2)**	**L (D2)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/5 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/3 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	2.2.2 Degradation and Failure of Urban Facilities' Materials	**Humidity**	**Annual increases by up to 1% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, Summer and Spring the coastal areas increases in relative humidity by up to 3%. In Autumn, most of the state increases in relative humidity by up to 1%.**	• Degradation, failure and replacement of facilities materials due to increases in frequency and size of movement and material breakdown. • Potential increased maintenance and replacement costs of facilities infrastructure. • Short term loss of use due to increase in maintenance and replacement regime. • Potential increase cost to councils and state government. • Degradation, failure and replacement of facilities materials. • Minor financial impact across state over time. • Negative local media.	**Low**	**L (C2)**	**L (C2)**	**L (C2)**	**L (D2)**
		Increased Temperature and Heatwaves	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 10 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 5 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.						
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	2.2.3 Increased Storm and Flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 27%.**	• Degradation and replacement of facilities due to increase damage from flooding, debris, fallen trees and landslides. • Increased maintenance and replacement costs of facilities infrastructure. • Potential short term loss of use of facilities.	**Moderate**	**M (D4)**	**M (D4)**	**L (D2)**	**M (D4)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**						

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	• Potential increase cost to residential and commercial building owners, investors and developers. • Unlikely, moderate financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Negative reports in state media.					
	2.2.4 Coastal Storm Surge and Flooding	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**	• Damage to facilities from coastal storm surge and flooding. • Permanent flooding of coastal facilities and therefore reduced usability. • Potential increased maintenance and replacement costs of facilities infrastructure. • Very unlikely short term loss of use of facilities. • Increase cost to coastal councils and state governments. • Permanent physical injuries and fatalities from storm event. • Will potentially result in local community outrage loss of facilities. • Negative state media.	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**	**M (D3)**
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 27%.**						
		Sea Level Rise	**Increase in sea level by 17 cm.**						
	2.2.5 Increased Bushfire Damage	**Increase in Bush fires**	**Increase in severity and number of Bushfires.**	• Facilities and structures damaged or destroyed in bush or park areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of facilities. • Potential increase cost to local government, communities and state government. • Permanent physical injuries and fatalities from bush fire event. • Negative State media.	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**	**M (D3)**

Buildings Risk Assessment 2070 Low

Buildings	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
3.1 Buildings and Structures	**3.1.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of building foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potentially increased maintenance and replacement costs of building foundations. Increased vulnerability to structural failures. May affect the serviceability of a building or structure. • Short term loss of public use due to increase maintenance and replacement regime. • Unlikely but significant increase cost to residential and commercial building owners, investors and developers. • Significant financial impact across state over time. • Community outrage over building standards and property losses. • Negative national media.	**High**	**M (C3)**	**H (C4)**	**M (C3)**	**H (C4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	3.1.2 Degradation and failure of Building Materials	**Increased Temperature and Heatwaves**	**1-1.5°C increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of building materials due to increases in frequency and size of movement and material breakdown. • Potentially increased maintenance and replacement costs of building infrastructure. Significant financial impact across state over time. • Short term loss of use due to increase in maintenance and replacement regime.	**Moderate**	**M (C3)**	**M (C3)**	**M (C3)**	**M (C3)**

		Humidity	**Annual increases by up to 1% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, Summer and Spring the coastal areas increases in relative humidity by up to 3%. In Autumn, most of the state increases in relative humidity by up to 1%.**	• Moderate increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative state media.					
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	3.1.3 Increased Storm and flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation and replacement of buildings due to increase damage from flooding, debris, fallen trees and landslides. • Potentially increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building. • Potentially increase cost to residential and commercial building owners, investors and developers. • Unlikely, but significant financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.	**High**	**H (C4)**	**H (C4)**	**L (C2)**	**H (C4)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
	3.1.4 Coastal Storm Surge and Flooding	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Damage to buildings from coastal storm surge and flooding. Degradation, failure and replacement of building and structure materials. • Permanent flooding of coastal buildings and therefore making them uninhabitable. • Potentially increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building. • Potential increase cost to residential and commercial	**Moderate**	**M (D4)**	**M (D4)**	**M (D3)**	**M (D4)**
		Sea Level Rise	**Increase in sea level by 7 cm**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**						

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	building owners, investors and developers. • Potentially significant financial impact to coastal councils and state governments over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.					
	3.1.5 Increased Bushfire Damage	**Increase in Bush Fires**	**Increase in severity and number of bushfires.**	• Buildings and structures damaged or destroyed in bush areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of building. • Potential increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative national media. .	**High**	**H (C4)**	**M (D4)**	**M (D3)**	**H (C4)**
3.2 Urban Facilities	**3.2.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of facilities foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potential increased maintenance and replacement costs of facilities foundations. • Localised loss of public use due to increase maintenance and replacement regime. • Increased vulnerability of facility structures, i.e. street light poles. • Minor regional financial impact on local government. • Negative local media	**Low**	**L (C2)**	**L (C2)**	**L (D2)**	**L (D2)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 20% for the majority of Victoria, with a 1/6 of the state experiencing up to a 40% increase. The annual reduction in the moisture balance for majority of Vic is between -100 and -200mm with a 1/4 between -200 and -400mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time						

	3.2.2 Degradation and Failure of Urban Facilities' Materials	**Humidity**	**Annual increases by up to 1% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, Summer and Spring the coastal areas increases in relative humidity by up to 3%. In Autumn, most of the state increases in relative humidity by up to 1%.**	• Degradation, failure and replacement of facilities materials due to increases in frequency and size of movement and material breakdown. • Potential increased maintenance and replacement costs of facilities infrastructure. • Short term loss of use due to increase in maintenance and replacement regime. • Potential increase cost to councils and state government. • Degradation, failure and replacement of facilities materials. • Minor financial impact across state over time. • Negative local media.	**Low**	**L (C2)**	**L (C2)**	**L (C2)**	**L (D2)**
		Increased Temperature and Heatwaves	**1-1.5℃ increase in temp over majority of the state and increase of 3 (Melbourne) to 9.5 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30 C° by 1 (Melbourne) to 4.5 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.						
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 2-4%.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	3.2.3 Increased Storm and Flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation and replacement of facilities due to increase damage from flooding, debris, fallen trees and landslides. • Increased maintenance and replacement costs of facilities infrastructure. • Potential short term loss of use of facilities. • Potential increase cost to residential and commercial building owners, investors and developers. • Unlikely, moderate financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Negative reports in state media.	**Moderate**	**M (D4)**	**M (D4)**	**L (D2)**	**M (D4)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
	3.2.4 Coastal Storm Surge and Flooding	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 3-6% increases in intensity of extreme wind events. A few places are predicted to experience up to a 9% increase**	• Damage to facilities from coastal storm surge and flooding. • Permanent flooding of coastal facilities and therefore	**Moderate**	**L (D2)**	**M (D3)**	**L (D2)**	**M (D3)**

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	reduced usability. • Potential increased maintenance and replacement costs of facilities infrastructure. • Very unlikely short term loss of use of facilities. • Increase cost to coastal councils and state governments. • Permanent physical injuries and fatalities from storm event. • Will potentially result in local community outrage loss of facilities. • Negative state media.					
		Increase in Extreme Daily rainfall	**Increases in extreme daily rainfall by up to 40%.**						
		Sea level Rise	**Increase in sea level by 7 cm**						
	3.2.5 Increased Bushfire Damage	**Increase in Bush fires**	**Increase in severity and number of Bushfires.**	• Facilities and structures damaged or destroyed in bush or park areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of facilities. • Potential increase cost to local government, communities and state government. • Permanent physical injuries and fatalities from bush fire event. • Negative State media.	**Moderate**	**M (D3)**	**M (D3)**	**L (D2)**	**M (D3)**

Buildings Risk Assessment 2070 High

Buildings	Risk Scenario	Climate Variable (Cause)	Climate Change Impact	Risk Description for Multiple Causes	Risk Rating (likelihood x consequence)				
					Risk Rating	Infrastructure Service	Social	Governance	Finance
4.1 Buildings and Structures	**4.1.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of building foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potentially increased maintenance and replacement costs of building foundations. Increased vulnerability to structural failures. May affect the serviceability of a building or structure. • Short term loss of public use due to increase maintenance and replacement regime. • Unlikely but significant increase cost to residential and commercial building owners, investors and developers. • Significant financial impact across state over time. • Community outrage over building standards and property losses. • Negative national media.	**High**	**H (B4)**	**H (B4)**	**M (B3)**	**H (B4)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time.						
	4.1.2 Degradation and failure of Building Materials	**Increased Temperature and Heatwaves**	**3-5℃ increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30℃ by 4 (Melbourne) to 19 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.	• Degradation, failure and replacement of building materials due to increases in frequency and size of movement and material breakdown. • Potentially increased maintenance and replacement costs of building infrastructure. Significant financial impact across state over time. • Short term loss of use due to increase in maintenance and replacement regime. • Moderate increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative state media.	**Moderate**	**M (B3)**	**M (B3)**	**M (B3)**	**M (B3)**
		Humidity	**Annual increases between 3-7% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, most of the state increases in relative humidity between 1-3%.**						

		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 4-8%, with some areas experiencing up to a 12% increase.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	4.1.3 Increased Storm and Flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation and replacement of buildings due to increase damage from flooding, debris, fallen trees and landslides. • Potentially major increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building. • Potentially major increase cost to residential and commercial building owners, investors and developers. • Unlikely, but significant financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.	**Extreme**	**E (C5)**	**E (C5)**	**M (C3)**	**E (C5)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
	4.1.4 Coastal Storm Surge and Flooding	**Increase in Extreme Daily rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Damage to buildings from coastal storm surge and flooding. Degradation, failure and replacement of building and structure materials. • Permanent flooding of coastal buildings and therefore making them uninhabitable. • Potentially significantly increased maintenance and replacement costs of building infrastructure. • Short term loss of use of building. • Potential significant increase cost to residential and	**Extreme**	**E (C5)**	**E (C5)**	**E (C5)**	**E (C5)**
		Sea Level Rise	**Increase in sea level by 52 cm.**						
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.**						

		Increase in frequency and intensity of storms	**Increase in intensity and number of storm events.**	commercial building owners, investors and developers. • Potentially significant financial impact to coastal councils and state governments over time. • Permanent physical injuries and fatalities from storm event. • Community outrage over building standards and property losses. • Negative national media.					
	4.1.5 Increased Bushfire Damage	**Increase in Bush Fires**	**Increase in severity and number of Bushfires.**	• Buildings and structures damaged or destroyed in bush areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of building. • Potential for significant increase cost to residential and commercial building owners, investors and developers. • Community outrage over building standards and property losses. • Negative national media.	**Extreme**	**E (C5)**	**E (C5)**	**H (C4)**	**E (C5)**
4.2 Urban Facilities	**4.2.1 Degradation and Failure of Foundations**	**Increased Variation in Wet/Dry Spells**	**An increase in variation of short intensive wet spells and prolonged dry spells.** Increased in fluctuation in groundwater levels, changes to soil composition and foundation structures	• Degradation, failure and replacement of facilities foundations due to increases in ground and foundation movement, shrinkage and changes in groundwater. • Potential increased maintenance and replacement costs of facilities foundations. • Localised loss of public use due to increase maintenance and replacement regime. • Increased vulnerability of facility structures, i.e. street light poles. • Minor regional financial impact on local government. • Negative local media	**Moderate**	**M (C3)**	**M (C3)**	**L (C2)**	**M (C3)**
		Decrease in Available Moisture	**The frequency of drought increases by up to 40-80% for the majority of Victoria. The annual reduction in the moisture balance for majority of Vic is between -400 and -800mm.** Soil movement generated in prone soils. Foundation failure generated through both increases in movement stresses and increased fatigue from changing of conditions more often over time						

	4.2.2 Degradation and Failure of Urban Facilities' Materials	**Humidity**	**Annual increases between 3-7% for the southern coastal region of Victoria with inland areas decreasing in annual relative humidity. In Autumn, most of the state increases in relative humidity between 1-3%.**	• Degradation, failure and replacement of facilities materials due to increases in frequency and size of movement and material breakdown. • Potential increased maintenance and replacement costs of facilities infrastructure. • Short term loss of use due to increase in maintenance and replacement regime. • Potential increase cost to councils and state government. • Degradation, failure and replacement of facilities materials. • Minor financial impact across state over time. • Negative local media.	**Moderate**	**M (B3)**	**M (C3)**	**M (C3)**	**M (B3)**
		Increased Temperature and Heatwaves	**3-5℃ increase in temp over majority of the state and increase of 13.4 (Melbourne) to 44.2 (Rutherglen) days over 35 and an increase in the number of heatwaves events over 30℃ by 4 Melbourne) to 19 (Rutherglen) p.a.** Stress on building integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants. Masonry work is also impacted by temperature affecting the mortar.						
		Increased Solar Radiation	**Majority of Victoria experiences an increase in radiation by 4-8%, with some areas experiencing up to a 12% increase.** Increased rate of degrading the asphalt, protective claddings and coatings and timber. Materials breakdown and exposure to corrosion increased.						
	4.2.3 Increased Storm and flood Damage	**Increase in Extreme Daily Rainfall**	**Increases in extreme daily rainfall by up to 40%.**	• Degradation and replacement of facilities due to increase damage from flooding, debris, fallen trees and landslides. • Increased maintenance and replacement costs of facilities infrastructure. • Potential short term loss of use of facilities. • Potentially significant increase cost to residential and commercial building owners, investors and developers. • Potential for significant financial impact across state over time. • Permanent physical injuries and fatalities from storm event. • Negative reports in state media.	**High**	**H (C4)**	**H (C4)**	**L (C2)**	**H (C4)**
		Increase in Intensity of Extreme Wind	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.**						
		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**						
	4.2.4 Coastal Storm Surge and Flooding	**Increase in Intensity of Extreme Wind**	**Majority of the state experiences up to between 9-15% increases in intensity of extreme wind events. A 1/3 of the state is predicted to experience up to an 18% increase.**	• Damage to facilities from coastal storm surge and flooding. • Permanent flooding of coastal facilities and therefore reduced usability.	**High**	**H (C4)**	**M (C3)**	**L (C2)**	**H (C4)**

		Increase in Frequency and Intensity of Storms	**Increase in intensity and number of storm events.**	• Potential for significantly increased maintenance and replacement costs of facilities infrastructure. • Very unlikely short term loss of use of facilities. • Significant cost increase cost to coastal councils and state governments. • Permanent physical injuries and fatalities from storm event. • Will potentially result in local community outrage loss of facilities. • Negative state media.					
		Increase in Extreme Daily Rainfall	**Increases in extreme daily rainfall by up to 40%.**						
		Sea Level Rise	**Increase in sea level by 52 cm.**						
	4.2.5 Increased Bushfire Damage	**Increase in Bush Fires**	**Increase in severity and number of Bushfires.**	• Facilities and structures damaged or destroyed in bush or park areas or on fringes of cities • Increased risk of injury or fatalities caused by bush fires. • Short to medium term loss of use of facilities. • Potential increase cost to local government, communities and state government. • Permanent physical injuries and fatalities from bush fire event. • Negative State media.	**Moderate**	**M (C3)**	**M (C3)**	**L (C2)**	**M (C3)**