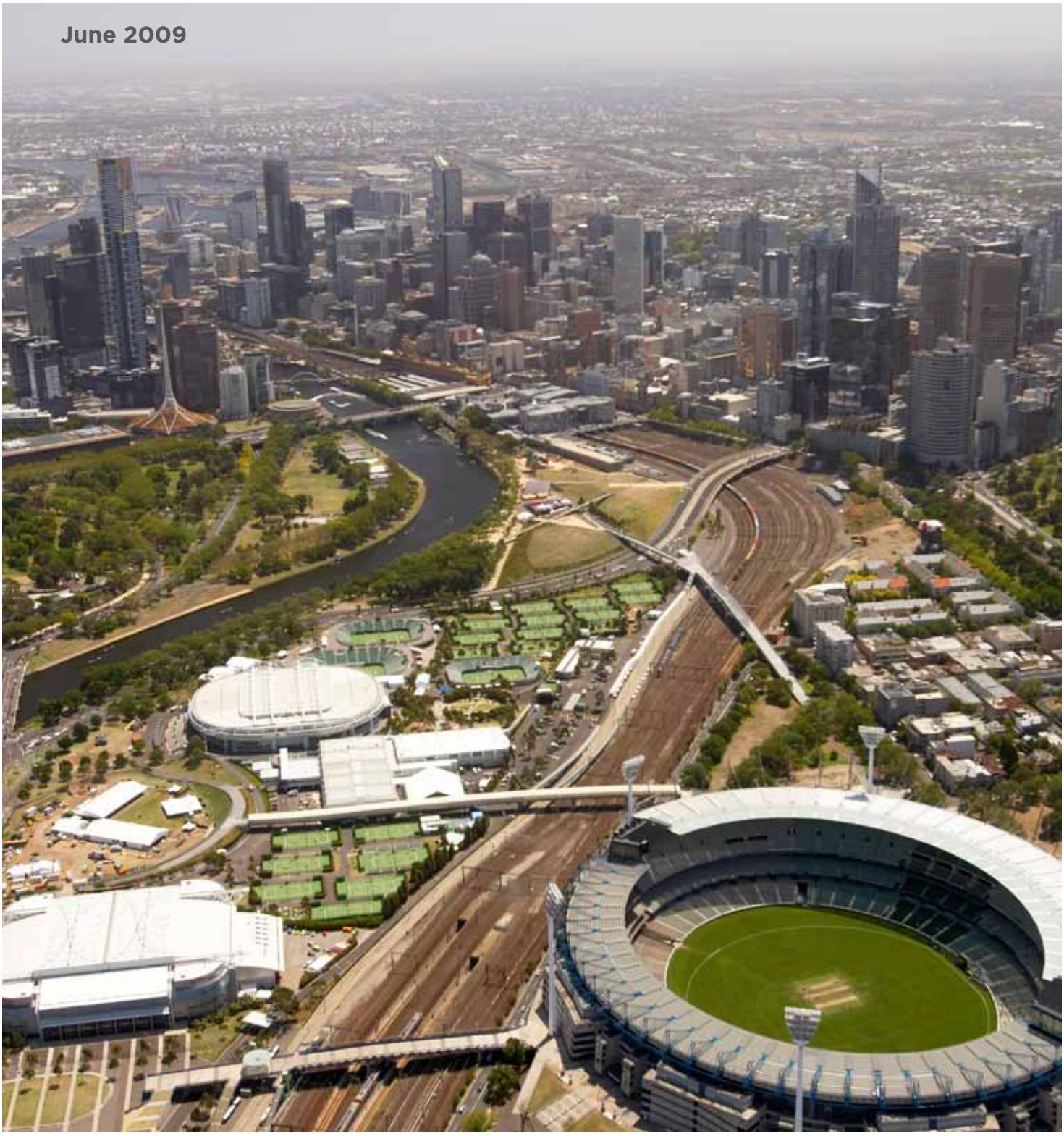
CITY OF MELBOURNE

City of Melbourne
Climate Change Adaptation Strategy

June 2009



Australian Government

Department of Climate Change

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Climate change in cities

The world is warming, and it is becoming an increasing imperative for cities to prepare for the impacts of climate change. Each city will have different climate change impacts to prepare for based on their geographical location and their unique mix of local sensitivity, resilience and response capacity (IPCC 2007, CSIRO 2007). Cities responding early to climate change are most likely to better withstand its impacts and maintain a platform for health and prosperity (IPCC 2007). Cities are likely to be affected by climate change in three key ways:

1. Impacts on resource productivity or changes in market demands for goods and services;
2. Performance of physical infrastructure and industries directly affected by changed climate conditions or damaging extreme events; and,
3. Populations affected by extreme weather, scarce resources, health status, changed economic conditions or migration (IPCC 2007).

Rising awareness and concern regarding potential climate change impacts has seen many policy responses and programs aimed at reducing greenhouse gas (GHG) emissions to previous levels. GHG mitigation initiatives are important to long term climate stabilisation, however scientists warn of the time it takes for the climate system to respond to GHG reductions. Regardless of future emissions, the GHG concentrations already in the atmosphere commit us to a likely range of climate change impacts in the near future.

By 2030 Melbourne is expected to likely be significantly affected by warmer temperatures and heatwaves, lower rainfall, intense storm events and flash flooding (CSIRO 2007). To minimise or avoid the effects of these impending impacts, effective and prompt adaptation is imperative.

It is important to understand that risk assessments represent conditions based on current dynamics, values, priorities and resources, they are not prophecies. Adaptation provides an opportunity to change course from the likely 'business-as-usual' outcome if management conditions do not change while climate conditions do. This is an assessment not of inevitability, but of possibility. It reflects possible outcomes if Melbourne does nothing to build resilience to climate change, and possible outcomes if Melbourne actively considers and addresses its vulnerabilities and capabilities in addressing climate change.

Scientists advise it is what we do today that will determine how climate change is described tomorrow. In developing this risk assessment and adaptation strategy, the City of Melbourne has provided the foundation for a better future for our city.

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What is climate 'adaptation'?

'Adaptation' encompasses measures that are taken in response to the actual or expected changes in climate to negate or mitigate their impact. These measures reduce the vulnerability of the local natural or human systems to the effects of climate change by increasing the system's resilience to it. Adaptation response measures generally have four categories:

1. Loss prevention – actions to reduce vulnerability to climate change.
2. Loss sharing – spreading the risk of loss among a wider population (such as insurance).
3. Behaviour modification – eliminating the activity or behaviour that causes the hazard.
4. Relocation – moving vulnerable population or systems away from hazards induced by climate change.

Climate change adaptation programs are a unique combination of these types of measures reflecting a city's most significant and imminent vulnerabilities, available resources and skills, population priorities and demographics, socio-economic dynamics and institutional roles and capabilities. The programs should have flexibility and scalability to maintain their relevance and currency over time. Effective implementation of the adaptation options proposed in this strategy will require ongoing work, capital investment and policy analysis by the City of Melbourne.

What is the City of Melbourne doing about climate adaptation?

In commissioning this climate change adaptation strategy, the City of Melbourne has taken a leadership role of prudent stewardship for the municipality in responding to climate change. The City of Melbourne aims to ensure all stakeholders share awareness of the issues, their influence and responsibilities, their inter-relationships and their role in an integrated climate change adaptation plan for the city. Such an integrated response ensures the benefits of shared resources and efficiencies, shared knowledge and understanding, effective communication and collaboration, cooperation under pressure and better outcomes overall.

An effective risk assessment provides a clear knowledge of the risks that can be tolerated and a system that minimises or addresses those risks that cannot be tolerated. This *Climate Change Adaptation Strategy* for the City of Melbourne provides such an assessment and response strategy. The result of this analysis is a comprehensive and integrated assessment of Melbourne's climate change risks for now, in 2030 and 2070. These risks are based on current climate change science, stakeholder input and the city's current and evolving conditions.

This document provides a risk analysis of the potential climate change impacts and implications for Melbourne over time, combined with the likely changing dynamics of its population and development into the future.

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Based on current known resilience levels and control measures, the assessment identifies critical risks for both the City of Melbourne and the municipality to address. It provides the foundation of an adaptation plan for all city stakeholders to contribute and respond to.

What are the identified climate change risks for the City of Melbourne?

While some climatic changes are an ongoing concern, four potential extreme event scenarios for Melbourne were identified that together embody the range of climate change risks for the municipality. These are:

- reduced rainfall and drought;
- extreme heatwave and bushfire;
- intense rainfall and wind storm; and
- sea level rise.

Identifying the most effective adaptation responses and use of resources to reduce the impacts of these events requires an understanding of how they unfold. Events are a logical sequence of causal happenings, of cascading consequences, initiated by the extreme climatic event, or events. Then, like aligned dominos, these impacts cause flow on effects and implications according to the conditions encountered (refer to section 1.0). The challenge is to control and prevent flow-on effects from occurring to minimise the extent of damage and scale of adaptation required.

Socio-economic considerations found that over the same period as climatic changes are likely to occur, greater Melbourne is expected to accommodate unprecedented population growth (to become Australia's largest capital city by 2030) and include a doubling of the population within the City of Melbourne to 145,000 people. While managing the impacts of climate change this growth presents the added challenge of accommodating more people and providing the necessary resources to service and protect them, as well as caring for an aging population (refer to section 5.1). All of these issues place added pressures on climate change impacts but may also provide processes and development into which adaptation can be integrated. This assessment of Melbourne's climate change resilience and vulnerability took into account this full range of changing attributes in an integrated assessment framework.

As a major metropolitan city some attributes were identified for the City of Melbourne that add particular challenges and dynamics for a climate change adaptation action plan for the city. Perhaps the most significant dynamic is the tide of more than 700,000 people that visit Melbourne each day, is expected to reach one million by 2016. Just over half of these visitors are coming to the city for employment which means the remaining people visit the city each day for various activities that are therefore somewhat mobile and unpredictable.

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This makes scenario planning and communication with these people challenging. Having so many people come into the city each day means the potential scale of an event can be significantly amplified if it happens while these people are in the city and for example storms or transport disruptions mean they are unable to leave. This daily transience identifies the importance for the City of Melbourne to work with a range of stakeholders to ensure public awareness programs also reach those people visiting the city each day as well as those residing in it.

Another unusual aspect of the city population is that approximately one third of the city's 70,000 plus residents are students. This skews the age profile slightly younger than average and also means a high level of annual turnover of city residents. Such turnover requires ongoing public education regarding climate change risks and responses and may warrant the City of Melbourne engaging with universities as a means of maintaining awareness. As many students are international this adds a required cultural dynamic to any communications program.

Each climate change adaptation risk was assessed on a one to five scale on both the likelihood of the risk occurring and, if it did occur, the consequences of that risk.

This helps to identify the seriousness of each risk, the necessary management and monitoring needed to minimise it. Critical risks were deemed as those with a combined rating of seven or more.

All critical risks have been detailed and identify risk attributes, stakeholders, key findings, recommended adaptation measures and next steps. Both organisational and municipality risks have been assessed and addressed for the city. Some risks the City of Melbourne has the ability to address independently, others will require discussion and cooperation with relevant stakeholders in city management and risk mitigation. Some risks are not in the City of Melbourne's control but, in its aim to act as a prudent steward for the city, it is important that the City of Melbourne knows these risks are being addressed.

The two most significant extreme weather events for Melbourne likely to be exacerbated by climate change are extreme heatwaves and intense rainfall events. While drought and sea level rise also have critical risks, these two priority events are likely to happen sooner, potentially more frequently, and can have significant and devastating effects for Melbourne, its visitors and residents.

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Heatwaves

Already a health issue for Melbourne, the most significant risk is the likely increased levels of heat stress and death caused by extreme temperatures. This is of particular concern for the elderly and infirm, as well as those with heart or respiratory problems and perhaps mental health issues.

An increase in violence and anti-social behaviour is also a potential implication of heatwaves, particularly when alcohol is involved. A recent Australian study has shown significant increases in facial fractures presenting at hospitals during hot, humid nights as a result of domestic or public violence.

With the prevalence of air-conditioner use during heatwaves, demand for power may potentially outstrip supply and cause a power blackout. This risk has significant flow on implications during a heatwave, particularly for those managing their heat stress with air-conditioning. If the outage is sufficient to disrupt public transport mass stranding of passengers may also occur.

Less concerning, but still significant, risks are the potential for food borne disease in the warmer conditions, and the increased maintenance costs to support assets and infrastructure under the more extreme heat conditions.

Intense rainfall and wind storm events

Flash flooding is the main threat in an intense rainfall event, with likely 'hotspots' identified in the City of Melbourne precinct (refer map in Appendix A). Even small flooding events have been known to cause public transport disruptions and significant outages can cause mass stranding of passengers. This can exacerbate the delays and put more people at risk of injury during the storm. Power outages due to storm damage can also cause transport delays and traffic chaos. Already, emergency services are reporting longer response times due to current transport congestion.

In situations of traffic disruptions these hindrances may cause significant adverse health outcomes for those requiring emergency care. Deaths and injuries due to storm damage or flash flooding are also a significant risk in these events. Studies show that of all natural disasters, floods cause the most injuries and deaths (Australian Government 2007). Encouragingly, these studies also indicate an informed public can reduce the number of injuries, deaths and stress due to the event.

During storm events the level of debris dislodged directly affects the extent of damage and injury. After an extended drought, many cities have very stressed trees that break more often in storms, causing death or damage.

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City of Melbourne has identified weak trees in the municipality and is working to improve them.

Many businesses can be forced to close after a flood event to undergo clean up works and business restoration. Research indicates one in four businesses that close under such circumstances do not reopen.

With many small to medium CBD businesses not having sufficient business interruption insurance, should a significant flooding event affect a business precinct, there is the risk that area may be severely impacted by business closures and an associated reduction in public appeal. Elizabeth Street, near Flinders Street, is such an area at risk that warrants early attention (refer to section 8.2.4.5).

Drought and reduced rainfall

Drought and reduced rainfall is an ongoing state Melbourne may attain with climate change, rather than a one-off event such as a heatwave or flood. Three risks are considered critical and require immediate and ongoing management.

The most significant and inherent risk in drought is insufficient water supply for Melbourne. While it is positive that Melbourne residents are aware of the scarcity of potable water and have made significant reductions in consumption in recent times, this may also mean the 'low hanging fruit' of water savings have been addressed and, with an increasing population, further savings may be challenging.

The assessment took into account the commitment of a desalination plant for Victoria producing 150 gigalitres (GL) of water annually from 2011, which meant the risk does not require active management although further pressures on supply should be closely monitored and addressed.

A lack of environmental flows is putting pressure on the biodiversity of our waterways, the Yarra and Maribyrnong Rivers. These waterways are home to some already endangered species and are at risk of further stress should additional environmental flows not be released. Stormwater events, although providing water inflows, are also considered the main cause of toxins in the rivers. The City of Melbourne's *Total Watermark -City as a Catchment* strategy is very important in addressing this risk set and should be closely aligned to its findings.

The water restriction regime of Melbourne has helped manage the significant drought issues of recent years. However, included in those heightened restrictions is the inability for sporting grounds to be irrigated. In areas across Australia, no rainfall and high evaporation resulted in many sporting grounds hardening to a point of increasing risks of serious injury. If sporting grounds are not able to be maintained sporting participants may be at risk of injury. Whether this risk is municipal or council depends on the ownership of the sporting ground involved.

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Sea level rise

Sea level rise is an often debated aspect of climate change projections. However, even the most conservative studies show sea levels have already risen, mostly due to thermal expansion, and are likely to reach a level of approximately 59cm by 2070. While no risks related to sea level rise are considered critical in the current timeframe, many do increase to critical by 2070. Adaptation to sea level rise is somewhat unique in that often the best and most cost effective adaptation measures are related to urban planning or infrastructure. As these decisions have very long time horizons, it is possible decisions excluding sea level rise considerations made by the City of Melbourne today could exacerbate issues related to sea level rise in the future. For that reason this assessment recommends all planning decisions and infrastructure programs in areas likely to be affected by sea level rise, such as Docklands, Fisherman's Bend and Southbank, be reviewed and provided appropriate guidelines in relation to rising sea levels. This should involve hydrological modeling, extensive stakeholder engagement and clarification of liability issues as early as possible. A long term strategy to address sea level rise is far more cost effective and integrated than potentially drastic and urgent measures undertaken much later when shores or piers are inundated.

What are considered the two key 'high value' adaptation measures?

Two key adaptation measures are considered 'high value' in that they have the potential to provide benefits across many risks, these are:

- Stormwater harvesting (refer to section 10.1): this can assist in both flash flooding events and with insufficient water supply. As stormwater volume in Melbourne is almost equal to potable water consumption, this is a valuable resource. Additional capacity in stormwater harvesting can also put less pressure on drainage systems during intense rainfall events.
- Increasing passive cooling efficiency of the city to reduce the heat island effect (refer section 10.3). Melbourne's CBD can be 7°C higher than other Melbourne suburbs in hot weather. This significant difference substantially heightens the vulnerability of people in the city to heat stress, injury or death. Measures to reduce the city temperature both inside buildings and at street level can provide considerable benefits to reducing overall exposure.

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How will the climate change risks be managed by the City of Melbourne?

As stewards of their local communities, local governments have a unique and challenging role in assessing and addressing the impacts of climate change. Although clearly involved with much of a city's management, the perceived responsibility by the community, particularly in times of challenge, can often differ from the scope of the City of Melbourne's statutory responsibilities or influence. With the strengthening prospect of increasing extreme weather events due to climate change however, legal experts argue local government is at increasing risk of incurring liability if they *'unreasonably fail to take into account the likely effects of climate change'* (England 2007). While the threshold for 'reasonableness' is currently considered high, largely focusing on the City of Melbourne's degree of control, increasing information on the potential impacts of climate change is quickly shifting the threshold lower. Legal experts advise local governments should maintain an active brief over their climate change risk management and response plan ensuring their appropriate diligence and duty of care.

The goal of risk management is to reduce the likelihood or consequence of the risk or increasing control of it. Adaptation measures are those undertaken to respond to the shifting pressures of climate change. Many adaptation measures recommended in this assessment aim to reduce the risk ratings to those considered tolerable.

Where more information is required to determine the best adaptation measure to address a risk, a series of next steps has been identified. As well as undertaking the high value adaptation measures and addressing critical risks that require active management, it is recommended these next steps be reviewed and undertaken as a first stage of action. City stakeholders, many of whom were involved in the development of this assessment, should be promptly engaged with to share the findings of this project and integrate or align stakeholder programs or action plans.

Risk management is not new to the City of Melbourne and therefore this climate change risk assessment aimed to build upon and align with the organisational risk management framework utilised by the City of Melbourne. Some recommendations have been made to better align the City of Melbourne framework with this exercise and it is recommended the risk assessment and strategy be managed as part of the City of Melbourne's risk management program.

1.0 Introduction

Almost all sectors of society and the economy are likely to be impacted by climate change. Indeed many changes are already being observed in Australia and scientific consensus warns with increasing confidence of many varied and more serious impacts to come. Even with considerable cuts to global greenhouse gas emissions the lag in the climatic system means, in the short term, these impacts are unavoidable and communities must ready themselves to deal with them.

Adaptation is the principal means by which to build resilience and reduce vulnerability in local communities and economies. It involves a combination of risk management, adjustment of economic activity, changes to urban infrastructure and a review of social services and changing community needs. Identifying priorities and appropriate actions to suit regional dynamics and projected local climate change impacts represents a significant challenge for local government decision-makers.

A locally-relevant, cohesive, multi-disciplinary response strategy that works across government and the community is key to successful adaptation that protects or insulates communities from the impacts of climate change. An effective adaptation plan needs to reflect the expected local impacts of climate change and build resilience specific to the strengths, vulnerabilities and resources of that area.

Such a response must be comprehensive, interdisciplinary and unrestrained by organisational boundaries.

This project is a cohesive climate change risk assessment and adaptation strategy for the City of Melbourne, as both an organisation and municipality. It aims to prepare the City of Melbourne for the projected impending impacts of climate change by increasing its resilience. As management of the city involves a range of stakeholders, where possible, these roles and responsibilities have been defined and incorporated to provide a comprehensive blueprint for action.

Few of the risks related to climate change will be completely new to the City of Melbourne; most will be already dealt with in some way but are perhaps exacerbated by climate change and therefore altering their risk profile. This adaptation plan builds upon existing risk management and response capacities within the City of Melbourne to deliver appropriate adaptive actions, building on existing knowledge and extending existing capacity to ensure climate change can be capably managed by the City of Melbourne.

Significant capacity building is required to ensure effective delivery of the adaptation options proposed in this report, including extensive capital investment and policy analysis by the City of Melbourne.

1.0 Introduction

Without appropriate financial, technical, and human capital being available, adaptation measures are likely to fail. Other barriers to implementation, such as the political feasibility of adaptation actions or the cost of these being delivered can also challenge the success of adaptation plans.

As with all risk management programs, adaptation measures should not be expected to completely mitigate climate risks – the aim is managing risks to accepted levels of tolerance. The limited nature of adaptation should be acknowledged and borne in mind.

2.0 Methodology

This analysis reflects the body of knowledge garnered from relevant City of Melbourne, stakeholder and climate change literature; as well as City of Melbourne specialist expertise and external stakeholder contributions.

The project risk management process aligned with the Australian and New Zealand risk standard AS4360 (refer Figure 1) and was developed in three phases: **Phase One: Risk Identification, Phase Two: Risk Assessment, and Phase Three: Adaptation Action Plan.**

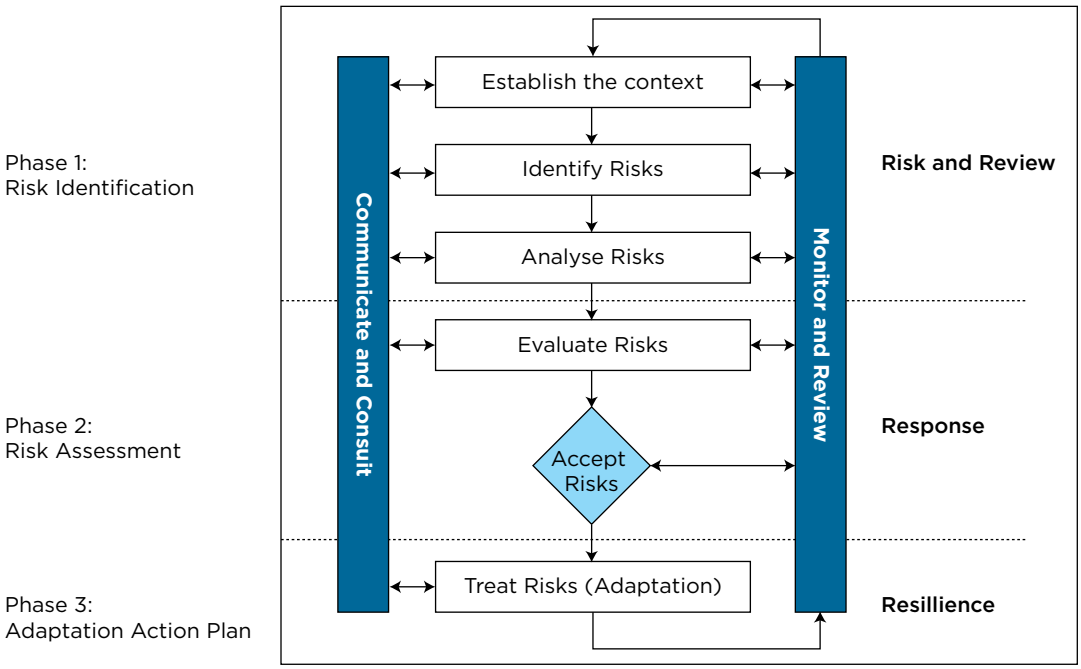

Figure 1: Risk management process (source: adapted from AS/NZS 4360:2004)
Further details on the methodology can be found in Appendix B.

3.0 City of Melbourne

The City of Melbourne is located in Australia within the state of Victoria. Melbourne is Victoria's capital city and the business, administrative, cultural and recreational hub of the state. The City of Melbourne is made up of the Melbourne city centre and a number of inner suburbs such as East Melbourne, North Melbourne, Parkville, Carlton, Southbank and Docklands (refer Figure 2 for map of suburbs).

The municipality has a resident population estimated at over 80,000 people (refer Figure 3), with a young median age of 28. Approximately 716,000 people enter the municipalities' boundaries every day, approximately 365,000 of them for work, and the remainder for other visiting purposes (See Section 5 for more detailed discussion of socio-economic factors of the City of Melbourne).

The City of Melbourne is well known for a full calendar of events and is a major shopping and recreational destination, with major event locations including the Melbourne Cricket Ground, Melbourne Tennis Centre Precinct, Etihad Stadium and the Crown Casino complex. The City of Melbourne attracts over one million international visitors every year. It supports Melbourne's position as Australia's pre-eminent centre for arts and culture, education, fine food and dining and shopping.

The City of Melbourne contains many natural features and recreational areas, including two major waterways (the Yarra River and Maribyrnong River), a well known network of parks, gardens and sports fields including the Royal Botanic Gardens.

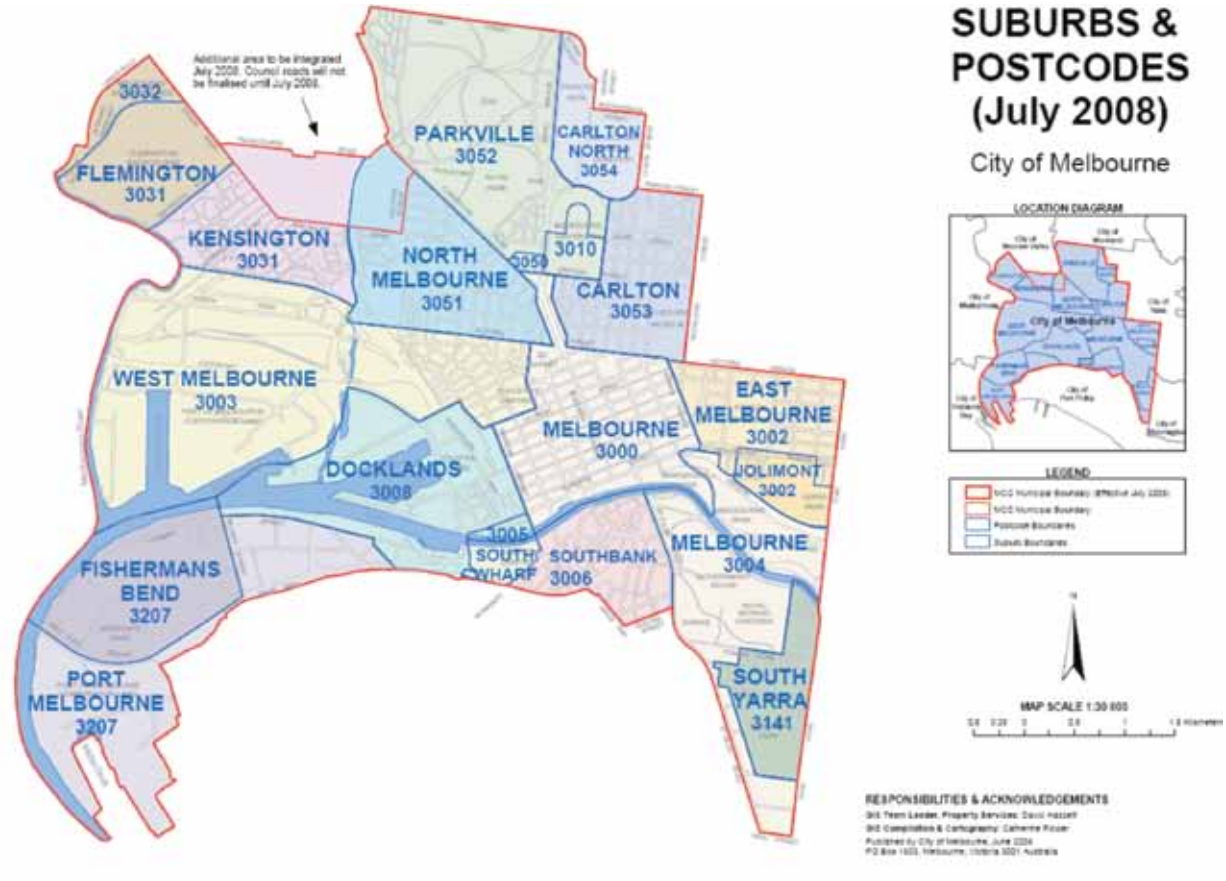

Figure 2: Suburbs and postcodes of City of Melbourne (provided by the City of Melbourne)

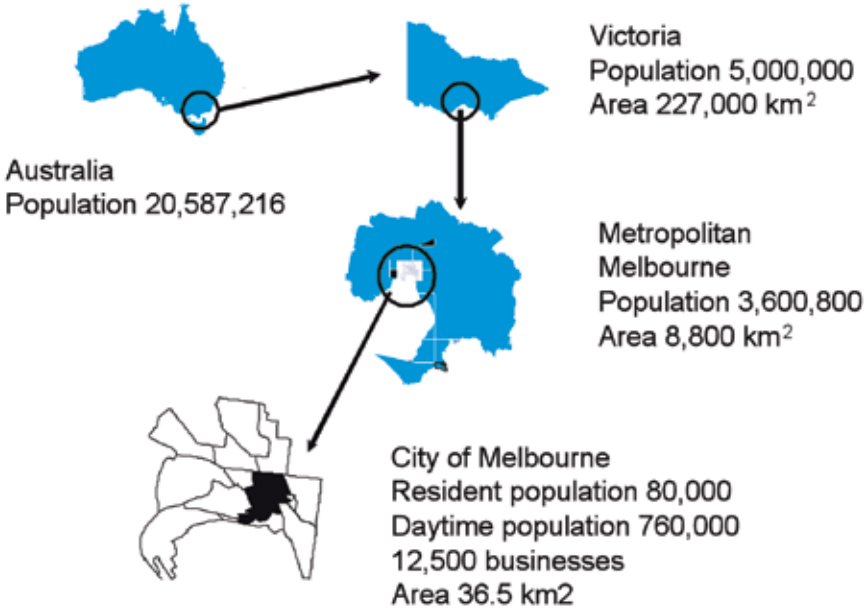

Figure 3: Geographical context of the City of Melbourne (provided by the City of Melbourne)

4.0 Climatic Changes for Melbourne

Climate change is having far reaching impacts across the globe with significant spatial variations. The projected changes for south east Australia is for the climate to become hotter and drier. During the decade 1998 to 2007 average annual temperatures in the region were 0.4°C warmer than the 30 year (1961 to 1990 average). Over and relevant to the same periods, Victoria has experienced a decline in average rainfall of 14 per cent (DSE 2008). The incidence of severe droughts has tended to be more frequent, and the impacts of the 2002 drought are now considered likely to have been enhanced by climate change (Victorian Government, 2008).

Climate change is already affecting metropolitan Melbourne and ever increasing research warns its impacts are expected to increase over time. Metropolitan Melbourne's future is expected to be hotter and drier and an increase in extreme weather events such as heatwaves, storms and flash flooding is likely. Specific climate change projections relevant for the Melbourne district are detailed in this section.

4.1 Climate modelling

The IPCC (2000) has prepared emissions 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. Each scenario represents a variation within one of four 'storylines': A1, A2, B1 and B2. The climate change projections in the assessment are based predominantly on *Climate Change in Port Phillip and Westernport* (DSE, 2008), which uses a medium emissions scenario (A1B) for 2030 and lower (B1) and higher (A1FI) emissions scenarios for 2070. The relevant IPCC storylines on which the climate data is based are summarised below.

The A1 storyline

This 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).

4.0 Climatic Changes for Melbourne

The B1 storyline

This 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.

For 2030, the A1B emissions scenario in *Climate Change in Port Phillip and Westernport* is used. For 2070, the more emissions intensive of the two available emissions scenarios has been selected (that is A1FI), based on recent climate change science which indicates we are currently tracking along the upper limit of the IPCC emission scenarios (that is Rahmstorf et al, 2007). Based on this and other recent literature, it is the opinion of the authors that the use of the medium emissions scenario for 2030 provides a conservative estimate. However, for the 2030 timeframe, the medium and high emissions scenarios are expected to produce similar degrees of climatic change in Victoria.

Table 1 provides an overview of the climate data used in the risk assessment. The projections are based on the results of climate modelling experiments provided in *Climate Change in Port Phillip and Westernport*, in which the effect of increased levels of greenhouse gases in the atmosphere is simulated in 23 global climate models.

Where data has been drawn from other sources, this is specified. Data is provided in a range to allow for uncertainty in the future growth in greenhouse emissions, and for differences between the simulated climate change from various climate models. The median for each range is also provided – this has been used as a basis for the risk assessment in most cases (the bold figures in the table are those used to rate consequence and likelihood). Notably, sea level projections use the upper limit of the data range (refer Section 8.4 for a justification of this).

4.0 Climatic Changes for Melbourne

Table 1: Climate change projections for Victoria

Climate variable		Now	2030 (A1B)	2070 (A1FI)
Victoria			**Estimate of change**	**Estimate of change**
Temperature	Annual average temperature	Max 18.7°C Min 8.3°C	**+0.8°C** (0.6 to 1.1°C)	**+2.6°C** (1.8 to 3.7°C)
Extreme temperature	Annual average number of hot days (over 35°C)	9 days	**11 days** (10 to 13 days)	**20 days** (15 to 26 days)
	Annual average number of warm nights (above 21°C)	Not available	Not available	15-**50%**[2]
Rainfall	Annual average rainfall	864 mm	**-4%** (8% to no change)	**-11%** (-24% to no change)
	Summer	166 mm	**-2%** (-10 to +7%)	**-7%** (-31 to +21%)
	Autumn	213 mm	**-2%** (-8 to +5%)	**-5%** (-24 to +16%)
	Winter	245 mm	**-4%** (-11 to +1%)	-**11%** (-26 to +4%)
	Spring	152 mm	**-7%** (-17 to no change)	**-21%** (-41 to -1%)
Extreme rainfall	Heavy rainfall intensity (99th percentile)	Not available	**+0.9%** (-7.7 to +15.2%)	**+5.9%** (-24.9 to +48.9%)
Wind speed	Annual daily extreme wind-speed	Not available	**No change** (-5 to +4%)	**No change** (-16 to +13%)
Sea level rise	Average sea level rise[3]	Not available	+5-**15cm**	+26-**59cm**
Additional	Annual average potential evaporation	Not available	**+3%** (1 to 5%)	**+9%** (2 to 17%)
	Annual average relative humidity	59%	**-0.6%** (-1.2 to -0.1%)	**-2%** (-4 to -0.3%)
	Annual average number of very high and extreme forest fire danger days[4]	9 days	**+2 days**	**+6 days**

The data in this climate change variables table is from *Climate Change in Port Phillip and Westernport* (DSE, 2008) apart from where otherwise specified.

2. *Climate Change in Australia - Technical Report 2007* (CSIRO 2007) – data is for 2100 not 2070
3. As sea level rise projections are not available in *Climate Change in Port Phillip and Westernport*, these have been taken from ACE CRC (2008a) projections. It should be noted these rely on an A1FI emissions scenario – therefore, unlike the rest of the data for 2030, sea level projections are based on A1FI not A1B. The projections are relative to 1990 sea levels – refer Section 4.6 for details of sea level rise projections.
4. *Bushfire Weather in Southeast Australia: Recent Trends and Projected Climate Change Impacts* (Bushfire CRC, 2007) data is for 2020 & 2050, not 2030 and 2070

4.0 Climatic Changes for Melbourne

4.2 Temperature

Victoria is expected to warm at a rate slightly faster than the global average, especially in the north and east of the state (CSIRO, 2007). By 2030, average annual temperatures are expected to rise by 0.6 to 1.1°C in Melbourne, with slightly more warming in summer and less warming in winter (refer Table 2). Concurrently with increasing temperatures Victoria is experiencing decreases in relative humidity (0.6 per cent decline by 2030) and potential increases in evapo-transpiration (3 per cent increase by 2030) (DSE 2008). The combined impact of these variables results in reduced soil moisture content which can have implications for agriculture, building design and water supply.

Table 2: Seasonal changes in temperature for Port Phillip and Westernport (DSE 2008)

Season	2030	2070
Spring	0.8°C	2.6°C
Summer	0.9°C	3°C
Autumn	0.8°C	2.6°C
Winter	0.7°C	2.1°C

4.3 Extreme temperature

As Victorian average temperatures rise, the frequency of hot days will also increase. A hot day is defined as a day where the temperature exceeds 35°C and a hot spell a period of three to five consecutive days where the temperature exceeds 35°C.

By 2070, Melbourne's annual average days:

- Above 30°C may increase from the current 30 days to 42-62 days;
- Above 35°C may increase from the current 9 to 15-26 days; and
- Over 40°C may increase from the current 1 to 3-8 days (refer Table 3).

It is also expected that hot spells (a period a 3 to 5 consecutive days where the temperature exceeds 35°C) will increase (refer Table 4). Night time temperatures in Australia are expected to rise with warm nights projected to increase between 15-50 per cent at the end of the 21st Century (CSIRO, 2007).

These changes in the frequency of hot summer days, spells and warm nights, is of potential importance to the occurrence of heat stress and energy demand for cooling (CSIRO, 2007). Melbourne's heat related deaths in those aged over 65 are expected to rise from the current 289 deaths per annum to 582-604 by 2020 and 980-1318 by 2050 (McMichael et al. 2003). Heat stress deaths will likely soon exceed the Victorian annual road toll (304 fatalities in 2008).

4.0 Climatic Changes for Melbourne

Table 3: Melbourne – projected days for 2030 and 2070 at temperature thresholds (DSE 2008)

	Frosts*	Over 30°C	Over 35°C	Over 40°C
Current	3	30	9	1
2030	2	34	11	2
2070	0	49	20	5

* 2°C or less

Table 4: Melbourne – current and projected average number of hot spells (Victorian Government, 2008)

	Hot spells
Current	1
2030	1
2070	1-2

4.4 Rainfall

Victoria is expected to become drier with annual average rainfall decreasing by 4 per cent by 2030 and 11 per cent by 2070; most of that decrease is expected in spring (a 7 per cent reduction in 2030 and a 21 per cent reduction in 2070) (DSE 2008) (refer Figure 2).

The projected decrease in rainfall and more evaporation will affect water supply. By 2030, the decline in annual rainfall and higher evaporation is expected to cause less run-off into rivers, that is a potential decline of up to 45 per cent in 29 Victorian catchments (Jones and Durack, 2005). For Melbourne, average stream flow is likely to drop 3-11 per cent by 2020 and 7-35 per cent by 2050 (CSIRO, 2007).

The latest CSIRO regional climate change projections for the Port Phillip and Westernport region indicate that by 2070, runoff into the Yarra, Maribyrnong, Werribee and Bunyip Rivers will decrease by up to 50 per cent (Victorian Government, 2008). Even with the current alternative sources of water supply these reductions in water storage pose a large threat to the water security of the affected area.

Decreased water supply along with warmer temperatures, is likely to increase drought risk and severity (CSIRO, 2007). As droughts become more severe fire risk is expected to also become greater. By 2070, the number of days with very high or extreme fire danger in Melbourne could average 15, from the current 9 days (Bushfire CRC, 2007). The warmer, drier and longer summers expected in Victoria are very likely to increase the frequency and intensity of bushfires.

Table 5: Projected seasonal changes (per cent) in Victorian rainfall by 2030 and 2070 (Victorian Government, 2008)

Season	2030	2070
Spring	-7%	-21%
Summer	-2%	-7%
Autumn	-2%	-5%
Winter	-4%	-11%

4.0 Climatic Changes for Melbourne

4.5 Extreme rainfall

Although the overall rainfall for Victoria is expected to decrease, extreme rainfall events are projected to increase by 5.9 per cent by 2070 (DSE 2008). The future precipitation regime will have longer dry spells interrupted by heavier precipitation events, especially in the summer and autumn (CSIRO, 2007).

Changes to extreme events have the potential to increase flood frequency. They also have the potential to reduce water quality through increased stormwater pollution and erosion with implications for the health of our water bodies. These risks can also impact on insurance risk and the design standards of bridges, roads, dams, stormwater and other infrastructure (CSIRO, 2007).

4.6 Sea level rise

Estimations for future sea level rise have been derived by fitting the IPCC's TAR time series projections to 2090-99 projections from AR4 (including future increased ice flow from Greenland and Antarctica). This yields the following 5-95 per cent percentile range of projections for the A1FI scenario (ACE CRC 2008a):

- 2030 relative to 1990: 5-15 cm
- 2070 relative to 1990: 16-47 cm
- 2100 relative to 1990: 27-82 cm

Additional sea level rise of 10cm has been added to these figures below to allow for thermal expansion occurring on the Australian East Coast for the 2070 and 2100 timeframes (CSIRO 2007). This yields the following projected sea level rise:

- 2030 relative to 1990: 5-15 cm
- 2070 relative to 1990: 26-59 cm
- 2100 relative to 1990: 37-92 cm

The upper limit of the 2100 projection is in line with the 80cm sea level rise which the Victorian Coastal Strategy (2008) recommends planning decisions allow for.

The channel deepening project in Port Phillip Bay is also expected to have a small effect on high water levels, but this is expected to be negligible, with PoMC (2007) estimating a rise of less than 1cm.

By 2070, higher sea-levels and more intense storms, coupled with increased storm surge heights, will greatly expand the coastal area likely to be inundated by storm events. Storm surge has the potential to be a significant hazard – even a 0.5m sea-level rise (that is a plausible projection for 2070) could lead to a present 1:100 year flooding event occurring every few months (Church et al. 2008).

4.0 Climatic Changes for Melbourne

This is a serious risk the impacts of which are currently poorly understood – hydrological modelling of the City of Melbourne to identify at risk areas is recommended.

4.7 Extreme wind speed

Uncertainty around model projections for changes in wind speed is high. Projections indicate nationally there is a tendency for increases in most coastal areas, with a best estimate of between 2-5 per cent (CSIRO, 2007). However, projections for Victoria indicate that wind speeds will remain similar to what they are today for both 2030 and 2070.

5.0 Socio-Economic Changes for City of Melbourne

Climate change does not occur in a vacuum and must be assessed in relation to the local community and built environment. This helps determine a city's sensitivity or resilience to certain conditions and therefore the likely affect of different climatic impacts.

While managing the impacts of climate change, Melbourne's projected population growth presents the added challenge of accommodating more people and providing the necessary resources to service and protect them, as well as caring for an aging population. These issues will place added pressures on climate change impacts and responses but may also provide processes and development into which adaptation can be integrated. This assessment of Melbourne's climate change resilience and vulnerability took into account this full range of changing attributes in an integrated assessment framework.

The significant numbers of people that visit Melbourne each day are an important consideration when developing adaptation responses. Just over half of these visitors are coming to the city for employment with the remaining visitors doing so for various recreational activities. This makes scenario planning and communication with these people challenging.

Having so many people come into the city each day means the potential scale of an event can be significantly amplified if it happens while these people are in the city. This daily transience identifies the importance for the City of Melbourne to work with a range of stakeholders to ensure public awareness programs also reach these people visiting the city each day.

The large number of students in the city means the age profile is slightly younger than average and also means a high level of turnover of city residents. Such turnover requires ongoing public education regarding climate change risks and may warrant the City of Melbourne engaging with universities as a means of maintaining awareness. As many students are international, this adds a required cultural dynamic to any communications program.

Socio-economic factors considered in this assessment for the City of Melbourne are:

- population and demographics;
- industry and employment;
- transport infrastructure;
- buildings, housing and development; and
- energy.

5.0 Socio-Economic Changes for City of Melbourne

These are explained in further detail below.

5.1 Population and demographics

The City of Melbourne is a rapidly growing municipality with an estimated population in 2006 of 76,678 increasing from approximately 51,000 people in 2001. It is predicted that by 2031 the City of Melbourne population will have grown to over 145,000 people from 76,000 people in 2008, with greater Melbourne predicted to become Australia's largest city by 2028. Daily visitation is expected to surpass 1 million people by 2016.

The city has a very large student population of 34,200 people (2006 estimate), approximately 45 per cent of the total population. Over 18,000 of these are international students. There was 33 per cent growth in the student population from 2001 to 2006. This, along with large numbers of young professionals, helps to account for the low median age of 28. Almost 61 per cent of the population is aged 15 to 34 years (City of Melbourne, 2007).

There is an increase in the population of people aged 55 to 64 of 48.6 per cent from 2001, making them 7.1 per cent of the population. There are nearly 10,000 residents in the City of Melbourne aged 55 and over (City of Melbourne, 2007). The South Yarra / St Kilda Rd district is the most concentrated area for residents aged 55-74 and 75+ (City of Melbourne, 2001).

The number of residents aged 60 years and over is expected to more than double to 15,246 people by 2031, compared to 6,671 in 2006 (Department of Sustainability and Environment, 2004). The growth in this age group will be slightly greater than the general population (Department of Sustainability and Environment, 2004). Residents aged 15 to 34 years will continue to represent a large amount of the population (over 49 per cent), but there will be a significant increase in those aged 35 to 49, increasing from 16.8 per cent of the population in 2006 to 20.8 per cent in 2031(City of Melbourne, 2007).

The population shows a high level of ethnic diversity with just over 33 per cent of the population reportedly speaking a language other than English at home (City of Melbourne, 2007).

5.2 Industry and employment

The City of Melbourne has a working resident population of over 38,000 people. Professionals (14,500 approx.), managers (5500 approx.) and clerical and administrative (5000 approx.) are the most significantly represented vocations (City of Melbourne, 2007). From 2001 to 2006, major growth was seen in professionals, technical and scientific services (50 per cent increase), retail services (67 per cent) and accommodation and food service workers (50 per cent).

5.0 Socio-Economic Changes for City of Melbourne

The "knowledge professional" is regarded as a key part of City of Melbourne's population (City of Melbourne, 2007b).

The City of Melbourne reports very good relationships with their business and industry sectors. The industry profile is dominated by business services, which is the number one industry in both employment numbers and numbers of establishments. Finance and insurance is the number two industry for worker numbers and retail trade is the number two in number of establishments. The Finance and insurance sectors in particular are concentrated in the CBD, while Docklands is emerging as a financial precinct outside of the central city; it is now home to the headquarters of the National Australia Bank, Medibank Private, and in future the ANZ Bank.

From 2002 to 2006 the City of Melbourne experienced the most employment growth in the finance and business services, education, public administration, and arts and recreation sectors. The advanced manufacturing sector (including aircraft manufacturing) is expected to be an area of future growth for the City of Melbourne. Development of this industry is concentrated in Fisherman's Bend where land parcels are large and there is room for expansion.

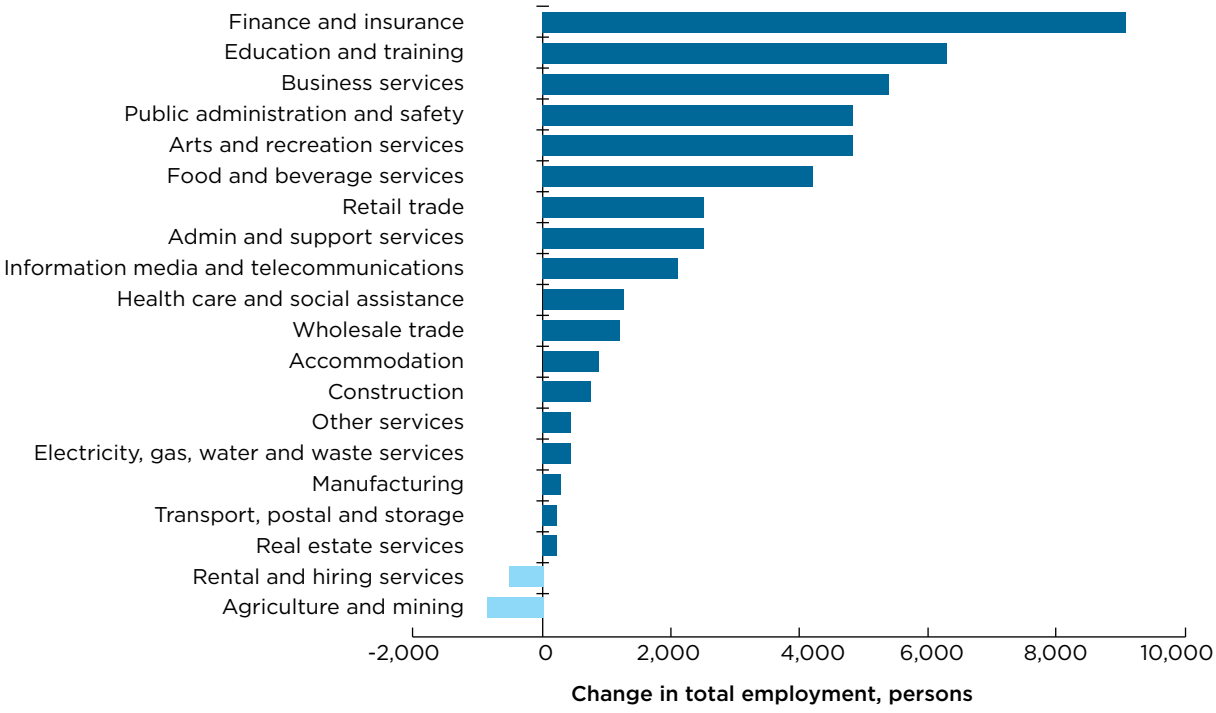

Figure 4: Increases in total employment by industry 2002- 2006 (City of Melbourne, 2007b)

5.0 Socio-Economic Changes for City of Melbourne

5.3 Transport infrastructure

The City of Melbourne has a daily population of 771,000 city users (City of Melbourne, 2008b-a). According to the *Central City Users Survey*, in 2006 the primary weekday mode of transport was trains (51 per cent), followed by trams (21 per cent) and cars (19 per cent). In 2001 to 2006 there was a 50 per cent growth in the number of households without a motor vehicle to over 10,000 households, with over 12,000 one-car householders (City of Melbourne, 2007). In 2006, 28 of City of Melbourne residents were walking to work, an increase of 3600 people since 2001.

In 2008 it is generally acknowledged that the public transport system is under considerable strain in peak period and road congestion is one of the most significant concerns for the City of Melbourne.

Major changes in Melbourne's transport system can be anticipated between now and 2030. The State Government's policy *Meeting our Transport Challenges* identified $10.5 billion in required transport spending. The Monash-CityLink-Westgate upgrade is underway to improve traffic flows along this route, however it is expected that full capacity will be reached within 15 years (The Age, March 15 2008,).

The overall potential net impact of the recommendations on the City of Melbourne is difficult to determine.

While improved public transport services may reduce strain on the existing system and attract mode share, these changes may be offset by increasing numbers of motorists utilising an expanded road network.

5.4 Buildings, housing and development

The growth in population has been mirrored by a growth in dwellings, with now over 42,000 dwellings, an increase from 26,000 in 2001 (Casey, 2008). The majority of new dwellings now being constructed are apartments, many of which will be small (1 to 2 bedroom), with the market dominated by young singles, couples and students. It has recently been estimated that 1.1million extra cars will likely need to be accommodated in greater Melbourne by 2028 (The Age, 6 March 2008).

The Docklands development is expected to be completed by 2025. VicUrban projections estimate that by 2020 Docklands will be home to 17,000 people (up from 6000 currently) and a work destination for 40,000 (up from 10,000 currently) (VicUrban 2008).

5.0 Socio-Economic Changes for City of Melbourne

By 2030 the rail lines to the east of Federation Square may be covered over between Flinders Street and Birrarung Marr, creating a substantial new activity area linking the Yarra with the CBD.

VicTrack land to the north of Footscray Road may undergo redevelopment following the shifting of its current rail gauge transfer operation to outside the City of Melbourne boundaries. It is immediately adjacent to the Docklands development, Moonee Ponds Creek and existing flood overlays. The nature of this development is unknown at this time.

By 2035 it is anticipated that the Port of Melbourne will be handling four times the number of containers, three times the volume of Bass Strait trade and two and a half times the volume of motor vehicles. The Webb Dock and Dynon Road precincts will be extensively redeveloped with increased capacity to move freight by rail. Footscray Road, Appleton Dock Road and Enterprize Road will be raised over the rail lines.

5.5 Energy

Nationally, primary energy consumption is projected to increase by 46 per cent from the period 2004 to 2005 to the period 2029 to 2030, with average annual growth of around 1.5 per cent (ABARE 2006) In Victoria however, average annual growth is projected to be relatively slow at 0.9 per cent per year.

Growth in primary energy consumption is projected to grow more quickly than population, with per person consumption projected to grow from 275 gigajoules per person in 2004 to 2005 to 319 gigajoules per person in 2029 to 2030 (ABARE, 2006).

Electricity generation in Australia is currently dominated by fossil fuels, accounting for 93 per cent of generation in 2004 to 2005. This dominance is projected to continue to 2029 to 2030, with the main change projected to be a significant increase in gas fired generation, and a corresponding decrease in generation from coal. While renewables are expected to grow strongly to 2029 to 2030, the projected growth is not sufficient to greatly change the proportion of national electricity generation, with renewable projects to account for 8 per cent of generation by 2029 to 2030.

The City of Melbourne itself has seen a significant growth in greenhouse gas (GHG) emissions from community generated emissions, with growth of 54 per cent in emissions between 2001 to 2002 and 2005 to 2006, driven particularly by growth in the commercial sector and an increase in the number of dwellings within the municipality (City of Melbourne, 2008a).

5.0 Socio-Economic Changes for City of Melbourne

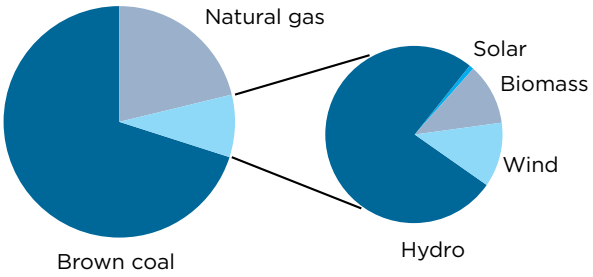

Figure 5: Electricity generating capacity in Victoria, 2004 (Sustainable Energy Authority Victoria, 2006)

Based on recent trends and current projections, the City of Melbourne will remain largely dependent on a fossil fuel intensive electricity supply to 2030, with likely increases in energy consumption per person. This will be in spite of greenhouse gas mitigation actions actively pursued by the City of Melbourne and others. These projections contextualise the challenge of the City of Melbourne commitments to GHG mitigation, as well as potential future exposure of the municipality to rising energy prices.

6.0 Urban System Assessment for City of Melbourne

Urban systems and infrastructure form the functional 'backbone' of human settlements and include bridges, roads, railways, airports, ports, electricity grids, water pipelines and reservoirs, stormwater drains, sewage systems, street lighting, telecommunications, waste systems and buildings.

Changing climatic conditions and increased frequency and intensity of storm events are expected to put unprecedented pressure on urban infrastructure (IPCC, 2001). Research reviewed suggests climate change impacts will have varying effects on infrastructure according to its type and location, and its relative *resilience, capacity and condition*.

The capability of the City of Melbourne's urban systems to withstand, or respond to, the impacts of heatwaves, storms, drought and generally changing climatic conditions determines the City of Melbourne's system 'resilience'. Engineering standards, building materials and techniques, technology and location can all contribute to the resilience of various infrastructures. As climatic events become more frequent and intense, infrastructure has a higher potential for damage or failure. Beyond the resilience of the infrastructure itself, a settlement's ability to continue to function, or not, with the failure of infrastructure, whether singular or in combination, is also an aspect of resilience.

Understanding the coping range of key urban systems to the projected impacts of climate change allows the City of Melbourne to evaluate the likely local implications of climate change and assist in prioritising and shaping effective protective responses.

This integrated assessment considered the following urban systems for the City of Melbourne:

- Water
- Transport and mobility
- Buildings and property
- Social, health and community
- Business and industry
- Energy and communications
- Emergency service

System states for each sector were informed by detailed literature review and stakeholder consultation.

6.1 Water

6.1.1 Current system state

Significant changes in water systems are expected to result from climate change.

The urban water supply of greater Melbourne has already been feeling the pressure of unprecedented drought. Responses have included water restrictions and considering alternative water sources such as rainwater tanks and desalination. Compounding this is increasing demand from a rapidly growing population

6.0 Urban System Assessment for City of Melbourne

Metropolitan Melbourne's water storages have been at persistently low levels for several years. With its dependence on the stressed centralised water supply system of greater Melbourne, the City of Melbourne has vulnerability to a shifting climate and potential further reductions in rainfall. The State Government and the water sector are working to secure Melbourne's future water supply through the implementation of major augmentation projects including the Victorian desalination plant.

The City of Melbourne responded to the water scarcity risk by setting targets that seek to reduce water use by residents, employees and the City of Melbourne by 40 per cent. To date, great savings have been made with a 48 per cent reduction per employee, a 39 per cent reduction per resident and 28 per cent reduction in water use from the City of Melbourne being averaged.

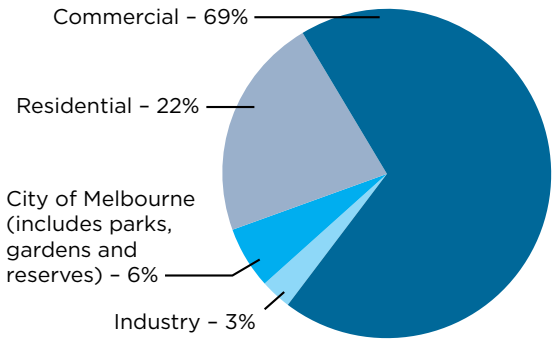

Figure 6: Total water consumption in City of Melbourne in 99/00

The City of Melbourne's drainage system is characterised by old infrastructure. The majority of drainage infrastructure is over 60 years old, with some drains date back to the 1850s. The flood mapping was poorly charted and understood until the late 1990s when areas where the underground system was exceeded in a one-in-a-hundred Average Recurrence Interval (ARI) event were recorded.

Generally areas can accommodate either 10 or 20 years ARI, however, much of the existing drain infrastructure is reportedly designed to accommodate one in five year events and many road locations are not designed to adequately accommodate overland flow. There are several locations of flash flooding risk in the City of Melbourne (refer maps in Appendix A). It is important to note that the Australian rainfall and runoff data underlying current understanding of flood risk in City of Melbourne is now 20 years old and is currently being updated at a national level.

The City of Melbourne has been committed to implementing water sensitive urban design treatments since 2005 as a stormwater management measure. Several examples of this new infrastructure have been implemented in the past few years and will continue to be a priority in order to meet stormwater quality targets to help improve the health of our waterways which have a history of poor water quality levels (Yarra, Maribyrnong and Moonee Ponds Creek).

6.0 Urban System Assessment for City of Melbourne

Waterway health, aquatic biodiversity and riverine habitat have the potential to be reduced due to larger accumulations of pollutants between significant rainfall events resulting from climate change.

The wastewater management system is in good order however will face increasing pressure from a growing population. Groundwater is generally not a strong supply opportunity for City of Melbourne as it is shallow and saline.

6.1.2 Potential climate change impacts

- Continuing long term reduction in annual rainfall will place growing pressure on the City of Melbourne, businesses and residents to curb water consumption and improve efficiency and invest in alternative supply sources at a local level.
- Parks and gardens will be under growing strain and will require more intense planning and management.
- The potential for storm drain inundation and flash flooding will likely increase with more intense rainfall events accompanied by sea level rise. These events have numerous flow on effects for example to business, transportation systems and health and safety.
- Episodes of riverine flooding will likely increase.
- Existing stormwater quality treatment systems may become stressed as a consequence of decreased rainfall and increased evaporation.

6.2 Transport and mobility

6.2.1 Current system state

Daily visitation to the City of Melbourne is large and forecast to grow rapidly. Currently approximately 771,000 people access the city daily and this is expected to grow to one million within a decade. This essentially creates a weekday “tide” of people coming into the city in the morning and exiting in the late afternoon/evening

The public transport system that serves the City of Melbourne is generally regarded as very stressed. It is subject to peaks and troughs, running at full capacity during peak hours. Recent increases in patronage of trains have exacerbated congestion which contributes to increases in service interruptions due to ill passengers, particularly on hot days.

The train signalling system is aged and in need of upgrading to permit more effective movement of trains. The train system in particular is highly interdependent; failures at one location, such as an accident or signal failure breakdown, can quickly impact the whole network. In addition to infrastructure and technological failures, passenger illness also causes significant delays. In March 2008, 25 sick passengers held up 894 services and in February 2008, 828 services were held up or cancelled because of passenger sickness (The Age, May 14 2008).

6.0 Urban System Assessment for City of Melbourne

The inner city road network is stressed and road congestion is one of the most significant concerns for the City of Melbourne. There is little opportunity to easily expand the road network and there is intense competition for road space. Metropolitan freight is growing at a rapid rate and most of this growth is expected to be road based.

There is a steady increase of cyclists accessing the City of Melbourne, doubling from 1 per cent to 2 per cent of all trips within the City of Melbourne between 2003 and 2006 (City of Melbourne, 2007). The bicycle infrastructure network is improving but requires further improvements in connectivity, extent and safety to permit further cycling growth. The networks are not necessarily stressed at present, that is cycling facilities are not optimal, but nor are they crowded. Pressure from road congestion is an increasing injury risk for cyclists.

Pedestrian traffic in the CBD is large, growing rapidly and subject to well understood peaks and troughs. The inner city pedestrian network is stressed, with a number of locations where people walk on the roads. The pedestrian network for walking into the CBD has substantial capacity for growth, however injuries are common; every second day a person is hit and injured by a car in the City of Melbourne municipality. The City of Melbourne records approximately 10 pedestrian fatalities and 85 serious injuries per year.

6.2.2 Potential climate change impacts

- Increased number and extent of disruptions to transport systems from extreme heat, flash flooding, intense storms.
- Flooding of train tracks, tram tracks, roads and pedestrian/bicycle paths.
- Falling branches, trees and other debris knocking out or blocking tramways, or blocking roads.
- Slowing of trams and trains and increased risk of tram derailment in intense heat.
- Increased incidence of illness on public transport, resulting in service disruption, contributed to by intense heat and congestion.
- Warping of train tracks from heat.
- Slowing of trains in heat.
- Power failures and or blackouts from heat or storms affecting operation of electrified train and trams, and traffic signalling.

6.3 Building and property

6.3.1 Current system state

Consultation with the City of Melbourne suggests that building stock in the city is in a stage of constant renewal and investment. However most buildings are very energy inefficient and require significant air-conditioning.

6.0 Urban System Assessment for City of Melbourne

Aged building infrastructure within the City of Melbourne is creating an oversupply of unsuitable building space. Reportedly many properties are under utilised, often from the second floor up, because retrofitting is required for compliance purposes, like sprinkler systems, or old, energy inefficient cooling towers. This situation may worsen with forecast rising energy costs, combined with rising temperatures, which further decreases the commercial attractiveness of this aging infrastructure. The building stock in the City of Melbourne is generally not considered resilient to climate pressures, as they are highly dependent on external power and water sources.

Changing climatic conditions are demanding a re-think of the focus of the management of the public realm. Previously there has been a focus on protecting residents and visitors from rainfall and wind. Increasingly, this focus needs to broaden to providing comfort in conditions of prolonged and extreme heat. The City of Melbourne also needs to consider the resilience and management of several emergency congregation points. The impact of prolonged drought and water restrictions on the City of Melbourne's iconic trees has been dramatic, with significant and widespread weakening of trees. Previous watering practices promoted shallow root development, rendering the now-stressed trees highly vulnerable to wind-throw. Revised watering practices have been implemented, and progressive mass tree replacement is planned.

The City of Melbourne reports problems with building management related to bushfires including clogging of filter systems and setting off of fire alarm systems.

City areas start to smell very bad when there has been no rain for a prolonged period of time.

Newly constructed buildings and properties need to conform to the Building Code of Australia's buildings standards. These are continually being upgraded and were recently updated to include energy efficiency standards. During consultation it was raised that existing standards are focused on current pressures, and do not yet adequately address future climate related needs.

Additionally, there is an existing flood risk to low lying precincts should high tides coincide with extreme rainfall events. A combination of climatic changes, including more frequent large rainfall events and sea level rise to the upper limits of current projections, mean that low lying precincts may begin to experience flooding of a frequency and severity that is greater than would be regarded acceptable today. Therefore it should be a priority to actively consider climate change projections in the development of low lying precincts including ensuring buildings under construction are equipped to handle future changed climatic conditions.

6.3.2 Potential climate change impacts

- Accelerated ground movement and cracking leading to damage to buildings and property.
- Accelerated degradation of buildings and properties.
- Increased repairs and replacement costs.
- Older buildings not withstanding the extreme weather events due to be being built according to old building code regulations.
- Infrastructure supporting buildings and properties failing – burst pipelines, inundated storm drains, damage to electricity infrastructure.

6.4 Social, health and community

6.4.1 Current system state

The population of the City of Melbourne is relatively healthy but has above average hospital admissions in relation to mental disease and disorder, alcohol and drug use injuries, poisoning, burns, and infectious and parasitic diseases. Hospital emergency facilities are reportedly stressed and at their maximum capacity and mental health services are reportedly beyond their maximum capacity and a pressing concern. There is a growing shortage of residential aged care services with a significant waiting list.

Unless this shortage is addressed, this may lead to growing numbers of aged residents receiving long term care in the home, which can increase the challenges of reaching this vulnerable population in response to a climatic event such as an extreme heatwave.

In contrast to the rest of the state, the City of Melbourne has a young population with approximately 61 per cent of residents aged 15 to 34 years; this is expected to remain as such into the future. However 15 per cent of the City of Melbourne population is aged 55+ and this age group has extensive and more complex health service needs. The City of Melbourne also experiences a large daily visiting population and a large number of events, which result in very large numbers of people congregating and moving through the city. Other key social considerations for the City of Melbourne include:

- large transitional and public housing sector with high needs residents;
- high levels of socio-economic disadvantage in particular pockets of the city;
- homelessness continues to be a pressing issue for the City of Melbourne; and
- continued decline in affordable housing stock as a proportion of all housing in the municipality.

6.0 Urban System Assessment for City of Melbourne

The City of Melbourne regards the quality and availability of open space facilities as good and numerous City of Melbourne policies highlight the important relationship between activity levels and health, particularly for older residents. However these important areas of public realm are under pressure. The impact of prolonged drought and water restrictions on the City of Melbourne iconic trees has been dramatic with significant and widespread stress and weakening among trees. Previous watering practices promoted shallow root development, rendering the now-stressed trees highly vulnerable to wind-throw. Revised watering practices have been implemented, and progressive mass tree replacement is planned.

Sports fields have also been affected by watering restrictions, with organised activity being restricted at a number of sites. The City of Melbourne is investigating solutions such as more drought resistant turf, or even artificial turf to enable ongoing high levels of organised sports.

6.4.2 Potential climate change impacts

- Exacerbated health and social issues due to climate change.
- Increased pressure on emergency services due to injuries as a result of extreme events (flash flooding, extreme wind and heat waves).
- Increased mental stress due to the impacts of extreme events.
- Increased heat deaths – especially in the 55+ population.

6.5 Business and industry

6.5.1 Current system state

In recent years the City of Melbourne has experienced substantial employment growth, with 10.6 per cent growth, or about 35,000 new employees working in the city from 2004 to 2006. This compares to 2 per cent growth from 2002 to 2004.

The City of Melbourne reports very good relationships with their business and industry sectors. The industry profile is dominated by business services, which is the number one industry in both employment numbers and numbers of establishments. Finance and insurance is the number two industry for worker numbers and retail trade is the number two in number of establishments. The finance and insurance sectors in particular are concentrated in the CBD, while Docklands is emerging as a financial precinct outside of the central city; it is now home to the headquarters of the National Australia Bank, Medibank Private, and in future the ANZ Bank.

From 2002 to 2006 the City of Melbourne experienced the most employment growth in the finance, business services, education, public administration, and arts and recreation sectors. With such significant growth in the finance and business services industries (see Figure 4), and a clear concentration of office space in the CBD, the growth in daily population in the City of Melbourne would be expected to be particularly concentrated in the CBD.

6.5.2 Potential climate change impacts

- Cancellation of events and festivals.
- Lost budget and resource allocation for planned activities.
- Increased repair and maintenance costs.
- Insurance payouts and liability costs.
- Increased unemployment.
- Business interruption and productivity loss – economic impacts.

6.6 Energy and telecommunications

6.6.1 Current system state

The electricity network serving the City of Melbourne is at maximum capacity. This means that there is a high level of "network efficiency", one of the key performance measures for Citipower for provide electricity distribution infrastructure. At present, the City of Melbourne has the second lowest security of electricity supply in Victoria. There are major infrastructure upgrades planned to address this security concern, including:

- Upgrading the CBD network from N-1 to N-1 Secure. With this upgrade in place the CBD should only experience power outages for a maximum of 30 mins. This upgrade is expected to be completed by 2012 (Citipower, 2007).
- The development of a new terminal substation in Brunswick. This additional substation will mean that 4 substations serve the CBD. Failures would be need to occur on three of the substations (or transmission lines leading to the substations) in order for a widespread blackout of the CBD. Completion of this new substation is expected by 2012.

This additional flexibility is expected to significantly mitigate the risk of widespread blackout. With these upgrades in place, likely causes of failure would be shifted to the transmission system, such as rural bushfires. However the additional system flexibility would mean that widespread blackout would require a "double order contingency" that is simultaneous failure of two major transmission lines serving Melbourne.

In 2003, a little over 50 per cent of Victorian households owned one or more air conditioners, and this figure is projected to rise approximately 70 per cent by around 2018 (National Appliance and Energy Efficiency Committee, 2004). While definite figures were not provided by participating stakeholders, the CBD is reportedly closer to saturation level in air-conditioning overall than greater Melbourne or Victoria. Rising energy demand in the city of Melbourne is therefore expected to be on a steady trajectory, with few sudden increases. However, there is the exception of localised demand peaks as older areas of housing are updated and rapidly introduce air conditioning.

6.0 Urban System Assessment for City of Melbourne

Electricity demand grows over a number of hot days, as buildings begin to retain heat. The worst electricity peaks normally occur after 2-3 days of extreme heat. It has also been observed that 2 of the last 3 summer peaks have occurred in March, when hot conditions with additional humidity strain air conditioning performance.

In situations of blackout, load shedding priorities have been clearly outlined by the Victorian Demand Reduction Committee, chaired by VENCorp. The load shedding principles are:

1) Ensure the health and safety of people.
2) Minimise social impacts on the community.
3) Minimise economic impacts on the community.
4) Maintain equity by 'sharing the pain' between customers within a particular class (for example, rotational load-shedding between residential areas).
5) Maintain equity by 'sharing the pain' between electricity businesses.

With these principles, locations like hospitals, aged care facilities, major intersections and public transport hubs are the last to lose power. Seriously ill individuals have their own emergency plans in place with their electricity retailer Three major hospitals in or near the City of Melbourne have co-generated power; the Royal Alfred, St Vincent and Royal Melbourne Hospital.

Other hospitals rely on diesel generated backup, and reportedly have a 12 hour supply. It is important to note that the last major power failure in Victoria (16 January 2007) resulted in loss of supply to 480,000 Victorian customers for a period of 4 and a half hours. During this period, four hospitals experienced problems with back-up supply, and patient transfer was underway from one hospital when power was restored (Department of Homeland Security and Maunsell, 2007). There were multiple other impacts, notably to train services and major intersections.

The key radio broadcasting communication channel in the event of a loss of power is 774AM. CitiPower liaise directly with this radio station in the event of power failure. This mode of communication is dependent on community knowledge of this channel, and availability of battery powered radio.

6.6.2 Potential climate change impacts

- Electricity infrastructure damaged due to increased extreme weather events.
- Blackouts due to damaged infrastructure or excessive demand.
- Increased risk for bushfires.
- Increased material deterioration.
- Ground movement and cracking due to reduced rainfall and heat waves.

6.0 Urban System Assessment for City of Melbourne

6.7 Emergency services

6.7.1 Current system state

The emergency plan for the City of Melbourne is positively regarded by the City of Melbourne stakeholders. The City of Melbourne has a good track record with emergency response and there have been no events that have spiralled out of control. The City of Melbourne reports good relationships with fire, police and ambulance services, but also cautions that the emergency response strategies do not always factor in high volumes of people.

Consultation with emergency service representatives suggested that there are no official communications among the emergency services with the onset of particular climatic conditions. The ambulance service indicated that informal local communication takes place regarding the expectation of increased call-outs for heat stress. The ambulance services report that response delays from traffic congestion is a major issue since "minutes mean lives". The CBD of Melbourne has known advantage for movement of emergency vehicles because of the presence of tram lines. However, traffic does not always keep the lines adequately clear. The CBD also has the advantage of a substantial network of cameras which could be used to assist in an extreme event.

Volunteer services that typically respond to emergencies such as the State Emergency Service (SES) report growing pressure on their services due to increasing frequency and severity of weather related emergencies. Volunteers tend to provide assistance "until they drop" and this places them under significant personal strain. This is of concern as "people are the first resource to run out in an emergency" (SES). An additional challenge can be accommodating large numbers of volunteers. During the July 2007 flood, volunteers were accommodated in high cost hotels due to heavy bookings across the city.

Victoria Police report they are beginning to consider the operational impacts of climate change, particularly severe heat and blackout. A loss of lighting and alarms in blackouts leads to security concerns and there is an acknowledged link between severe heat and violent behaviour.

6.7.2 Potential climate change impacts

- Stressed emergency services.
- Climate change induced increased public disorder will lead to pressure on police force.
- Public transport systems failures will cause the emergency services to become increasingly stressed.

7.0 Climate Change Risk Management for City of Melbourne

7.1 What is adaptation?

'Adaptation' encompasses measures that are taken in response to the actual or expected changes in climate, to negate or mitigate their impact. These measures reduce the vulnerability of the local natural or human systems to the effects of climate change, by increasing the system's resilience to it. Adaptation response measures generally have four categories:

1. Loss prevention – actions to reduce vulnerability to climate change.
2. Loss sharing – spreading the risk of loss among a wider population (for example, insurance).
3. Behaviour modification – eliminating the activity or behaviour that causes the hazard.
4. Relocation – moving vulnerable population or systems away from hazards induced by climate change.

7.2Responding to climate change risks

Risk management is about avoiding unacceptable circumstances and outcomes (Pittock, 2005).There are two broad response strategies open to business and society in the climate change context:

1. Mitigation; and
2. Adaptation.

By reducing greenhouse gas emissions, mitigation strategies aim to reduce the potential extent of climate change or reduce the probability of reaching a certain level of climate change. Adaptation strategies aim to cushion, neutralise, adjust to or avoid the impacts of climate change. They can be technological (such as desalination), behavioural (such as consumption choices), managerial (such as maintenance practices) or policy (such as planning regulations). Such strategies might include building coastal retainer walls, improving urban drainage, increasing public awareness or halting inappropriate development. These strategies allow 'larger levels of climate change to be acceptable' but aim to 'reduce the adverse consequences' and increase any positive consequences (Pittock, 2005).

The City of Melbourne wishes to take a leadership position in responding to climate change by acting as a prudent steward for the municipality, ensuring an active duty of care by the City of Melbourne, shared awareness of the risks among stakeholders and actions for addressing them. As such, this risk assessment reviews the collective risks of climate change to the City of Melbourne municipality for now, in 2030 and in 2070.

7.0 Climate Change Risk Management for City of Melbourne

Risks have been categorised as either 'Council', 'municipal' or 'both Council and municipal'. Municipal risks are the responsibility of the relevant stakeholder or stakeholders but ideally will work together with the City of Melbourne in addressing the findings of this assessment.

All risks are given a combined rating out of 10 that reflects their likelihood of occurrence (for now, in 2030 and in 2070) and the consequence of their occurrence. Ratings are based on the current scientific consensus and expected changing dynamics of the City of Melbourne. Risks rated as a 7 or higher are considered 'critical' and therefore a priority for review and response. All critical risks are detailed in Section 8.0.

An assessment of the effectiveness of the current known control measures in place to address the risks, either at Council or municipal level, is also provided. These control measure ratings reflect a business-as-usual progression and do not take into account any adaptation measures or increased controls that may be implemented in the future.

Undertaking adaptation measures that build resilience for the City of Melbourne to climate change will change the future profile of the City of Melbourne risks addressed and ideally shift the risk to a tolerable level, rather than critical. Therefore a subsequent risk rating assessment based on agreed adaptation measures will ensure currency of priorities for concern and action.

7.3 City of Melbourne risk management framework

7.3.1 The City of Melbourne risk management framework matrix

The City of Melbourne has developed descriptors and categorisations for likelihood and consequence ratings which are listed in Appendix D. The City of Melbourne corporate risk framework uses a '5+5' combined risk rating index (consequence + likelihood). In order to effectively manage these risks it is recommended that their combined risk rating is plotted against a 1 to 5 rating of their control effectiveness. The risk matrix in Figure 7 is used to plot the risk according to their risk rating and control effectiveness, the risk management priority is then determined in line with the matrix quadrant they sit in.

Risk management categories are:

No major concern – Combined risk rating of 6 or less and control measure rating of 1 to 2

Periodic monitoring – Combined risk rating of 6 or less and control measure rating of 3 to 5

Control critical – Combined risk rating of 7 to 10 and control measure rating of 1 to 2

Active management – Combined risk rating of 7 to 10 and control measure rating of 3 to 5

7.0 Climate Change Risk Management for City of Melbourne

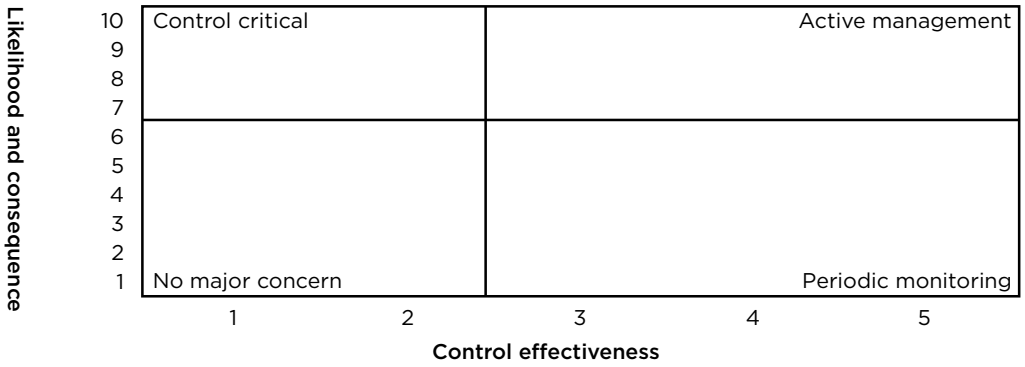

Figure 7: Risk rating framework and thresholds (adapted from the Melbourne Water Risk Framework Matrix 2007)

Risks sitting in the following quadrants:

- *No major concern* – risks in this quadrant are generally of no concern and management consists of periodic re-evaluation, including underpinning assumptions, to ensure conditions are the same.
- *Periodic monitoring* – risks in this quadrant are generally unable to have control measures that can suitably minimise the risk, and are therefore monitored accordingly to ensure organisational awareness and preparedness.
- *Control critical* - risks in this quadrant are considered of enough likelihood and consequence to be a concern however have a control measure that is considered effective and vital to their appropriate mitigation.
- *Active management*- risks in this quadrant should be of the highest priority to all concerned. These risks are of sufficient likelihood and consequence to be above the risk threshold and have unacceptable level of control.

For the 'active management' category, risk control measures should be reviewed and refined, with the goal of increasing effectiveness to move the risk to 'control critical' if possible. It is important to remember however that not all risks can be controlled and some may need to remain in this quadrant. For those risks that do remain in 'active management' they should be actively monitored, assessed, prepared for and contextual conditions well understood.

It is only in understanding and refining risk control measures that a risk profile can be effectively managed.

7.3.2 Risk Assessment Timeframes

The risks have been assessed at three different points in time. These are considered to be short term/now (in the next two to three years), medium term (by 2030) and long term (by 2070). This helps to analyse any potential changes to the level of risk to the municipality over time.

8.0 Climate change risks for City of Melbourne

Integrated risk assessment is critical to developing a comprehensive understanding of the impacts and implications of climate change in a local setting. Integrated assessment also helps identify priorities for action and the causal relationships and interconnectivities of impacts and adaptation responses.

This assessment considered four main climatic events for which Melbourne should ideally prepare:

1. drought and reduced rainfall;
2. heatwave and bushfires;
3. intense rainfall and storm event; and
4. sea level rise.

This approach represents a somewhat simplified consideration of climate change risks, as it does not directly account for the affects of long term smaller changes in climatic conditions (such as overall temperature rise), or more frequent occurrences of smaller events. However this should not be considered a weakness in the risk assessment approach, rather as a means of distilling and organising key risks.

Adapting effectively to the larger scale climatic extremes also means that smaller, more progressive changes and events should also be better controlled in routine management.

The four events considered in this assessment encapsulate the implications of the climatic changes that are most relevant to the City of Melbourne.

Two of the events, *Heatwave and bushfires* and *Intense rainfall and storm events*, can be sudden and severe in onset and the City of Melbourne is known to have existing vulnerability in both of these events. *Drought and reduced rainfall* and *Sea level rise* are relatively gradual in onset, though Melbourne is clearly already dealing with the impacts of drought. Adapting to all of these scenarios requires a range of short and long term measures, from improved communication and warning systems, to fundamental changes in planning and infrastructure.

Consideration of major events allows for systems thinking to be applied, which assists in identifying risks that are particular to the characteristics and sensitivities of the City of Melbourne and that occur as a result of the interdependence and interaction of different functions of the City of Melbourne. This is illustrated through the use of *cascading consequence* diagrams, which map the cascading nature of implications from a single climatic event or variable. This visual representation of climatic events helps to identify parts of the system where efforts and resources for adaptation can be most effectively applied to control or even avoid the risks. This is critical given the twin challenges of competition for resources and that climate change implications that are broad and far-reaching.

8.0 Climate change risks for City of Melbourne

8.1 Drought and reduced rainfall

This scenario refers to a continuation and worsening of recent water supply conditions in the City of Melbourne.

Melbourne has recently experienced 11 years of below average rainfall, with supply reservoirs consistently reaching levels of approximately 30 per cent capacity. This reduced urban water supply has resulted in the imposition of water restrictions and system augmentation through major water supply infrastructure projects and significant water saving measures by government, industry and the community.

As indicated by the cascading consequences map, the highest value adaptation measures for a drought and reduced rainfall scenario are those that can secure alternative water supplies or exploit water use efficiency opportunities, thereby negating the flow-on implications of water security.

8.1.1 The City of Melbourne risks identified and assessed

Risk number	Risk title and rating	Now	2030	2070
W1	Insufficient urban water supply	**8**	**7**	**7**
W2	Impacts to biodiversity in upstream waterways due to insufficient environmental flows resulting from reduction in water availability	**7**	**8**	**8**
W3	Increased injuries due to activities on hard sporting grounds	**7**	**7**	**7**
W4	Increase in health problems related to declining water quality	6	6	6
W5	Loss of social cohesion due to inability to fully utilise sports grounds because of declining quality due to lack of water	5	**7**	**8**
W6	Increased issues of social inequity and public conflict resulting from prolonged water restrictions, causing incidents of water theft and restrictions infringement	5	6	6
W7	Loss of revenue due to the forced suspension of sports and events due to inadequate irrigation	5	6	6
W8	Reduced public amenity on waterways due to insufficient environmental flows resulting from reduction in water availability	5	5	5
W9	Loss of public amenity due to decreasing quality of public gardens	5	5	5
W10	Increased liability costs due to declining quality of water leading to public health issues	5	5	5
W11	Declining public health due to inability to access and fully utilise sports grounds because of restricted / suspended activities due to inadequate watering	4	4	4
W12	Future liability and reputation damage relating to the construction of dwellings unsuited to projected climatic conditions, specifically resilience to low urban water supplies	3	6	6

Table 1: Drought and reduced rainfall risks and ratings

8.0 Climate change risks for City of Melbourne

8.1.2 Cascading consequences

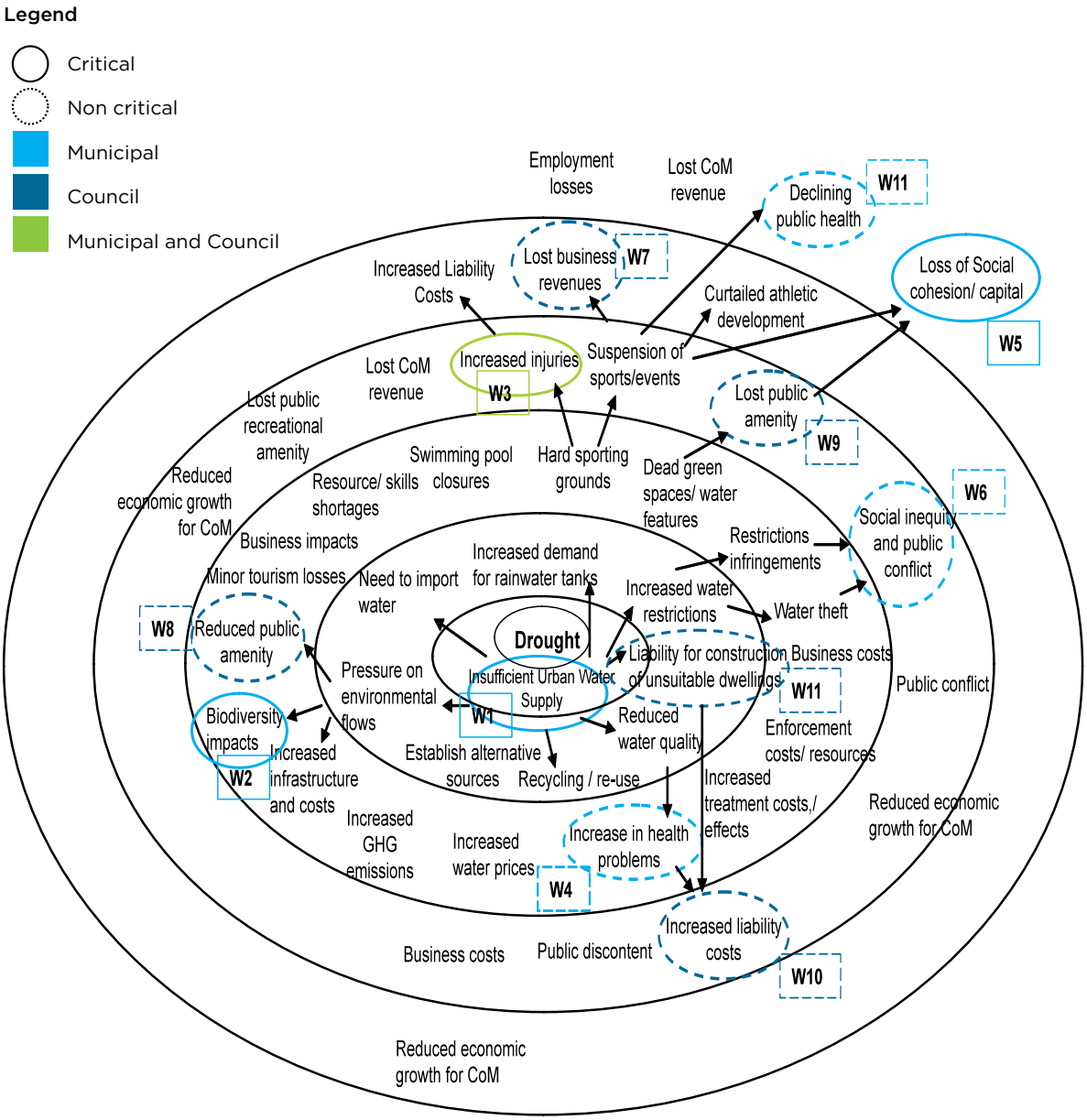

Figure 8: Cascading consequences for drought and reduced rainfall

8.0 Climate change risks for City of Melbourne

8.1.3 The City of Melbourne and municipal risk ratings

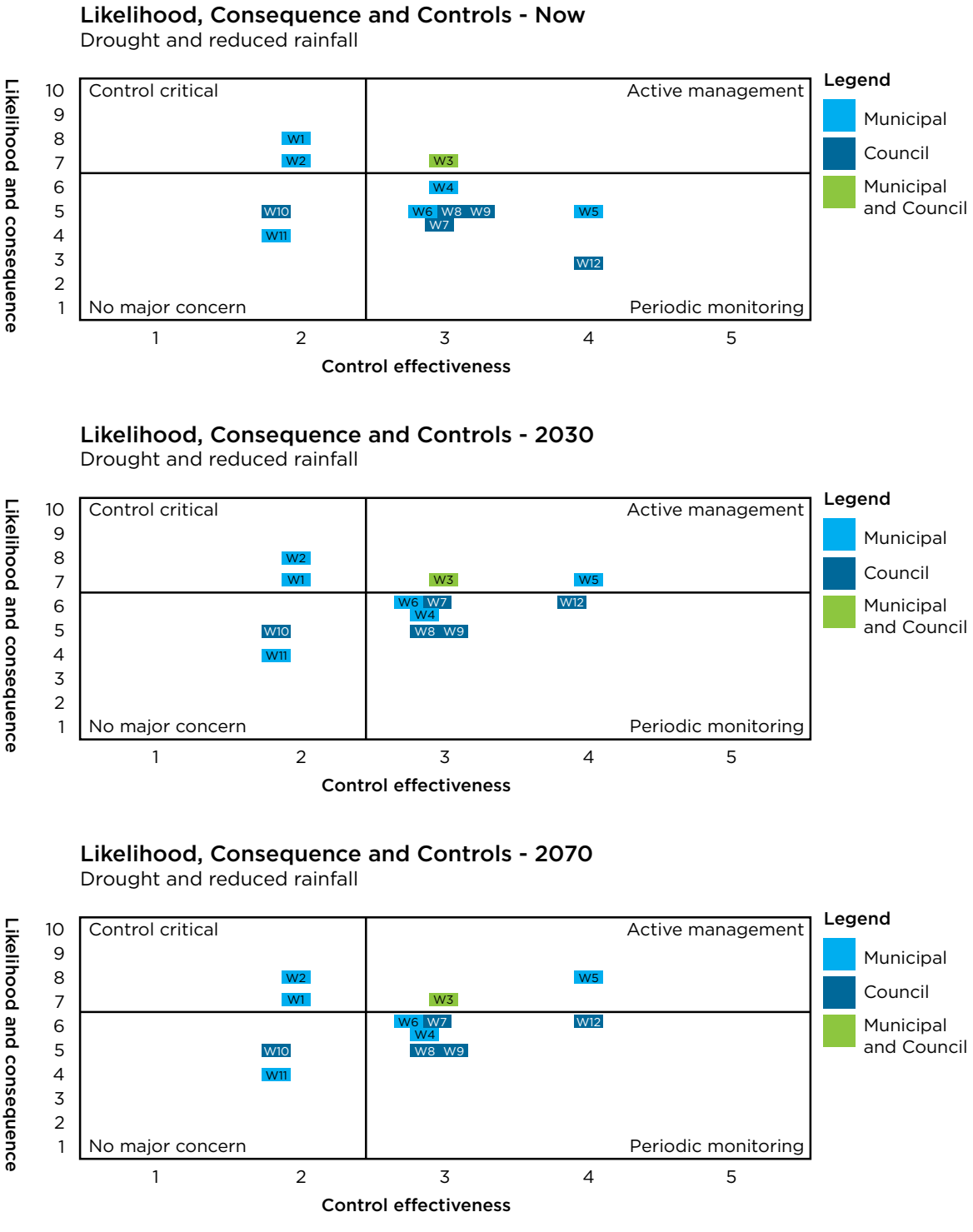

Figure 9: Cascading consequences for drought and reduced rainfall

8.0 Climate change risks for City of Melbourne

8.1.4 The City of Melbourne critical risks of drought and reduced rainfall

The critical risks identified for extreme drought and reduced rainfall for the City of Melbourne are:

- insufficient urban water supply;
- biodiversity impacts in stressed waterways;
- injury due to hard sporting grounds; and
- loss of social cohesion due to inability to fully utilise sporting grounds in drought period.

These risks have a combined likelihood and consequence rating of 7 or above. Their control effectiveness rating determines if they are categorised as 'control critical' (less than 3), or in 'active management' (3 or above).

8.1.4.1 Insufficient urban water supply (W1 – municipal – active management)

Greater Melbourne has experienced 11 years of below average rainfall that has placed pressure on water supplies. The City of Melbourne's population is also growing quickly; it is expected to grow by 120 per cent by 2020.

At current rates of growth Melbourne will become Australia's largest city by 2030. Should very low rainfall conditions continue in the short to medium term, there is a risk of Melbourne experiencing serious water shortages from its centralised mains water supply.

Key findings:

- Water shortage is a serious risk which the City of Melbourne has been actively managing since 2002.
- Water conservation efforts are progressing well as shown on the next page:

8.0 Climate change risks for City of Melbourne

Water saving targets				
Base year	**Existing targets established in *Total Watermark 2004***	**Progress**	**Comments**	**Proposed revised targets**
99/00	40% reduction in potable water consumption *per employee* in the municipality by 2020	48% reduction per employee. Water use down from 181 litres/ person/day to 95 l/p/d (target is 109 l/p/d). 38% reduction in total commercial water use from 18,243 ML/yr to 11,430 ML/yr. The target is 13,327 ML/yr factoring employee growth.	Remarkable progress by the commercial sector and well exceeding target already. Recommended revised target of 50% reduction per employee (91 l/p/d) The revised total commercial water consumption target is 11,127 ML/yr factoring employee growth (from 323,000 in 99/00 to 335,000 in 2020).	50% reduction in potable water consumption *per employee* by 2020.
99/00	40% reduction in potable water consumption *per resident* by 2020	39% reduction per resident. Water use down from 296 l/p/d to 179 l/p/d (target is 178 l/p/d). To date, 21% reduction in total residential water use from 5541 ML/yr to 4399 ML/yr. The target is 7461 ML/yr factoring residential growth.	Great progress by residents. Much of the savings due to water restrictions – water use likely to increase once these restrictions are lifted. In light of this, it is considered appropriate to retain 40% water saving target per resident. Refined resident population forecast of 120% increase (not 141% used in Total Watermark 2004) gives revised residential water consumption target of 7419 ML/yr.	40% reduction in potable water consumption *per resident* by 2020
99/00	40% reduction in potable water consumption *by the City of Melbourne* by 2020	29% reduction in City of Melbourne use. Water use down from 1,686 megalitres per year to 1,197 ML/yr. The target is 1012 ML/yr.	Very good progress by the City of Melbourne. The organisation will continue to reduce demand to meet water saving targets, and is also committing to increased alternative water sourcing which will help achieve the target	40% reduction in potable water consumption *by the City of Melbourne* by 2020
99/00	12% 'absolute' water saving target by 2020	Currently 34% absolute saving.	Absolute saving already exceeds the target and challenge remains to keep an absolute saving while the population grows by 120% With the above increase in commercial water saving, along with a revised population the expected absolute water saving will nearly double to 22%	22% 'absolute' water saving target by 2020

Table 6: Water saving targets

8.0 Climate change risks for City of Melbourne

The City of Melbourne has developed its *Total Watermark -City as a Catchment* strategy that responds to climate change by seeking to reduce reliance on centralised mains water supply and instead look for local water sources including rainwater and stormwater harvesting and water recycling.

Efforts to seek alternative water sources have also commenced as shown below:

Alternative water use targets				
Base year	**Existing targets**	**Progress**	**Comments**	**Proposed new targets**
N/A	None in place	Total amount of alternative water sourced by the City of Melbourne is 4% or 74 megalitres	Alternative water sourcing commenced in 2007 for the City of Melbourne with the operation of the Royal Park wetlands and the use of watering trees by trucks and bollards with recycled water.	City of Melbourne to source 30% or 480 megalitres of its water needs from alternative water sources by 2020
N/A	None in place	Total amount of alternative water sourced by non-City of Melbourne land managers is 1% or 238 megalitres	Alternative water sourcing has commenced. This is the best data available to date.	Non-City of Melbourne land managers to source 9% or 2800 megalitres of its water needs from alternative water sources by 2020.

Table 7: Alternative water use targets

The State Government is also seeking ways to increase the security of supply for its centralised mains water supply system (refer 'changes over time' below).

Likelihood: (Now: Possible – 3 / 2030: Unlikely – 2 / 2070: Unlikely – 2)

Rainfall is projected to continuously decrease and with growing population the pressures on water supply will increase.

Over time the likelihood of this risk should reduce somewhat as alternative water sources become available such as the desalination plant (and possibly grey water and stormwater harvesting – although this uncertain so has not been included as a control that reduces future likelihood).

8.0 Climate change risks for City of Melbourne

Consequence: (Catastrophic - 5)

The catastrophic consequences of Melbourne running out of urban water supply are what hold this risk rating in the 'active management' category. A future with multiple urban water sources would in theory reduce the consequence by ensuring alternative supply, however, this assessment has considered future alternative supplies together with 'urban water supply'. This means alternative supplies can reduce the likelihood of the risk occurring, and reduce the combined rating accordingly, while not reducing the underlying severity of the risk.

Current control measures: (2)

- Daily reservoir monitoring by Melbourne Water which are published in Weekly Water Update which is also available from the Melbourne Water website.
- Stage 3a water restrictions are in place in Melbourne to limit outdoor water use.
- Application of national Water Efficiency Labelling Scheme (WELS) as a mandatory water efficiency labelling system and minimum performance standards for household water-using products across all of Australia.
- Parks water management seeking alternative water sources, increased mulching, changed irrigation practices and changed planting regimes.
- Business water efficiency in fittings, appliances, cooling towers, fire sprinkler testing.
- Communication, education and behaviour change programs to prevent water wastage.

Changes over time:

Melbourne is expected to have an operational desalination plant online by 2011 which will provide an additional 150GL of water per year (can potentially be increased to 200GL/yr in the future). The North South pipeline from regional Victoria will bring water gained from reducing evaporation in the irrigation system will provide 75 GL/yr by 2010, upgrading the Eastern Treatment Plant will provide over 100GL/yr, along with continuation of new and existing water conservation programs.

Local stormwater harvesting potential to be increased as proposed in City of Melbourne's *Total Watermark – City as a Catchment* strategy.

These alternative water sources could collectively reduce the likelihood and consequence rating of this risk. However, the success of these alternative water sources needs to be considered against a backdrop of further projected decreases in rainfall as outlined in section 4.4.

8.0 Climate change risks for City of Melbourne

Stakeholders:

Melbourne Water, City West Water, South East Water, DSE, major water users.

Success criteria / performance management:

- Development of a diverse range of water supply sources for the City of Melbourne starting with localised options of rainwater and stormwater harvesting, grey water recycling and lessening the dependence on rainfall-fed mains water supply.
- Efficient use of water supply ensuring water usage is appropriate for its purpose

8.1.4.2 Biodiversity impacts in stressed waterways (W2 – municipal – control critical)

The Yarra and Maribyrnong Rivers feature in the City of Melbourne district and broadly define the western and southern boundaries. These waterways feed into Port Phillip Bay at Port Melbourne.

The consistent below average rainfall experienced in Melbourne over the past 11 years, with only 40 per cent of average rainfall in 2007, has put significant strains on Melbourne's rivers. Low flow conditions as a result of reduced water availability act as an environmental stressor causing biodiversity impacts. Several drains in the lower reaches of the Yarra have high bacterial readings during dry weather, having adverse effects on water quality.

Deaths of large numbers of fish also occur during periods of low flow. The lower reaches of the Yarra are already subject to poor water quality and this is likely to be exacerbated with projections of further reduced rainfall over time.

Key findings:

- The most recent river health reports from Melbourne Water show that 25 per cent of Melbourne's rivers and streams are in good condition, 30 per cent are in moderate condition and 45 per cent are in poor to very poor condition.
- Deaths of large numbers of fish are reported in Victorian waterways from time to time. The cause of the deaths often relates to environmental stresses such as low flow conditions, elevated water temperatures, or on occasions pollution. As drought conditions will provide additional environmental stress, it is likely that more fish death events will be reported.
- In October 2006, the *Yarra Environmental Entitlement (2006)* was granted to provide the Yarra River with 10GL of environmental flow. On April 2007, the introduction of these new environmental flows was deferred until Melbourne returns to stage 1 water restrictions (Melbourne Water, 2007). The government and water authorities are working to release supplementary environmental flows (for example, through the Regional River Health Strategy).

8.0 Climate change risks for City of Melbourne

- The Yarra River is home to a number of native animals, such as frogs, platypus and fish, including many endangered species such as the growling grass frog, and fish such as grayling, Macquarie perch and Murray cod.
- Generally the water quality in water ways declines in summer months and following rainfall events. The concentration of pollutants is higher during the summer months as illegal sewer connections to stormwater continue to outfall when water levels are dropping. Stormwater is the biggest pollutant to the river system; following storm events the Yarra River reaches its highest pollution levels.
- Phosphorus levels in the lower Yarra River have remained constant and nitrogen levels have increased slightly due to urban growth.

Likelihood: (Now: Likely – 4 / 2030: Almost certain – 5 / 2070: Almost certain – 5)

An adverse impact on biodiversity as a result of reduced rainfall is already happening in the lower reaches of the Yarra River. With projections of continued reduced rainfall and increasing population pressures on water supply this risk is almost certain to occur beyond 2030 if no adaptation measures are undertaken.

Consequence: (Environment - Moderate - 3)

The Yarra River is home to some endangered native species. Additional environmental stresses from reduced flows could drive them to extinction (Yarra River Action Plan, 2006). Deteriorating water quality as a result of reduced flows could have impacts on human health as many people use the Yarra River for recreation.

Current control measures: (2)

- Environment Protection Authority (EPA) Victoria monitoring regime
- State Government projects to protect the health of the Yarra River include:
  - works in the Yarra catchment to improve waterway and stormwater quality;
  - maintenance and upgrade of the sewerage system; and
  - water quality programs.
- Development and implementation of the Yarra Action Plan, initiatives include:
  - $930,000 set aside to improve monitoring and communicating the health of the river. This involves a three year investigation program involving testing at 52 locations along the Yarra River and its tributaries to track down likely sources of faecal pollution.

8.0 Climate change risks for City of Melbourne

- Weekly water quality sampling of E-Coli at 12 sites on the Yarra River from Docklands to Warburton is undertaken by Melbourne Water's Yarra Watch Program.
- Melbourne Water monitoring regime, monitors water quality monthly at 33 sites along the Yarra and its tributaries.

- The City of Melbourne is at the 'bottom of the catchment' and home to only the final reaches of the Yarra River, Maribyrnong River and Moonee Ponds Creek. Whilst flows in these lower reaches are not of such environmental significance, it is important for the City of Melbourne to help manage this risk as it relates to the upstream parts of the waterways. This includes efforts by the City of Melbourne in:
  - undertaking riverine habitat protection initiatives; and
  - reducing water demand to help reduce load on mains water supply and therefore help make more water available for environmental flows.
- Waterway health and aquatic diversity from stressed waterways is also managed to deal with adverse water quality impacts from more intense rainfall and wind events.

Changes over time:

- Alternative water supplies can take some time to implement, therefore providing sufficient environmental flows to maintain waterway health in the meantime is vital.
- Notwithstanding other pressures on waterway biodiversity, increasing flows will reduce the likelihood of impacts to biodiversity due to stressed waterway conditions. Increasing environmental flows would reduce the likelihood rating, which, with a continued diligent monitoring regime, could reduce the risk rating to 'no major concern'.

Stakeholders:

Melbourne Water, EPA Victoria, Department of Sustainability and Environment (DSE)

Success criteria / performance management:

- Healthy river systems with thriving biodiversity.
- Water quality and levels above stressed state thresholds.

8.0 Climate change risks for City of Melbourne

8.1.4.3 Injury due to hard sporting grounds (W3 – municipal and council – active management)

Stage 3a water restrictions limits watering of sporting grounds using mains water to only one in four grounds. Many sporting grounds rely on rainfall or irrigation for watering. During summer months, without watering, many grounds lose their grass cover and become very hard. Informal grounds in gardens are also often used for recreational sports. There has already been a noticeable impact of the drought on recreational players with an increase in the number of traumatic injuries due to falling on hard surfaces (University of Melbourne, 2007).

Key findings:

- Average water use by councils across Victoria is 11.75GL per annum to maintain sports facilities (GHD, July 2007). The City of Melbourne uses 82 per cent of its annual water use for landscape management in parks and gardens.
- The City of Melbourne is already planting drought tolerant grasses and investigating artificial turf.

Likelihood: (Now: Likely – 4 / 2030: Likely -4 / 2070: Likely – 4)

There has been a documented increase in injuries due to harder sporting surfaces. With projections of further rainfall reductions this risk is likely to become more common. Without any adaptation this risk will increase in likelihood post 2030.

Consequence: (Minor to Moderate – 2 to 3)

The type of injuries likely to be sustained range from very severe (such as head and spinal injuries) to more moderate injuries (such as sprains and fractures).

Current control measures:(3)

- Use of reclaimed stormwater for irrigation such as in Trin Warren Tam-boore and the Royal Park North Wetlands (383 million litres of water are treated per annum and these parks have a 15 million litre storage capacity. The water is being used for nearby sports fields, Royal Park Golf Course and tree watering (City of Melbourne, 2008b-b).
- Grass replacement to drought tolerant species.
- Restrictions on playing sports on hard sporting grounds.
- Turf surfaces are expected to be able to grown and maintained successfully with lower quality water.
- Installed underground drippers in playing fields.

Changes over time:

- Alternative sporting surfaces, such as astroturf, can take some time to be installed.
- The City of Melbourne has a number of existing and proposed initiatives to secure alternative water sources.

Given rainfall projections, this risk remains likely to 2030 and 2070. Widespread implementation of alternative water sources could move this risk to regular monitoring by 2030.

Stakeholders:

Sporting clubs, grounds managers, insurance companies, City of Melbourne grounds managers, VicHealth, Department of Human Services, Department of Planning and Community Development, Melbourne Water, City West Water, South East Water.

Success criteria / performance management:

- Active use of sporting grounds throughout summer and winter seasons while maintaining health of sporting grounds and minimising ground related injuries.

8.1.4.4 Loss of social cohesion due to inability to fully utilise sporting grounds in drought period (W5 – municipal – active management)

Melbourne is an active city with formal and informal sporting recreation. Extended periods of restricted use of sports fields could cause a loss of social cohesion and connectivity in Melbourne and reduce the community's enjoyment of the public realm.

Key findings:

Throughout Victoria, sporting activities have been suspended because of drought conditions. For instance, in the City of Casey, all pre-season winter training was suspended to ensure the sporting grounds were in a usable state upon season commencement.

Likelihood: (Now: Possible – 3 / 2030: Likely – 4 / 2070: Almost certain –5)

Based on current rainfall projections and control measures, a loss of social cohesion due to restricted sports use is possible and eventually likely. It's almost certain that use of sporting grounds will be restricted at times. The duration and extent of these restrictions will be directly relative to the impact on social cohesion.

Consequence: (Reputational – Minor to moderate – 2-3)

As the use of sporting grounds becomes more restricted, alternative sporting facilities and activities will be sought. It is anticipated that these alternatives will alleviate the consequence of this risk over time.

8.0 Climate change risks for City of Melbourne

Current control measures: (3)

- Recycled water purchased by the City of Melbourne. Use of reclaimed water such as at Royal Park Wetland.
- Grass replacement to drought tolerant species.
- Astroturf surfaces.
- Managed and limited irrigation at certain sport grounds.

Changes over time:

More resilience of sporting grounds to drought, through adaptation measures will reduce the likelihood of social cohesion being affected by usage restrictions. If these adaptation measures meant control measures were also improved, this risk could shift from 'active management' to 'no major concern'.

Changes to the use of sporting grounds by the sporting groups themselves, perhaps due to them finding alternatives or athletes changing to other sports, will likely reduce the importance of sporting grounds to social cohesion.

Stakeholders:

Sporting clubs, grounds managers, the City of Melbourne grounds managers, City of Melbourne Parks and Recreation branch, City West Water

Success criteria / performance management:

- Active use of sporting grounds throughout summer and winter seasons by organised sports clubs.

8.2 Intense rainfall and wind event

This scenario envisages the onset of a very severe wind and rainstorm event on the City of Melbourne at a key time, such as a Friday afternoon/evening peak period, with an additional overlay of major events in the CBD, such as a major football match and concert. Such events most commonly occur in Melbourne during spring and summer (September to March) and are of some concern given that within the City of Melbourne, flash-flooding hotspots data is now 20 years old. While average rainfall is expected to decrease, the frequency of intense rainfall events is expected to increase. New rainfall patterns and extreme event scenarios are likely to increase the extent of flooding but are unlikely to create new flooding hotspots altogether.

Intense rainfall can cause severe flooding in and around Melbourne's CBD which can cause trains to stop operating from major stations such as Flinders Street and Richmond Station potentially stranding many thousands of people, who begin walking to seek alternative transport. In the poor conditions, with higher than normal foot traffic, there are several serious accidents involving pedestrians.

8.0 Climate change risks for City of Melbourne

High winds result in falling branches, trees and other wind-blown debris, which contribute to injuries, traffic congestion, and further flooding by blocking drains. The torrential rain causes spillage at several sewerage emergency overflows, resulting in a disease exposure risk in several locations in the City of Melbourne. Emergency services are stretched in responding to accidents and clean-up incidents, and are hindered by severe traffic congestion.

Extreme rainfall events combined with future sea level rise or storm surge could worsen flooding.

In an intense rainfall and wind scenario, the highest value adaptation measures are those that can reduce the risk of direct negative impacts of these events, such as flooding and wind damage by reducing inundation and increasing resilience.

8.2.1The City of Melbourne risks identified and assessed

Risk number	Risk title and rating	Now	2030	2070
RW1	Mass stranding of people due to public transport stoppages, as a result of flooding or storm damage.	**8**	**9**	**9**
RW2	Adverse health outcomes due to emergency services being hindered by storm and flood impacts, such as flooded roads, traffic delays, and other blockages.	**8**	**8**	**8**
RW3	Increased potential for injuries or deaths occurring as a result of flash flooding.	**7**	**9**	**10**
RW4	Increased reparation costs following intense rainfall and wind events, including damaged buildings, damaged or collapsed roads, damage to river banks and associated infrastructure, general clean up.	**7**	**8**	**9**
RW5	Business closure and job loss due to business interruption from storm damage and flooding.	**7**	**8**	**8**
RW6	Increased potential for injury, death, damage or delays resulting from damage to or falling of trees.	**7**	6	6
RW7	Lost tourism following storms or intense rainfall events.	6	**7**	**7**
RW8	Burst water supply pipes.	6	5	5
RW9	Increased potential human health risk as a result of sewer inundation.	5	6	6
RW10	Cleanup costs and disruptions from cars damaged/stranded by flash flooding.	5	6	6
RW11	Increased frequency and severity of public health risk from waterways. This is due to increased toxin concentrations entering waterways following intense rainfall events and reduced access for amenity purposes.	5	5	4
RW12	Public discontent due to reduced access to rivers and river banks for amenity and bike/pedestrian commuting purposes following intense rainfall events.	4	4	**4**

Table 8: Intense rainfall and wind event risks and ratings

8.0 Climate change risks for City of Melbourne

8.2.2 Cascading consequences

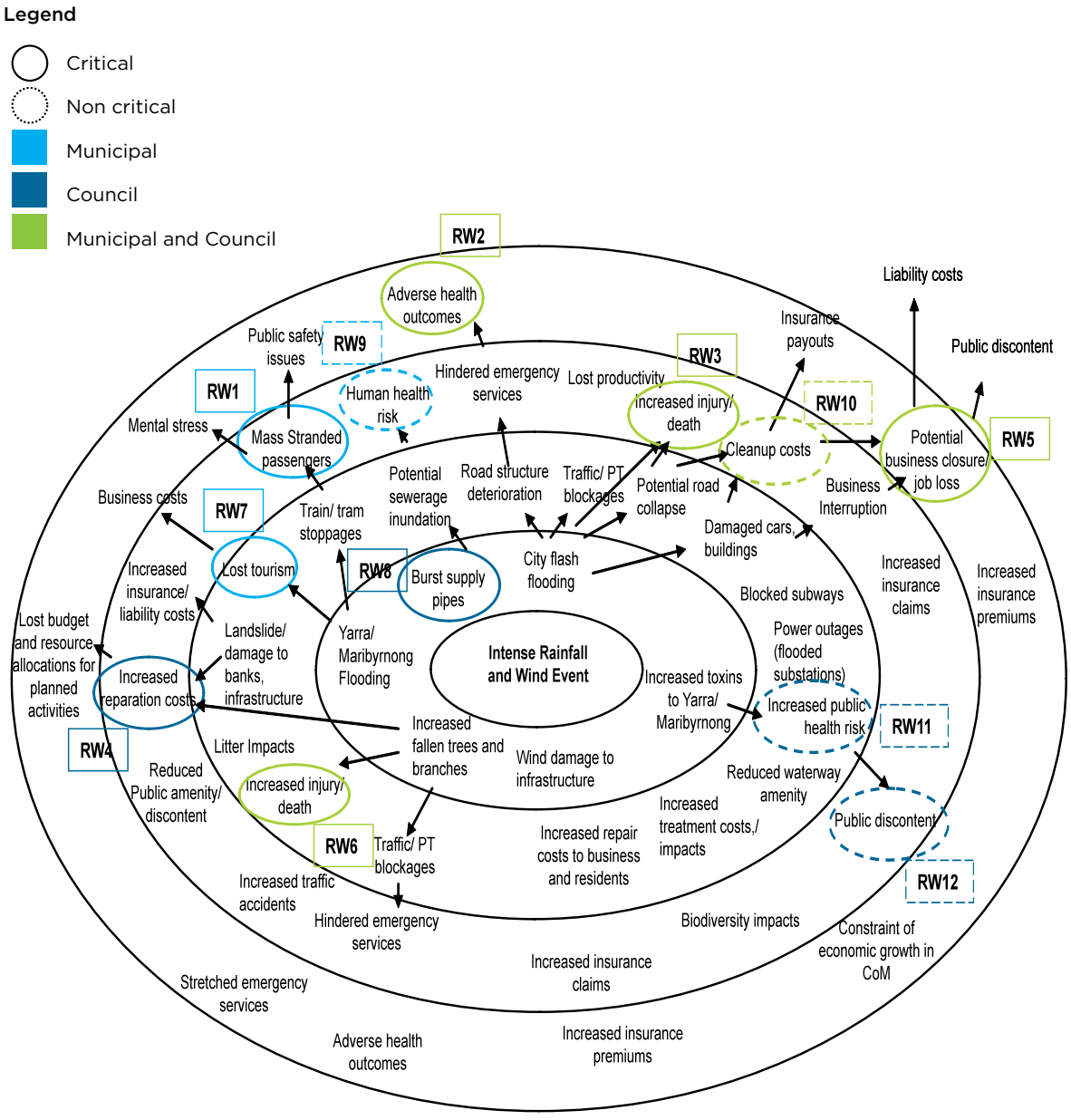

Figure 10: Cascading consequences for intense rainfall and wind event

8.0 Climate change risks for City of Melbourne

8.2.3 The City of Melbourne and municipal risk ratings

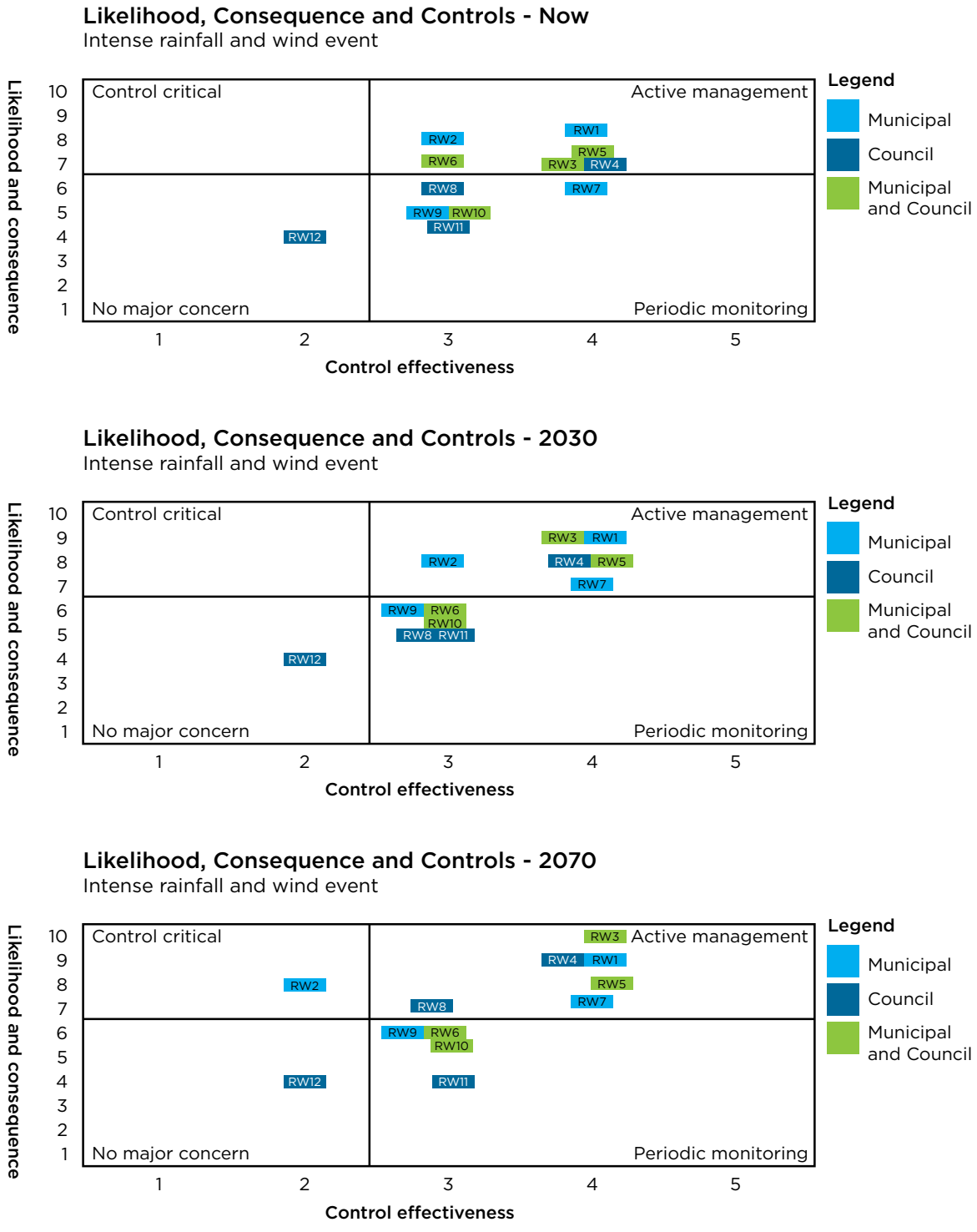

Figure 11: The City of Melbourne risk ratings for intense rainfall and wind storm event for now, in 2030 and in 2070

8.0 Climate change risks for City of Melbourne

8.2.4 The City of Melbourne critical risks of extreme rainfall and wind storm event

The critical risks identified for extreme rainfall and wind storm event for the City of Melbourne are:

- Mass public stranding due to flooding or storm damage.
- Adverse health impacts due to delayed emergency response services hindered by storm and flood impacts.
- Public injury or death due to flash flooding or storm damage.
- Increased reparation costs due to increasing intense rainfall and wind events.
- Business closures and job losses due to storms and floods.
- Injury and death due to falling trees.

These risks have a combined likelihood and consequence rating of 7 or above. Their control effectiveness rating determines if they are categorised as 'control critical' (less than 3), or in 'active management' (3 or above).

8.2.4.1 Mass public stranding due to flooding or storm damage (RW1 – municipal –active management)

Over 700,000 people enter the City of Melbourne precinct each weekday, just over half for recreation and the remaining predominantly for employment. 19 per cent come into the city in cars and the remainder by public transport, mainly trains (51 per cent) and trams (21 per cent) (City of Melbourne, 2006). Flash flooding and storm damage due to intense rainfall and wind events has the potential to block roads, disrupt traffic lights, stop trains and trams and generally stop people from exiting the city until access and service is reinstated. The extent of this kind of impact largely depends on the timing, duration and extent of the disruption. It would be further exacerbated by any additional compounding factors such as large scale events, power disruptions or emergency situations, such as multiple deaths or injuries.

Key findings:

- Some locations of the train system are susceptible to flash flooding that disrupts service.
- More than 400,000 people are undertaking recreation in the city precinct, rather than at fixed working addresses, and are therefore more difficult to coordinate in an emergency.
- As one transport mode fails others generally become overloaded and impaired also.
- Evening peak periods (4.30-6.30pm weekdays) are the worst time for a transport disruption to occur.
- There is a higher incidence of traffic accidents in inclement conditions, but generally of lesser severity due to reduced speed.

8.0 Climate change risks for City of Melbourne

Likelihood: (Now: Likely – 4 / 2030: Almost Certain – 5 / 2070: Almost Certain – 5)

Significant storms already cause disruptions to transport flow and passenger delays. Based on current response measures, an increase in storm intensity is very likely to cause transport disruptions and delay or strand passengers.

Consequence: (Minor to Almost Certain – 2 to 5)

The magnitude of the impact will be based on the extent of the transport failure, the time of day it occurs and the duration for which it continues. People's ability to shelter from the storm or find alternative transport somewhat easily will also factor into the significance of the event.

Changes over time:

Building resilience of the transport network to flash flooding and storms will reduce the likelihood of such a stranding event occurring, while better communications and warning systems could control the consequences. If resilience measures to storm events were effectively addressed, it is possible this risk could shift from 'active management' to 'periodic monitoring'. Better control measures could shift the risk rating to 'control critical'; and if both were addressed, the risk could be reassigned to 'no major concern'.

Given the transport system is undergoing considerable review in preparation for an upgrade to alleviate transportation congestion and accommodate population increase, added services and better strategic design of rail networks will help to isolate the extent of the impact. Throughout this transport review there is perhaps also opportunity to address the issue of climatic vulnerability. However without these changes, this risk rises over time with both changes in climate and growing visitation to the City of Melbourne, and remains a major concern.

Through its implementation, the *Total Watermark - City as a Catchment* strategy will improve resilience to urban flooding through increased capture and storage of stormwater.

Current control measures: (4)

- Safe evacuation centres
- Bus services for cancelled trains and trams. Response times are known to be variable and dependent on the availability of bus resources.
- Connex text communications systems inform subscribers of delays on individual train lines.
- Communication through radio station 774 ABC Melbourne
- Communication through media outlets.
- Bureau of Meteorology weather warnings through media outlets.
- Storm water harvesting for flood control.

8.0 Climate change risks for City of Melbourne

Stakeholders:

Connex, V-Line, Yarra Trams, Bus Victoria, VicRoads, Bicycle Victoria, Transurban, emergency services, power companies, Worksafe, State Emergency Service, Transport Accident Commission, Department of Sustainability and Environment, Department of Transport, Melbourne Water and City West Water.

Success criteria / performance management:

- A transport system that can effectively maintain a high level of function during and after storm events, with low likelihood of mass stranding.

8.2.4.2 Adverse health impacts due to delayed emergency response services hindered by storm and flood impacts (RW2 – municipal and council – active management)

Significant storms generally cause traffic delays already, extreme wind events and flash floods can hinder traffic across wide areas of the city. Hindrance of emergency services places people at risk of worsened injury or death.

Key findings:

- Ambulance response times in CBD have recently increased by approximately two minutes. In emergency response "minutes means lives".
- Tram lines are the most useful bypass for emergency services. They can be blocked by drivers seeking to escape congestion. Maintaining these areas for emergency vehicles is critical.
- Current projections regarding transport and population growth strongly suggest that even with proposed modifications to the transport system, congestion in the City of Melbourne will remain a serious concern.

Likelihood: (Now: Likely – 4 / 2030: Likely – 4 / 2070: Likely – 4)

We are already seeing an increase in storm and flooding events and these are projected to increase into the future. Without any adaptation this risk will continue to be likely into the future.

Consequence: (Moderate to Major – 3 to 4)

For those requiring emergency assistance, whether storm related or not, any delays to paramedics arriving can be crucial to survival or the extent of injury or illness. Clearly any resultant deaths attributed to storm delays would be of the most concern and the specific cause of the delay relevant to the level of consequence.

Current control measures: (3)

- Using available tram lines for emergency access.
- Existing driver behaviour to clear roads, where possible, for emergency services with sirens.

8.0 Climate change risks for City of Melbourne

Changes over time:

Managing, or ideally reducing, road congestion is the main means of reducing this risk. Current transport and population projections suggest that congestion will remain a major challenge in future - even with the application of effective control measures, this risk will likely move to control critical.

Stakeholders:

Vic Roads, Transurban, Victoria Police, Emergency Services, Metropolitan Ambulance Service, Metropolitan Fire Service

Success criteria / performance management:

Containment of emergency response times within the City of Melbourne to agreed benchmarks in a variety of conditions e.g. “normal”, “peak” and “crisis event”.

8.2.4.3 Public injury or death due to flash flooding or storm damage (RW3 – municipal and council – active management)

Flash flooding is known to cause the most deaths or injuries of all natural disaster weather events (Australian Government 2007b). Increased wind speeds have an exponential effect on building damages which results in more debris flying through the air. Depending on the cause and location the risk of public injury or death during a storm event is significant at both a municipal and Council level.

Key findings:

- Impervious surfaces in the built environment contribute to greater run off and drainage overflow.
- The majority of the drainage system is over 60 years old, with some dating back to the 1850s (City of Melbourne, 2007).
- Disruption of transport during a storm event results in many more people being potentially exposed to the storm.
- Power failures result in commercial buildings being evacuated, usually to open areas, which in turn further increase the number of people vulnerable to storm impacts.
- If power failures result in businesses sending employees home, even though transport is potentially disrupted, there is increasing public vulnerability.
- Community awareness of stormwater risks can often be poor, and this is contributed to by media portrayals of stormwater as “fun”.
- People in cars often attempt to cross flooded roads or open their doors in floodwaters, which puts them at serious risk of drowning.
- Safe behaviour in floods is one of the best protections against injury and death.

8.0 Climate change risks for City of Melbourne

- Land Subject to Inundation Overlay (LSIO) overlays for the City of Melbourne clearly identify flooding hotspots in the City of Melbourne, however the data that contributes to this overlay does not include rainfall data since 1987, and is currently under review.
- Further review is being undertaken of rainfall and run-off to incorporate climate change projections of increased storms.

Likelihood: (Now: Possible – 3 / 2030: Likely – 4 / 2070: Almost Certain – 5)

While rainfall is difficult to model and project; CSIRO considers, with increasing confidence, projections around increased intensity of storm and rainfall events. Should these events occur with greater frequency and severity, the likelihood of an injury or death is present in the immediate term, and builds into the future.

Consequence: (Negligible to Catastrophic – 1 to 5)

Clearly even a single death in such an event is significant. Should the death be considered as a result of a malfunction that could have been reasonably expected or prevented, there may be escalating consequences for those parties considered in 'control' of that situation. Multiple injuries or deaths would obviously increase the significance of the consequences and concern.

Current control measures: (4)

- The *Total Watermark - City as a Catchment* strategy, improving water quality and increasing water harvesting through water sensitive urban design measures.
- Actions outlined under the *City of Melbourne Drainage Strategy,* especially actions under the following themes: Asset Failure; Construction and Renewal; and Drainage Capacity. NB These can only be considered control measures if they are implemented or certain to be implemented.
- Confidence in the full implementation of measures outlined in the *City of Melbourne Drainage Strategy* would likely modify the assessment of control measures to 3.
- Safe shelters are nominated premises within the City of Melbourne which have an agreement with the City of Melbourne to open as an evacuation shelter upon request.

Changes over time:

Without adaptation, and with rising daily visitation to the City of Melbourne and larger and more intense storm events, this risk rises over time to where a potentially catastrophic outcome is considered almost certain.

A better informed public is an almost immediate measure that can reduce the likelihood of injury and death in a storm event along with providing accessible safe zones that can reduce public exposure to storms.

8.0 Climate change risks for City of Melbourne

The strengthening of potential debris, such as trees or awnings, can also reduce vulnerability. Pumps could be installed to help expel flood water from flooded basements and car parks, or where water is unable to drain away.

Reducing the likelihood of the flood itself through water sensitive urban design, improved drainage and potentially stormwater harvesting are the most effective in reducing vulnerability. Stormwater harvesting is proposed to increase through the *Total Watermark- City as a Catchment* strategy which can assist in stormwater detention and prevent flood risk.

The consequences of death or injury are generally considered to be consistent over time therefore reducing likelihood is the best measure to lower the risk rating to 'periodic monitoring'.

Stakeholders:

Melbourne Water, City West Water, emergency services, State Emergency Service (SES), Department of Sustainability and Environment (DSE), Worksafe, CitiPower, Connex,, V-Line, Yarra Trams, Bus Victoria, VicRoads, Transurban

Success criteria / performance management:

- No deaths or injuries during flash flooding or storm events.
- A demonstrable reduction in the potential for flash flooding itself.

8.2.4.4 Increased reparation costs due to increasing intense rainfall and wind events (RW4 – council – active management)

Extreme weather such as intense rainfall and wind events are known to cause significant damage to our urban environment; including damaged buildings, damaged or collapsed roads, damage to river banks and associated infrastructure. The clean up after these events is largely the City of Melbourne's responsibility and involves significant costs.

Key findings:

- Projected increased frequency and severity of weather events will cause increased damage resulting in greater reparation costs.
- Cost to the City of Melbourne of clean up after major weather events is significant.
- These events are most likely to occur in September through to March.
- Damages are more likely to occur in mapped flood risk areas, riverbanks and areas with weak trees.

Likelihood: (Now: Possible– 3 / 2030: Likely – 4 / 2070: Almost Certain – 5)

The City of Melbourne reports high costs from clean up after weather events. The forecast increase in extreme weather events is only going to exacerbate the likelihood of this risk.

8.0 Climate change risks for City of Melbourne

Consequence: (2030: Major – 4)

The City of Melbourne reports that the cost of such clean ups is already significant. This is likely to remain the case.

Current control measures: (4)

- Selective tree lopping.
- Aged buildings replacement/ refurbishment.
- Flood prone areas identification.
- Insurance – reduced liability.
- Tree replacement and revised watering procedures.
- Drainage management.
- Water sensitive urban design measures can detain and slow stormwater flows, however smaller systems are bypassed for extreme rain events. Rainwater tanks and large wetlands are able to detain larger stormwater flows.
- Existing clean up protocols and capacity.

Changes over time:

Without adaptation measures, this is expected to remain a significant risk for the City of Melbourne, with growing likelihood, through to 2070.

Proactive adaptation measures should reduce the likelihood of events creating levels of damage that incur major costs. Reduction of likelihood should be achievable, moving this risk to 'periodic monitoring', potentially by 2030.

There may be additional control measures, such as planned and costed priority responses, that will control the costs of these events better. If such measures could be applied, this risk could potentially be 'no major concern' by 2030.

Water sensitive urban design modelling is adjusted to climate change scenarios to ensure infrastructure is upgraded to prevent flooding from increased storm events whilst at the same time improving water quality where possible.

Stakeholders:

State Emergency Service (SES), Country Fire Authority (CFA), emergency Services, contractors

Success criteria / performance management:

Containment of annual storm clean-up costs following major events, to a benchmarked level.

8.2.4.5 Businesses closures and job losses due to storms and floods (RW5 – council and municipal risk - active management)

Following storm and flood events many businesses are forced to close due to significant damage. The City of Melbourne policy identified that one in four affected businesses do not reopen. The level of insurance plays an important role in determining whether a business will be able to recover from the damage or not.

8.0 Climate change risks for City of Melbourne

Key findings:

- Impacted businesses most likely to be found in mapped flood risk areas.
- Impacted businesses are likely to be underinsured (common among small-medium enterprises).
- Many businesses that close following extreme events fail to reopen.

Likelihood: (Now: Possible – 3 / 2030: Likely –4 / 2070: Likely – 4)

Given current knowledge of flood risk and business preparedness, this risk is considered possible in the immediate term.

Consequence: (Moderate to Major – 3 to 4)

The loss of a single anchor tenant for a period of time can have a major detrimental impact on a retail area. Similarly, the loss of a large number of small tenants at once can have a major impact.

Current control measures (4):

- *City of Melbourne – Mind Your Business* assists small businesses prepare their own emergency plans.
- Complimentary controls from other risks that may reduce the likelihood and consequence of damage from flooding and storms.

Changes over time:

Without adaptation measures to reduce the likelihood of destructive flooding, or better controls to protect businesses in such as event, the likelihood of this risk rises over time in line with projections of more intense rainfall events. Through its implementation, the *Total Watermark - City as a Catchment* strategy will improve resilience to urban flooding through increased capture and storage of stormwater.

Flood control measures such as drainage improvements could reduce likelihood.

Greater protection for at risk businesses could reduce consequences, and this should be achievable in a relatively short timeframe, to hold this risk in 'periodic monitoring'.

Stakeholders:

- Victorian Employers Chamber of Commerce and Industry, Business Council of Australia, retail centre management, insurance groups, Australian Council of Trade Unions (ACTU) and other trade unions, Department of Innovation, Industry and Regional Development (DIIRD).

Success criteria / performance management:

Demonstration that if a major event such as a one in 100 year event (based on 2008 climate) occurs, businesses and employment levels in the City of Melbourne will not experience substantial or long-term negative impacts.

8.0 Climate change risks for City of Melbourne

8.2.4.6 Injury and death due to falling trees (RW6 - council and municipal risk – active management)

During extreme weather events with intense rainfall and wind it is frequent that trees are blown over or lose their branches. There is potential for injury or death of members of the public. The impacts are likely to be worse where vulnerable, weak trees are located in high traffic areas. The City of Melbourne has a high number of weak trees due to overwatering in the past causing shallow roots.

Key findings:

- Trees are blown over or lose branches in high winds causing several associated impacts.
- Impacts are likely to be worse where vulnerable, weak trees are located in high traffic areas.
- Trees have become weak due to recent drought and previous overwatering creating shallow roots.

Likelihood: (Now: Likely – 4 / 2030: Possible – 3 / 2070: Possible – 3)

Many trees in the City of Melbourne are known to be in a weakened state due to current drought conditions combined with negative effects of previous watering practices. Injuries have occurred, an example being at the 2008 Melbourne International Flower and Garden Show.

Consequence: (Moderate – 3)

There is clearly potential for serious injury or even death as a result of falling trees or branches.

Current control measures (3):

- Parks and recreation controls.
- Revised watering practices to strengthen roots.
- Mass tree replacement.

Changes over time:

The mass tree-replacement program and revised watering practices underway by the City of Melbourne should reduce likelihood of this risk, which contains the risk to 'periodic monitoring' by 2030. Interim measures may be required until the replacement program is well advanced to reduce risks, such as changes at high risk locations. Effects of tree replacement will be moderated by the potential for more frequent severe events.

Stakeholders:

This risk is considered predominantly the management concern of the City of Melbourne.

Success criteria / performance management:

- Containment of injury and death due to falling trees or branches.
- Demonstrated actions to control high risk locations.
- Reduction in tree and branch falling over time.

8.0 Climate change risks for City of Melbourne

8.3 Extreme heatwave and bushfire

This scenario envisages an extreme, prolonged heatwave in Melbourne, with an overlay of poor air quality due to a major rural bushfire in surrounding areas. The type of heatwave conditions being considered are five consecutive days with a daily maximum of greater than 35 degrees, and very high overnight minimums of greater than 24 degrees. Drier, hotter conditions increase the frequency and intensity of bushfire occurring throughout Victoria.

This scenario envisages that late in the heatwave, record electricity demand causes a failure of the power supply system, resulting in blackouts. The loss of power greatly exacerbates already increasing morbidity and illness due to heat stress among the City of Melbourne residents, as they are no longer able to operate air conditioners.

The very poor air quality due to the bushfire is placing additional demand on emergency services to respond to those affected by respiratory illness.

The extreme conditions cause disruption to the transport systems that serve Melbourne at a critical time such as a Friday afternoon. Trains or trams are derailed due to expansion of tracks, potentially causing injury; air-conditioning fails on public transport, resulting in stoppages and illness among passengers.

Major intersections lose power due to blackouts. Multiple failures result in widespread stoppages and delays in public transport, stranding large numbers of commuters in very hot, unpleasant conditions. The power and transport system failure leads to severe traffic congestion. A number of minor road accidents worsen this congestion. Pressured emergency services are hindered in their operation by this congestion, increasing the risk of fatalities among those awaiting assistance.

In an extreme heatwave and bushfire scenario, the highest value adaptation measures are those that can manage the microclimate of the City of Melbourne to be less sensitive to temperature rises and provide improved thermal performance of the urban environment.

8.0 Climate change risks for City of Melbourne

8.3.1The City of Melbourne risks identified and assessed

Risk number	Risk title and rating	Now	2030	2070
H1	Increased heat stress related death / illness among at risk population groups	**8**	**8**	**9**
H2	Passengers become stranded as trains and trams to the City of Melbourne are delayed / cancelled in hot weather	**8**	**8**	**9**
H3	Blackout	**7**	**6**	**6**
H4	Increased violence / anti-social behaviour causing increased public nuisance and hospital admissions	**7**	**7**	**7**
H5	Increased prevalence of food borne disease	6	6	6
H6	Increased maintenance costs of assets and infrastructure	**7**	**7**	6
H7	Disruption to any outdoor event due to hot weather	6	6	**7**
H8	Reduced public and social use of space during heat waves	6	6	**7**
H9	Business interruption due to electricity blackout	6	5	5
H10	Heat stress related illness among outdoor City of Melbourne workers. This is caused by an increased number of hot days, and becomes especially exacerbated during hot spells.	6	6	6
H11	Respiratory illness and social disruption due to bushfire-related poor air quality	5	6	6
H12	Train and tram derailments / accidents result in injuries and major disruptions	5	5	6
H13	Increased closure of schools due to poor air quality	5	5	5
H14	Future liability and reputation damage relating to construction of dwellings or infrastructure unsuited to projected climatic conditions	3	6	**8**

Table 9: Intense extreme heatwave and bushfire risks and ratings

8.0 Climate change risks for City of Melbourne

8.3.2 Cascading consequences

Legend

Critical
Non critical
Municipal
Council
Municipal and Council

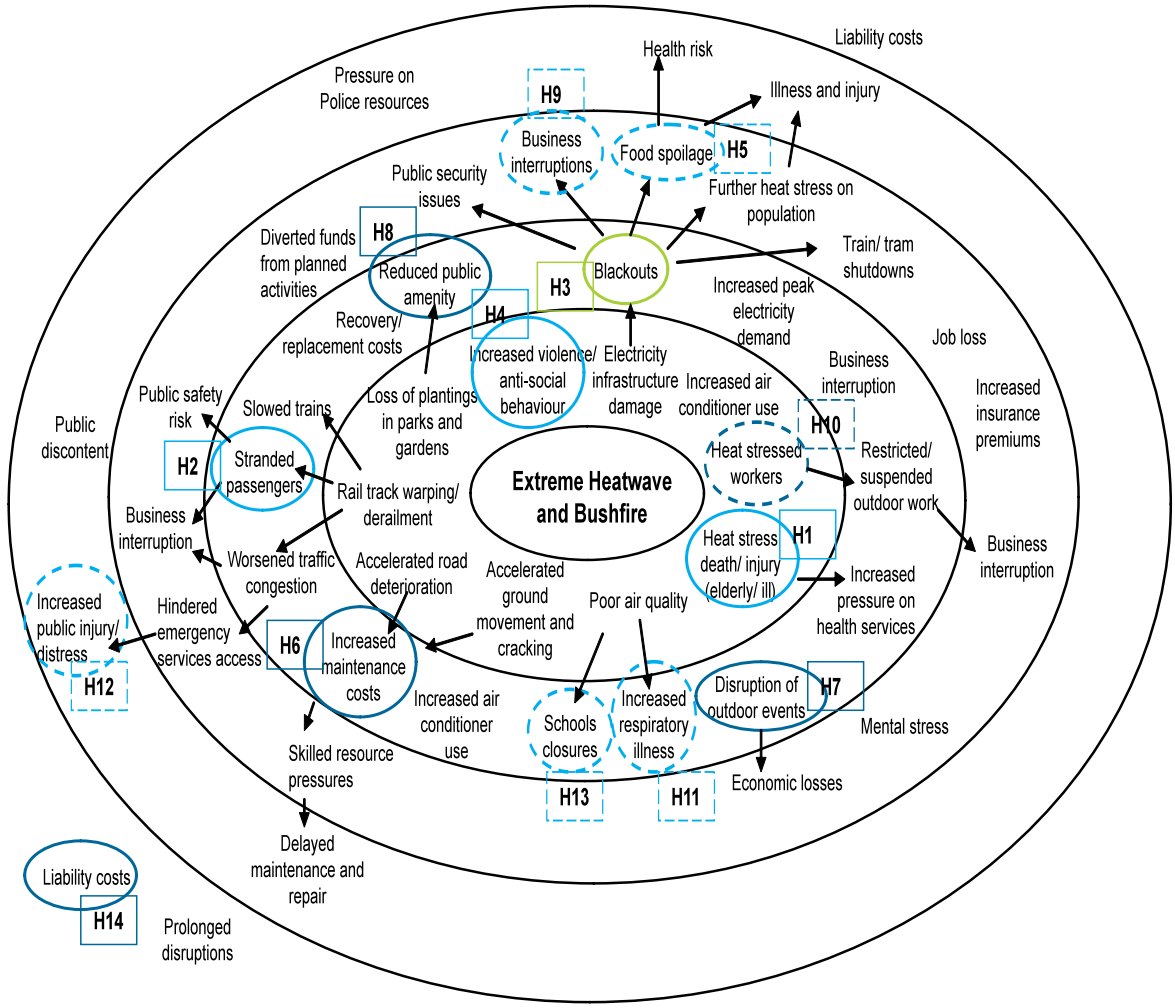

Figure 12: Cascading consequences for extreme heatwave and bushfire

8.0 Climate change risks for City of Melbourne

8.3.3 The City of Melbourne and municipal risk ratings

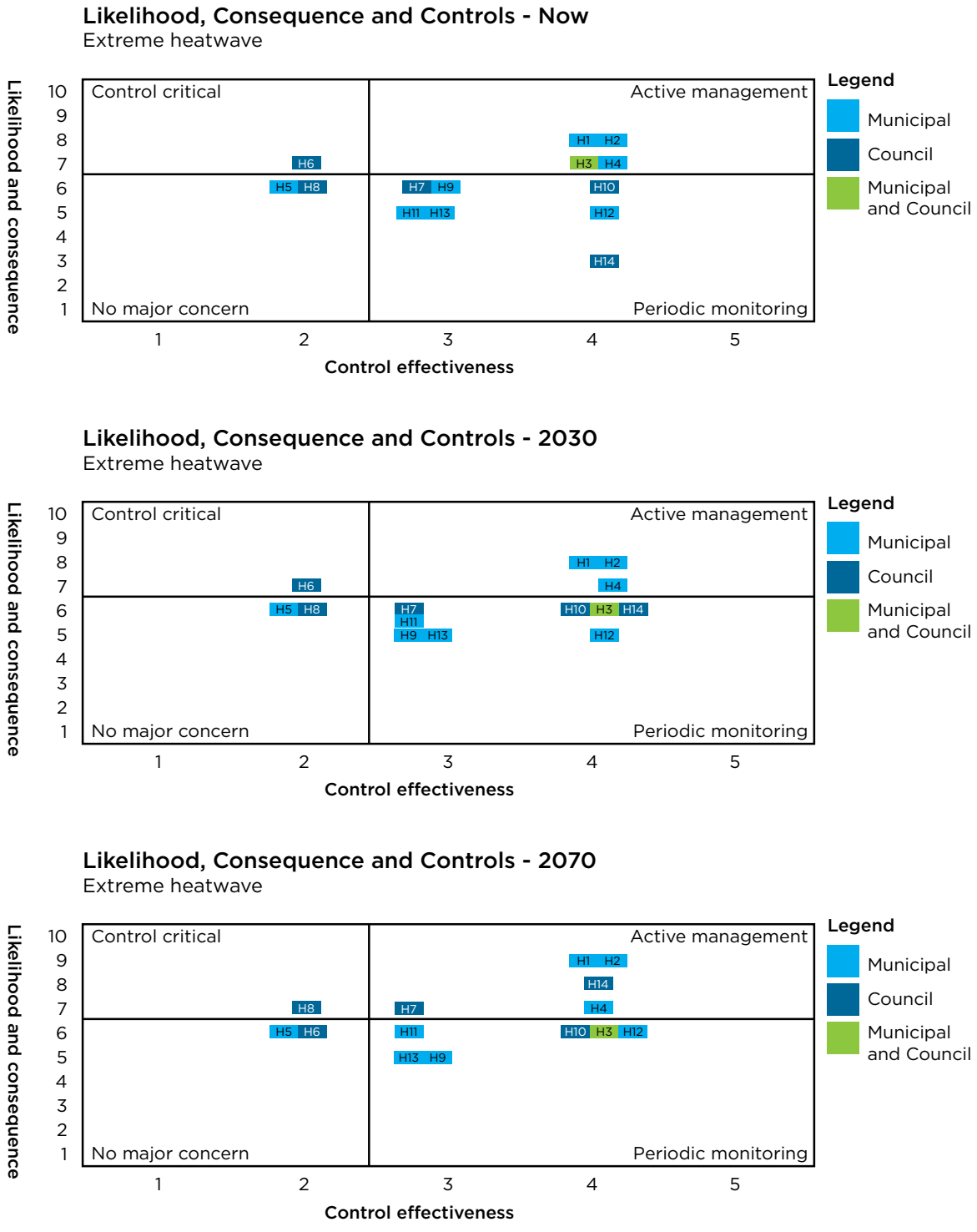

Figure 13: The City of Melbourne risk ratings for extreme heatwave for now, in 2030 and in 2070

8.0 Climate change risks for City of Melbourne

8.3.4 The City of Melbourne critical risks of extreme heatwave event

The critical risks identified for extreme heatwave event for the City of Melbourne are:

- Increased heat stress death/ illness.
- Passengers become stranded as trains and trams in the City of Melbourne are delayed or cancelled in hot weather.
- Power blackout.
- Increased violence/ antisocial behaviour causing increased public nuisance and hospital admissions.
- Increased maintenance costs of assets and infrastructure.
- Disruption to any outdoor event due to hot weather.
- Reduced public and social use of space during heat waves.
- Future liability and reputation damage relating to the construction of dwellings or infrastructure unsuited to projected climatic conditions.

These risks have a combined likelihood and consequence rating of 7 or above. Their control effectiveness rating determines if they are categorised as 'control critical' (less than 3), or in 'active management' (3 or above).

8.3.4.1 Increased heat stress death / illness (H1- municipal- active management)

There are significant current concerns regarding the health impacts of extreme heat conditions. High confidence levels in rising temperatures due to climate change increases concerns regarding this risk.

Key findings:

- Hot nights are the main indicator for increased heat stress death and illness.
- The average daily mortality of people aged 65 years or more is 15 to17 per cent greater when the mean daily temperature exceeds 30 degrees. Similar numbers (19 to 21 per cent) occur when daily minimums exceed 24 degrees (Nicholls et al, 2007).
- Socio-economic status is a strong indicator for morbidity in short events heat events. Age becomes the more prevalent morbidity indicator in longer events.
- Incidence of heat attacks and respiratory disease increases in heat events.
- Increasing numbers of ill passengers on public transport are observed during heat events. Congestion is also a contributing factor.
- Heatwave response plans are being developed by some local governments (such as the City of Melbourne and the City of Whitehorse) with funding provided by the Department of Human Services (DHS) through the *Victorian Climate Adaptation Strategy*.

8.0 Climate change risks for City of Melbourne

- Passive dissemination of information is not an adequate response for controlling risk of illness and injury. At risk populations need to be identified and cared for.
- Air pollution exacerbates illness and injury during heatwaves.

Likelihood: (Now: Likely – 4 / 2030: Likely – 4 / 2070: Almost Certain – 5)

Likelihood for this risk is almost certain in the immediate term given what is already understood about the impacts of recent heatwaves. Even considering changes such as increased air-conditioning, given high confidence regarding rising temperatures, likelihood does not reduce in future without adaptation measures.

Consequence: (Major- 4)

Similar to likelihood, consequence does not reduce over time without adaptation measures. The extent of the consequences may rise with rising population.

Changes over time:

Likelihood of this risk is expected to remain high, and consequences have the potential to become more widespread. Effective implementation of adaptation measures may move this risk to 'control critical.'

Current control measures: (4)

- Weather warnings
- Air conditioning
- Heat wave response plans for events
- Heatwave Response Plans (in development)
- Occupational Health and Safety responsibilities for aged care
- Activity suspension thresholds (schools, outdoor events, sports)

Stakeholders:

Emergency Services, aged care workers, medical services, power companies, Victorian Council of Social Service (VCOSS), counselling services, mental health support services, refuge shelters, Department of Human Services.

Success criteria / performance management:

- Evidence of improved local climatic conditions in the City of Melbourne during heatwave events.
- Effective containment / control of heat stress related death and injury in the City of Melbourne during hot conditions.

8.0 Climate change risks for City of Melbourne

8.3.4.2 Passengers become stranded as trains and trams in the City of Melbourne are delayed or cancelled in hot weather (H2- municipal- active management)

In extreme heatwaves, a combination of impacts to the transport system can lead to system wide delays and mass stranding of large numbers of people within the City of Melbourne.

Key findings:

- Trains and trams are susceptible to heat impacts that disrupt service. Older trams are the most likely to derail.
- More than 400,000 people per day use the city precinct for recreational purposes, rather than being at a fixed working address, and are therefore more difficult to prepare for a heatwave or contact.
- As one transport mode fails others generally become overloaded and impaired.
- Evening peak periods (4.30pm to 6.30pm weekdays) are the worst time for a transport disruption to occur.
- Yarra Trams is in discussion with drivers regarding potential work stoppage in non-air-conditioned trams in very hot conditions, as many older trams lack adequate air-conditioning

Likelihood: (Now: Likely –4 / 2030: Likely – 4 / 2070: Almost Certain – 5)

Severe heat and power failure already causes disruptions to transport flow and passenger delays. Based on current response measures, an increase in hot conditions is likely to cause transport disruptions and delay or strand passengers.

Consequence: (Moderate-Major – 3 to 4)

The magnitude of the impact will be based on the extent of the transport failure, the time of day it occurs and the duration for which it continues. People's ability to shelter from the heat event or find alternative transport somewhat easily, will also factor into the significance of the event.

Current control measures: (4)

- Response protocols from public transport providers such as the response for provision of buses.
- SMS Connex train service.
- Police response.
- Public transport attendants.
- Long term replacement of aged tram stock.
- Measures to improve CBD energy security.
- Progressive introduction of new tram stock.

8.0 Climate change risks for City of Melbourne

Changes over time:

Building resilience of the transport network to extreme heat will reduce the likelihood of such a stranding event occurring. Increasing use of non-motorised forms of transport (such as walking and cycling) may also reduce dependence on centralised transport infrastructure to a limited extent. Given the transport system is undergoing considerable review in preparation for an upgrade, to alleviate transportation congestion and accommodate population increase; there is perhaps also opportunity to address the issue of climatic vulnerability.

If resilience measures to heatwave events were effectively addressed, it is possible this risk could shift from 'active management' to 'periodic monitoring'. Better control measures could shift the risk rating to 'control critical'; and if both were addressed, the risk could be reassigned to 'no major concern'.

Stakeholders:

Connex, Yarra Trams, bus companies, emergency Services, Department of Transport.

Success criteria / performance management:

A transport system with rolling stock (such as, trains and trams) that can function during extreme heatwave events without putting people or property in danger.

8.3.4.3 Power blackout (H3-municipal- active management)

In periods of heat and humidity, electricity demand peaks. If demand for electricity exceeds the available supply, there can be a power failure.

Key findings:

- The CBD of Melbourne has among the lowest security of electricity supply in Victoria.
- Planned upgrades will improve this security. These include an upgrade from N1 to N1-Secure, which ensures power loss of no greater than 30 mins, and the construction of an additional substation supporting the CBD. These upgrades are expected to be complete by 2012.
- A loss of power supply exacerbates other consequences, such as heat stress outcomes, traffic congestion, and security.
- Continual upgrade of the electricity supply system to accommodate demands is a key performance measure for electricity distributors.

Likelihood: (Now: Likely –4 / 2030: Possible – 3 / 2070: Possible – 3)

Given the recent very hot conditions that have been experienced in Melbourne and the current vulnerability of the electricity supply system, some loss of power is considered likely in the immediate term.

8.0 Climate change risks for City of Melbourne

Consequence: (Moderate - 3)

A major bushfire related outage in 2006 saw a loss of power for 5 hours in very hot conditions. Assuming that most outages will be of lesser severity, consequences should be contained to 'moderate'. However consequences could escalate quickly if outages are prolonged, especially adverse health outcomes (H1).

Current control measures: (4)

- Load shedding principles
- Emergency response such as traffic intersection control
- Communication via radio station 774 ABC Melbourne

Changes over time:

The current upgrades should reduced likelihood of this risk by 2012. Assuming ongoing system upgrades as per normal operation of electricity distribution companies, this risk should be held in 'periodic monitoring'. Consequences could be reduced over time by the proliferation of decentralised power supply to high risk locations, however this outcome is not certain.

Stakeholders:

Electricity distribution companies, electricity transmission companies, Department of Energy and Resources, Department of Primary Industries

Success criteria / performance management:

- Likelihood of power failure within the City of Melbourne is comparable or less than other local areas in Victoria.
- In the event of power failure, high risk locations in the City of Melbourne have suitable contingency plans, and are acknowledged as priorities under load shedding principles.

8.3.4.4 Increased violence / anti-social behaviour causing increased public nuisance and hospital admissions (H4- municipal- active management)

Studies and anecdotal reports indicate a correlation between violence and anti-social behaviour and high temperatures. Rising temperatures are expected to exacerbate this effect.

Key findings:

- Victoria Police have commented that they need to consider the operational implications of hotter conditions, including increased violence and security concerns.
- A recent study has indicated correlation between very hot and humid conditions and hospital admissions for facial fractures.

Likelihood: (Now: Likely – 4 / 2030: Highly Likely– 4 / 2070: Highly Likely – 4)

Indications are that increases in violence and anti-social behaviour are already occurring in hot conditions, and only relief from hot conditions is likely to impact likelihood.

8.0 Climate change risks for City of Melbourne

Consequence: (Moderate – 3)

Consequences will vary depending on the nature of injuries and incidents but are considered to be moderate

Current control measures (4):

- 2am licensing lockdown (trial).
- Police and security presence.
- Reviews of licenses, laws and policing plans.

Changes over time:

Without effective adaptation measures, rising temperatures and growing populations will increase this risk. Expected changes to infrastructure over time for better heat resilience, and a degree of acclimatisation to hotter conditions may mitigate this risk somewhat over time.

Stakeholders:

Emergency Services, Victorian Council of Social Service, Victoria Police, event managers, licensees, private security industry, alcoholic beverage industry, Metropolitan Ambulance Service, hospitals, Victorian Taxi Directorate.

Success criteria / performance management:

Demonstrated containment or reduction in violent and anti-social behaviour in the City of Melbourne during hot conditions, at or below current levels, as temperatures rise.

8.3.4.5 Increased maintenance costs of assets and infrastructure (H6 - council - control critical)

Rising temperatures affect the lifespan and performance of assets and infrastructure, contributing to rising costs for maintenance and replacement.

Key findings:

- Increase temperature and solar radiation could reduce the lifespan of asphalt on road surfaces. Increased temperatures stresses the steel in bridges, causes expansion of concrete joints, protective cladding, coatings and sealants on bridges and buildings.
- Accelerated degradation may occur through increased ground movement and changes in groundwater.

Likelihood: (Now: Almost certain –5 / 2030: Very Likely– 4 / 2070: Very Likely–4)

Studies indicate that there are already impacts to existing infrastructure due to relatively recent changes in climatic conditions.

Consequence: (Minor to Moderate – 2 to 3)

Consequences in the immediate term are considered minor, as damage to infrastructure from temperature, generally occurs slowly over time.

8.0 Climate change risks for City of Melbourne

Current control measures: (2)

- Annual asset structure conditions.
- Annual life cycle costing report.
- Monthly building structure audits.
- Quarterly maintenance and cost audits.
- Retrofitting as per new contract.
- The City of Melbourne asset management plans such as Bridge Management Plan and Road Management Plan.

Changes over time:

Moving towards 2030, it is expected that large amounts of existing infrastructure, built to standards that pre-date consideration of climate change, will be due for renewal and replacement, leading to an increase in consequences in the medium term.

The next infrastructure cycle towards 2070 will face tougher climatic conditions, but with infrastructure that is likely to be more robust. Hence this risk may mitigate slightly towards 2070. Application of good control measures, such as revised standards, contingency standards, and revised asset management plans, maintain this risk in 'control critical' in 2030, and 'no major concern' in 2070.

Stakeholders:

External stakeholders driving key infrastructure standards such as VicRoads and the Department of Transport.

Success criteria / performance management:

Timely implementation of revised infrastructure standards and management plans that effectively control the maintenance costs of infrastructure and assets in higher temperature conditions.

8.3.4.6 Disruption to any outdoor event due to hot weather (H7- council- periodic monitoring)

In conditions of extreme hot weather (and bushfire air pollution), the outdoor events can be disrupted.

Key findings:

- Melbourne has a full calendar of events during periods of high heatwave risk.
- The functioning of events has been affected (the Australian Open Tennis), and in some cases cancelled (sports events during bushfires) in current climatic conditions.

Likelihood: (Now: Likely – 4 / 2030: Likely – 4 / 2070: Almost Certain – 5)

Given the confidence in information regarding temperatures, disruption of outdoor events is considered likely. The only way to reduce likelihood is to reduce the impact of high temperatures at event venues.

Consequence: (Minor – 2)

Given the number and range of events both during at-risk periods and throughout the year, and the existing propensity of Australians to participate in events in very hot conditions, the consequence is considered to be minor.

8.0 Climate change risks for City of Melbourne

Current control measures: (3)

- Emergency plans, communications
- Events protocols for hot conditions

Changes over time:

Given current confidence in temperature projections, if adaptation measures are not implemented it is considered that by 2070 larger numbers of event interruptions would accumulate in effect to raise the consequences of this risk, moving it to 'active management'. Improved control measures could instead move the risk to 'control critical', and if sufficiently effective, may reduce the likelihood and take this risk to 'no major concern'.

Stakeholders:

Major event organisers

Success criteria / performance management:

Maintaining successful delivery of a full range and calendar of events in the City of Melbourne in conditions of rising temperature and more frequent heatwaves.

8.3.4.7 Reduced public and social use of space during heat waves (H8 – council - no major concern)

In extreme hot conditions, areas of the public realm can become unappealing for use, detracting from the successful functioning of the municipality.

Key findings:

Extreme heat conditions can alter the public use of space. This was noted during the recent Adelaide heatwave, with significant slow down of the CBD retail sector due to heat.

Likelihood: (Now: Likely – 4 / 2030: Likely– 4 / 2070: Almost Certain– 5)

Very high temperatures are considered to change the use of open space, with higher use of air-conditioned and shady areas, and avoidance of hot spaces.

Consequence: (Minor – 2)

Given that changed use of public space in response to climate conditions is normal and the existing propensity of Australians to circulate in public in even very hot conditions, more pronounced changes due to increased temperatures and heatwaves may be undesirable but are considered minor in consequence.

Current control measures: (2)

The City of Melbourne provides a varied public realm, subject to ongoing improvement and re-invention.

Changes over time:

Based on temperature projections, if no additional adaptation of the public realm is undertaken, then by 2070 this risk will move to 'active management', based on increasing likelihood of significant changes in the use of the public realm.

8.0 Climate change risks for City of Melbourne

Ongoing improvements to the public realm to accommodate higher temperatures will keep this risk in 'control critical'. If adaptation options are also undertaken to mitigate the urban heat island effect, this risk could remain in 'no major concern'.

Stakeholders:

This risk is considered primarily the concern of the City of Melbourne

Success criteria / performance management:

Ongoing use of a wide range of the public realm, similar or better than current usage, during future conditions of higher temperatures.

8.3.4.8 Future liability and reputation damage relating to the construction of dwellings or infrastructure unsuited to projected climatic conditions (H14 – council - periodic monitoring)

At this time, most dwellings are constructed with current climatic conditions in mind, and are significantly dependent on mains power supply for vital ventilation and cooling services.

Based on current temperature projections, dwellings constructed today will become increasingly unsuitable in hot conditions, and increasingly dependent on mains energy supply.

Key findings:

- On the current business-as-usual trajectory, there is high confidence of a 3.4 degree temperature rise in Melbourne by 2070.
- Councils must be vigilant from now and into the future regarding the legal liability risks posed by climate change.
- Information and certainty regarding climate change impacts is growing rapidly, and the definition of "reasonable foreseeable" impacts in relation to climate change is changing and expanding.

Likelihood: (Now Rare, 1/ 2030 Unlikely, 2/ 2070 Possible, 3)

Currently the threshold for local governments unreasonably failing to take into account the impacts of climate change is high and direct impacts of rising temperature are mostly manageable, and relate to previously constructed dwellings. The likelihood of liability in the immediate term is 'rare'.

Consequence: (Minor to Major – 2 to 4)

Any consequence in the immediate term is likely to be at most 'minor', since the number of dwellings to which liability may be relevant is contained

Current control measures: (3)

- Adherence to and enforcement of relevant planning guidelines by the City of Melbourne within the authority of the limits of the municipality's responsibility.

8.0 Climate change risks for City of Melbourne

Changes over time:

The likelihood of liability escalates over time assuming measures to manage risks and revise guidelines are not taken. Consequences also escalate with the growing likelihood of climatic events that could illustrate the extent of potential liability. This risk moves from 'periodic monitoring' in the current timeframe to borderline 'active management' by 2030, and then to 'active management' by 2070.

Stakeholders:

Urban developers, development authorities, state government planning authorities, Department of Planning and Community Development, the Building Commission.

Success criteria/ performance management:

The effective demonstration and documentation of reasonable decision-making processes by the City of Melbourne, as a planning authority that reflect projections of higher temperatures.

8.4 Sea level rise

This scenario envisages a rise in sea level of 59cm by 2070, which is the highest of current estimates (26 to 59cm) as outlined in Section 4.0. The upper limit of the range for 2070 projections has been used for the risk assessment due to the uncertainty surrounding sea level rise projections and the severity of the consequences of underestimating future rises.

In line with current expectations, the scenario envisages that both Docklands and Fisherman's Bend continue to successfully develop as residential / business / commercial and industrial areas respectively, with high levels of daily visitation. Workers in Fisherman's Bend predominantly depend on private vehicle transport, with most relying on access via the at-times congested Westgate Bridge.

The risks posed by sea level rise are negligible during the current timeframe but become far more concerning by 2070 by which time many are deemed 'active management'. The least disruptive and most economic approach to minimising the impacts of sea level rise in the long term is the integration of measures into infrastructure design and development planning in the short term. This makes the long term risks of sea level rise an active management issue for today.

The consequences for low lying areas, such as parts of Docklands, Southbank and Fisherman's Bend, of a combined event of significant rainfall and extreme high tide event with sea level rise are extensive flooding of increasing frequency and severity. This may be due to coastal inundation or to low lying drainage structures being quickly overwhelmed. The potential damages of intense rainfall and flooding is detailed in 8.2 on page 56.

8.0 Climate change risks for City of Melbourne

Minor flooding can impact upon the use of the city's public realm, increase clean-up costs and pressure resources, inconvenience residents and workers, and damage infrastructure; affecting productivity and increasing renewal and replacement costs. Major flooding can result in damage to businesses and residential complexes, disruption of activity at the Port of Melbourne, stranding of residents and employees, injuries and fatalities, business disruptions, environmental damage due to inundation of sewage or contaminated sites, interruption of freight and economic activity, and damage to low lying recreational areas and coastal / foreshore amenity. The impact of greater frequency of both minor and major flooding may contribute to a significant loss of property value in these areas, higher insurance costs, and increased infrastructure expenditure.

As well as major storm events, consistent higher water levels result in greater water exposure and accelerated deterioration of marine structures, such as marinas and channel banks.

A key area of concern for the City of Melbourne is major residential, business and recreation areas being constructed along waterfront land.

Understanding the impact of sea level rise is important in considering the potential for flood events in this area. Guidelines for development in low lying precincts reflect somewhat outdated information regarding sea level rise and may benefit from increased consideration of current projections and impacts on the project and stakeholders.

The range of potential sea level rise is highly debated, with increasing concerns about additional dynamic ice sheet contributions. Although the addition of dynamic ice sheet contributions is never specifically done in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, the total projected range in sea level rise would be 18 to 79cm if included (ACE CRC, 2008b). This report states, "larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a better estimate or an upper bound for sea-level rise". The City of Melbourne is advised to remain abreast of potential future revisions of sea level rise estimates to ensure a reasonable foundation for decision making is maintained. Should larger and more rapid sea level rise occur, Melbourne may need to consider dramatic adaptation, such as protective sea walls across Port Phillip Bay, which would significantly alter the functioning of the city, and would come at substantial environmental, economic and social cost.

8.0 Climate change risks for City of Melbourne

Storm surge also has the potential to be a significant hazard – even a 0.5m sea-level rise (a plausible explanation for 2070) would lead to a present 1:100 year flooding event occurring every few months (Church *et al*. 2008). Future impacts of storm surge on the City of Melbourne are currently poorly understood but have the potential to become a serious risk should storm surge become much more frequent. Further investigation of the City of Melbourne's vulnerability to storm surge is strongly recommended.

8.4.1 Risks identified and assessed

Risk number	Risk title and rating	Now	2030	2070
S1	Residential property damage from increased flood return to habitable areas	4	6	**7**
S2	Costly infrastructure adaptations as a result of increased flood return to habitable, marine and waterfront recreation areas	4	6	**8**
S3	Environmental damage due to flooding of industrial areas in expanded flood zone.	4	6	6
S4	Injury and death due to increased flood return period to waterfront leisure and recreation areas	4	6	**7**
S5	Stranding of residents due to increased flood return to habitable areas	3	6	**7**
S6	Decreased waterfront property / precinct values due to increased flood return to habitable, marine and waterfront recreation area	3	6	**7**
S7	Mental stress resulting from the consequences of increased flood return to habitable areas	3	5	**7**
S8	Potential of City of Melbourne liability due to approved residential and business construction that did not account for increased flood return to habitable areas	3	5	**7**
S9	Damage to businesses due to flooding caused by expansion of flood zone (Fishermans Bend)	3	6	6
S10	Damage to road and rail infrastructure due to flooding resulting from expansion of flood zone (Fishermans Bend / West Melbourne)	3	6	6
S11	Interruption of freight movement due to expansion of flood zone (Fishermans Bend)	3	6	6
S12	Mass stranding of workers as a result of flooding in Fishermans Bend / West Melbourne	3	6	6
S13	Decreased waterway activity and loss of major events due to reduced bridge clearances	2	5	6
S14	Increased maintenance, cleaning refurbishment and replacement of marine structures and bridges due to higher water levels and increased flood return	2	5	6
S15	Decreased use of boating facilities due to increased flood return of berthing and marine structures	2	5	6
S16	Damages to waterfront businesses due to increasing flood return period of waterfront leisure/ recreation areas	2	6	**7**
S17	Decreased use of public realm due to increased flood return period to leisure and recreation area	2	5	6

Table 10: Sea level rise risks and ratings

8.0 Climate change risks for City of Melbourne

8.4.2 Cascading consequences

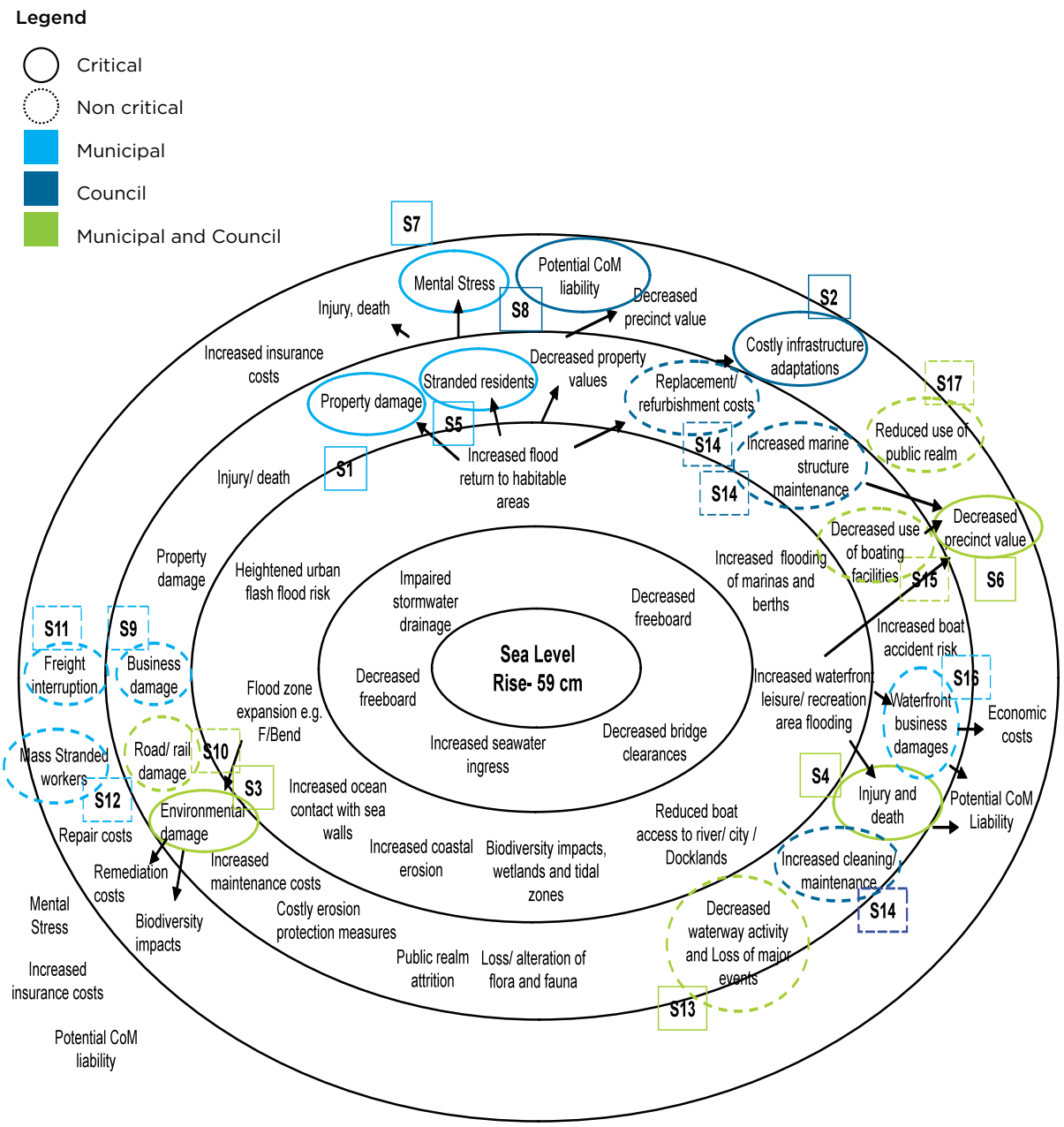

Figure 14: Cascading consequences for sea level rise

8.0 Climate change risks for City of Melbourne

8.4.3 The City of Melbourne and municipal risk ratings

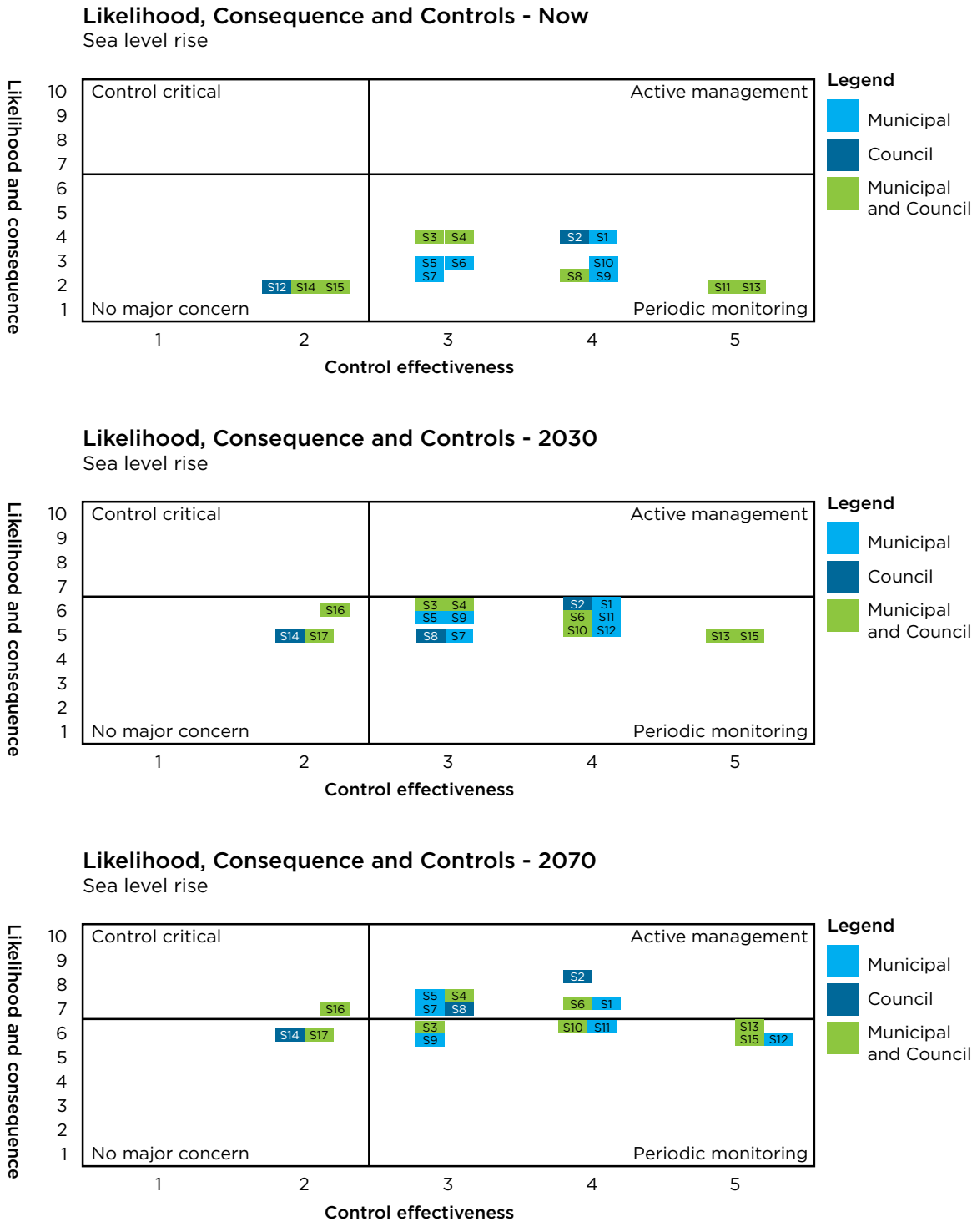

Figure 15: The City of Melbourne risk ratings for sea level rise for now, in 2030 and in 2070

8.0 Climate change risks for City of Melbourne

8.4.4 The City of Melbourne critical risks of sea level rise

The critical risks identified for sea level rise for the City of Melbourne (detailed below) are:

- Property damage from inundation in low lying areas.
- Infrastructure damage due to increased inundation in low lying areas requires rapid adaptation.
- Injury and death due to increased flooding.
- Stranding of residents due to increased flooding.
- Mental stress for affected residents.

These risks have a combined likelihood and consequence rating of 7 or above. Their control effectiveness rating determines if they are categorised as 'control critical' (less than 3), or in 'active management' (3 or above).

8.4.4.1 Property damage from inundation in low lying areas (S1 – municipal - periodic monitoring)

Sea level rise of 59cm has the potential to inundate low lying areas, either through direct inundation by sea water, or by shortening the return period of floods due to its impact on the drainage systems of low lying areas. Major flooding events (such as current 1:100 year events) will begin to occur more frequently, resulting in levels of damage to residential and commercial properties greater than currently anticipated in design guidelines.

Key findings:

Low lying precincts within new developments have been identified to be at risk of flooding. Existing guidelines consider the impacts of 1 in 100 year rainfall flood events but do not account for sea level rise. For example, the Docklands design guidelines consider a minimum building floor level of 2.2m AHD. Guidelines for new developments in low lying precincts should be revised and updated as a matter of urgency.

From consideration of these guidelines, along with projection of sea level rise of 59cm (590mm), the following is assumed:

- In current climatic conditions, convergence of both a 1:100 year tide event and 1:100 year rainfall event would result in serious flooding. The likelihood of such an event occurring is very low.
- Flooding could also result from convergence of lesser tidal events and lesser rainfall events in current climatic conditions. The likelihood of such convergence is greater.
- The addition of 59cm of sea level would all but eliminate the 600mm freeboard of habitable floor levels. In this situation a one in 100 year tidal event would only require a very minor rainfall event to result in flooding. A one in 100 rainfall event would require only a very minor tidal event to result in flooding.

8.0 Climate change risks for City of Melbourne

- Higher sea levels would also decrease the return periods of lesser tidal and rainfall events that could converge causing flooding of habitable floor levels.
- When combined with projections for higher return frequencies of major rainfall events due to climate change, independent of sea level rise, the possibility for flooding of habitable floor levels increases further.
- Non-habitable areas of less than 2.2m AHD would be subject to even greater frequency of flooding. These could include wharf or marina areas, parks and other recreational areas.

Likelihood: (Now: Rare- 1/ 2030: Unlikely- 2/ 2070: Possible- 3)

The current level of flood risk from sea level rise is 'rare'.

Consequence: (Moderate to Major – 3 to 4)

The consequence of flooding is likely to be 'moderate' in the immediate term

Current control measures: (4)

- Stormwater control measures (such as capture and harvesting) within the City of Melbourne
- Existing drainage infrastructure

Changes over time:

As the century progresses, and the projected 59cm of sea level rise eventuates, likelihood of flooding rises.

Flooding still requires either major events (1:100) or convergence of lesser events, however this has recent precedent in Melbourne with the 2005 flooding of Southbank where a 1:20 rainfall event coincided with a moderate tide to produce river flood levels of 1.366 AHD (Carolyn Tsioulos, 2008,). Consequences grow over time as at-risk areas become more fully developed. This risk moves from 'periodic monitoring' in the current timeframe to 'active management' by 2070.

Stakeholders:

VicUrban, private urban developers, Melbourne Water, Department of Sustainability and Environment, property owners

Success criteria/ performance management:

Containment of the flood return risk to within the parameters considered acceptable without the overlay of sea level rise.

8.4.4.2 Infrastructure damage due to increased inundation in low lying areas requires rapid adaptation (S2 – council - periodic monitoring)

This risk supposes that minimal action is taken to proactively mitigate the additional flood risk posed by sea level rise until significant increase in return of flooding events is observed. In this situation, it is supposed that rapid infrastructure adaptation is required to manage this risk.

8.0 Climate change risks for City of Melbourne

Key findings:

Rapid changes to fully developed urban areas are likely to be significantly more costly, and bring fewer benefits, than early adaptation actions which have been planned and staggered over time.

Likelihood: (Now: Rare - 1 / 2030: Possible- 3 / 2070: Likely- 4)

There is little prospect of rapid, radical infrastructure adaptation being forced on the City of Melbourne in the immediate term. Likelihood in the immediate term is 'rare'. The longer the risk remains unrecognised, the greater the likelihood that rapid changes will be suddenly demanded.

Consequence: (Moderate - 3)

Rapid infrastructure adaptation will be costly at any time, hence a 'moderate' consequence in the immediate term. Consequence becomes greater as areas become more fully developed, providing less flexibility in adaptation design.

Current control measures: (4)

- Flood control measures with City of Melbourne catchment.
- Stormwater control measures (such as capture and harvesting) within City of Melbourne catchment.

Changes over time:

Likelihood increases over time with growing flood risks. Significant events causing death, injury or damage are likely to drive rapid adaptation. Consequence worsens over time as areas develop and become fully utilised, and adaptation flexibility is reduced. Existing control measures become less effective as the impacts of sea level rise grow. This risk moves from 'periodic monitoring' in the current timeframe to 'active management' by 2070.

Stakeholders:

- Urban developers, Department of Sustainability and Environment, property owners, government authorities that manage infrastructure

Success criteria / performance management:

- Containment of adaptation costs while successfully reducing flood risks.

8.4.4.3 Injury and death due to increased flooding (S4 - municipal and council - periodic monitoring)

As outlined under S1, sea level rise has the potential to lead to increased return frequency of flood events. Floods are a very hazardous natural event. There is a related risk of death and injury

8.0 Climate change risks for City of Melbourne

Key findings:

As outlined under S1.

Likelihood: (Now: Rare, 1/ 2030: Possible 3, / 2070: Likely, 4)

This risk considers the additional flooding risk provided by sea level rise. The additional risk rises as the century progresses, and the projected 59cm of sea level rise eventuates. Flooding still requires either major events (1:100) or convergence of lesser events, however this has recent precedent in Melbourne with the 2005 flooding of Southbank where a 1:20 rainfall event coincided with a moderate tide to produce river flood levels of 1.366 AHD. Likelihood is greater in 2030 and 2070 than for S1, as dangerous floods do not need to be of a size capable of reaching habitable floor levels of Docklands; hazards may occur in lower lying areas. Likelihood also increases as areas become more fully utilised.

Consequence: (Moderate – 3)

Moderate consequence has been assigned to this risk in all timeframes, however there is the potential for more serious consequences.

Current control measures: (3)

- Flood control measures within the City of Melbourne catchment.
- Stormwater control measures (such as capture and harvesting) within the City of Melbourne catchment.
- Emergency response capabilities.

Changes over time:

Likelihood increases over time with growing flood risks and greater utilisation of at-risk areas. Existing control measures become less effective as the impacts of sea level rise grow. This risk moves from 'periodic monitoring' in the current timeframe to active management' by 2070.

Stakeholders:

- Emergency services, residents of at-risk areas, developers of at-risk areas

Success criteria / performance management:

- Containment of the flood return risk to within the parameters considered acceptable without the overlay of sea level rise.

8.4.4.4 Stranding of residents due to increased flooding (S5 – municipal - periodic monitoring)

In the event of flooding that reaches habitable floor levels, residents may become stranded until waters subside or safe passage can be provided by emergency services. Stranding poses health risks, particularly for the ill or infirm, and is likely to result in considerable stress.

Key findings:

Residential developments in low lying areas of the City of Melbourne are predominantly high rise. There is the potential for large numbers of people to become stranded in these locations.

8.0 Climate change risks for City of Melbourne

Likelihood: (Now Rare, 1/ 2030 Unlikely, 2/ 2070 Possible, 3)

Likelihood of stranding is tied to the likelihood of flooding that reaches habitable levels causing property damage (S1). In the immediate term this likelihood is 'rare'.

Consequence: (Minor to Major – 2 to 4)

Consequence grows as low lying developments become more fully utilised over time. In the medium term this likelihood is 'moderate', reflecting the partial development of Docklands. As well as the health and safety consequences associated with stranding, such an event would likely result in high profile reputational and political consequences.

Current control measures: (3)

- Flood control measures within the City of Melbourne catchment.
- Stormwater control measures (such as capture and harvesting) within the City of Melbourne catchment.
- Emergency response capabilities.

Changes over time:

Likelihood increases over time with growing flood risks and greater utilisation of at risk areas. Existing control measures become less effective as the impacts of sea level rise grow.

Stakeholders:

Emergency services, residents of at-risk areas, developers of at-risk areas

Success criteria / performance management:

- Containment of the flood return risk to within the parameters considered acceptable without the overlay of sea level rise.
- Demonstrable emergency procedures that would result in rapid and safe transfer of residents from flooded premises.
- Demonstrable access modifications that would allow or assist in safe transfers in the event of serious flooding.

8.4.4.5 Mental stress for inundation affected residents (S6 – municipal - periodic monitoring)

Victims of sudden natural disasters, such has floods, can experience considerable mental stress from the experience, particularly related to injuries or fatalities, or uncertainty of future well-being due to the loss of property.

Key findings:

Following the Queen's Birthday long weekend flooding in Newcastle in 2007, additional crisis counselling services was one of the greatest needs to assist in the management of mental stress of those affected.

Likelihood: (Now Rare, 1/ 2030, Possible, 3/ 2070, Likely, 4)

Likelihood of mental stress resulting from increased flooding return to habitable areas is tied to the likelihood of flooding that reaches habitable levels causing property damage (S1). In the immediate term this likelihood is 'rare'.

8.0 Climate change risks for City of Melbourne

Consequence: (Minor to Moderate – 2 to 3)

Consequence depends on the severity and frequency of return of flood events, including the number of people adversely affected. Consequence of this risk is also dependent on different individual levels of resilience in adverse circumstances. In the immediate term consequence is considered 'minor'.

Current control measures (3):

- Flood control measures within the City of Melbourne catchment.
- Stormwater control measures (such as capture and harvesting) within the City of Melbourne catchment.
- Emergency response capabilities.
- Business continuity insurance (flood protection).
- Home and contents insurance (flood protection).

Changes over time:

The risk of mental stress grows with time as the likelihood of increased flood return grows, as well as fuller utilisation of low lying developments increasing the number of people who will be exposed to the flood event. This risk moves from 'periodic monitoring' in the current timeframe to 'active management' by 2070.

Stakeholders:

- Business and residential owners and tenants in low lying developments, insurance companies, mental health services (Department of Human Services)

Success criteria / performance management:

- Effective deployment of adaptation measures identified in S1-S5 to minimise risks from sea level rise.
- Demonstrable ability to swiftly deploy crisis counselling and mental health assessment services to high risk areas following an extreme event.

9.0 Adaptation Actions for City of Melbourne

The measures proposed in this section aim to build resilience and reduce vulnerability to climate change by implementing adaptation measures that engage all stakeholders.

The recommended actions have been placed into two separate tables denoting short and long term timeframes. These align with the short, medium and long term timeframes identified in section 7.0, Climate Change Risk Management for City of Melbourne of this report. Short term in this case is considered to include both the short and medium term timeframes being from now up to 2030 whilst the longer term actions are up to 2070.

9.1 Drought and reduced rainfall

9.1.1 Adaptation responses - key themes

Actions undertaken by the City of Melbourne to adapt to drought and reduced rainfall should be classified under the following strategy themes:

- maximise water use efficiency;
- diversify water supply;
- maximise water harvesting; and
- improve waterway and bay health.

9.1.2 Actions

The City of Melbourne will action its sustainable water management program through the *Total Watermark - City as a Catchment* strategy by:

1. Saving water and preventing stormwater pollution *at source* by using *non-structural techniques* including demand management strategies which engage, communicate and educate to bring about behavioural change. Other strategies include regulation, town planning controls and fiscal incentives.
2. Saving water and preventing stormwater pollution *at source* by using *structural techniques* to treat and/or harvest alternative water supplies.
3. Saving water and preventing stormwater pollution *in system* by using *structural techniques*. Such infrastructure is installed within drainage/stormwater systems to manage stormwater quality and quantity before it is discharged to receiving waters.

   The City of Melbourne has committed to a range of integrated water cycle management targets directed at water conservation, stormwater quality and wastewater minimisation.

   To attain the 2020 targets, it is necessary to undertake the following on-ground works across the public and private sectors using the *Water Sensitive Urban Design Guidelines:*

   Water sensitive urban design projects for City of Melbourne managed assets:

- Undertake alternative water sourcing for a range of parks and gardens in the City of Melbourne to meet 61 per cent of the City of Melbourne's irrigation demand. Some suggested scenarios are outlined in the draft *City as a Catchment* strategy.

9.0 Adaptation Actions for City of Melbourne

- Double the current annual rate of uptake of water sensitive urban design projects treating road runoff driven through the Lower Yarra Stormwater Quality Program.
- Double the current uptake rate of tanks for harvesting roof runoff across City of Melbourne managed assets.

Water sensitive urban design projects across private non-residential sector:

- Proceed with proposed water harvesting and treatment schemes at Royal Botanic Gardens, Southern Cross Station, Melbourne Museum, Melbourne Cricket Ground, Melbourne Convention Centre and Flemington Racecourse.
- Proceed with the rollout of water conservation projects currently being trialled including installation of waterless woks, cooling tower program, fire sprinkler testing program, green hotels and sustainable office building program.
- Increase uptake rate of rainwater tanks on private non-residential properties to 50 times the current uptake/installation rate a year (300 tanks per year).

Water sensitive urban design projects across private residential sector:

- Increase uptake of water demand management in households through flow restrictors and showerheads.
- Rate of rainwater tanks for toilet flushing on private residential properties to 1000 installation a year.

Sporting grounds:

- Evaluate all sporting grounds for potential injury threat, likelihood of use restrictions, and sporting groups that utilise them and numbers of users.
- Seek quantification of any increased injury reported in using the City of Melbourne sports grounds in recent years.
- Confirm whether restricted use of sports grounds has been required in the City of Melbourne to date due to ground hardening.
- Reassess insurance and liability status for the use of the City of Melbourne sports fields to ensure that coverage is appropriate and liability is reflective of changing conditions.
- Engage with sporting grounds managers and sporting groups to convey risks of hardening grounds and likely adaptation measures; ensure awareness of all athletes.
- Consider public signage of sports fields during risky periods to restrict usage or convey injury risk.
- Continue investigation of the use of artificial turf on certain sports fields, and identify sporting grounds that would be well suited to this measure in order to minimise risk and maximise use.

Advocacy:

- Engage with eWater Cooperative Research Centre and Melbourne Water to update rainfall and pollutant load data to make modelling for water sensitive urban design more responsive to climate change.

9.0 Adaptation Actions for City of Melbourne

- Engage with Environmental Protection Authority Victoria and Melbourne Water to discuss potential for increased river monitoring to better inform decision making.
- Revisit the delayed environmental flows for the Yarra River which cannot be released until water restrictions are lowered to stage 1, in light of Melbourne's short-term need for water prior to planned system augmentations.

9.1.3 Adaptation measures – short term

The following potential immediate and short term adaptation measures are proposed for the City of Melbourne in managing the scenario of drought and reduced rainfall

Proposed potential adaptation measures	Risks influenced / controlled											
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
Low to mid-level water restrictions established as water use standards	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water efficiency product standards within CoM	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Increased fequency of waterway monitoring to ensure critical level changes in river health are identified early		✓						✓				
Expansion of grass replacement in sports fields to drought tolerant species	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Installation of artificial turf for sports fields where natural turf cannot be maintained	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Relocation of sport activities to indoor sporting facilities cannot be maintained			✓		✓		✓			✓		
Restrict usage of sports grounds during summer months and/or dry periods to minimise risk of injury and associated liability until alternative irrigation sources are in place			✓									
Increase insurance coverage for Council and sports clubs to control the potential costs from increased injuries			✓		✓							
Implement requirements for protective sporting gear to minimise injuiries												
Ensure a diversity of sporting choices that are not all dependent on irrigated sports grounds			✓				✓				✓	

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 11: Adaptation measures: drought and reduced rainfall - immediate and short term

9.0 Adaptation Actions for City of Melbourne

9.1.4 Adaptation measures – long term

The following potential medium term adaptation measures are proposed for the City of Melbourne in managing the scenario of drought and reduced rainfall.

No long term measures have been identified for these priority issues, however there will be ongoing commitment to water saving and water harvesting into the future.

Proposed potential adaptation measures	Risks influenced / controlled											
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
Widespread increased rainwater storage for use in suitable purpose through increased penetration of domestic and community rainwater tanks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Widespread implementation of local water recycling and grey water use in new and retrofitted buildings	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Widespread expansion of stormwater capture, harvesting and treatment and water recycling for use in a range of purpose, Early uses may include parks, gardens, sports fields, cleaning and washing, toilet flushing and some industrial uses.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Municipally wide fit for purpose water policy, to encourage exploitation of water sources other than potable mains water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Release of allocated environmental flows to Yarra River, currently being withheld		✓			✓			✓				
Ensure a diversity of sporting choices that are not all dependent on irrigated sports grounds			✓				✓				✓	

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 12 Adaptation measures: drought and reduced rainfall – long term

9.0 Adaptation Actions for City of Melbourne

9.2 Intense rainfall and wind event

9.2.1Adaptation responses- key themes

Actions undertaken by the City of Melbourne to adapt to intense rainfall and wind events should be classified under the following strategy themes:

- better drainage and stormwater capture;
- early public warning system;
- integrated emergency services and stakeholder response;
- better public knowledge and safe behaviour;
- minimise debris potential; and
- increased infrastructure standards.

9.2.2 Actions

- Explore the introduction of a tiered warning system for incoming severe weather beyond main media outlets (such as Hong Kong typhoon warnings).
- Investigate drainage improvements at all known flash flood points of transport system with the City of Melbourne boundaries in collaboration with Melbourne Water, and advocate similar actions outside the City of Melbourne boundaries. Flood mapping of the local drainage system should also be conducted to confirm other 'hotspots' or areas at risk of flooding.
- Continuing upgrading stormwater infrastructure using water sensitive urban design methods and ensuring that modelling caters for climate change.
- Investigate a communications program to public and business to build capacity for dealing with transport delays in extreme events.
- Advise of the location and function of safe shelters within the City of Melbourne that can be accessed in the event of a mass stranding.
- Review transport upgrade recommendations for Melbourne with relevant stakeholders to consider potential for inclusion of additional climate resilience measures.
- Liaise with identified stakeholders to discuss emergency response time trends and proposed benchmarking and control measures.
- Review any educational efforts underway or in preparation, for inclusion of content on safe behaviour around stormwater.
- Establish a level of cost containment for clean up following major events for benchmarking purposes.
- Identify major sources and locations of clean-up expense in the City of Melbourne following major events.
- Identify priority adaptations to mitigate clean-up expense in balanced consideration of other risks.

9.2.3 Adaptation measures – short term

The following potential immediate and short term adaptation measures are proposed for the City of Melbourne in managing the risks of intense wind and rainfall event.

9.0 Adaptation Actions for City of Melbourne

Proposed potential adaptation measures	Risks influenced / controlled											
	RW 1	RW 2	RW 3	RW 4	RW 5	RW 6	RW 7	RW 8	RW 9	RW 10	RW 11	RW 12
Increase directional and information staff at all major transport hubs and information announcements on transport	✓											
Emergency pumps either located in, or rapidly deployed to, high risk areas to reduce flooding impacts	✓	✓	✓	✓	✓			✓	✓	✓		
Widespread and early storm warning and communication system, incorporating transportation system status information	✓	✓	✓		✓					✓		✓
Build awareness of safe shelters that can be used in the event of mass stranding (ideally located at or new major transport hubs)	✓		✓									
Business and retail security education program on safe practices during transport delays	✓		✓									
Standby mobilisation of buss ervices with early warnings of severe storms for improved response times	✓											
Identify and apply protective measures from potential flying/falling debris	✓	✓	✓	✓	✓							
Communicate importance of keeping roads and tramways clear for the passage of emergency services	✓	✓	✓									
Identify critical road locations and routes for control and access for emergency procedures, and devise a response plan to ensure emergency passage and acess		✓	✓									
Business and public education program regarding stormwater risk			✓						✓		✓	
Create storm-protected evacuation locations for buildings and businesses			✓									
Rapid response cordoning of flooded areas to prevent entry by pedestrians and vehicles			✓						✓			
Increase cleaning regime for drains to ensure maximum capacity	✓	✓	✓	✓	✓				✓	✓		
Increase building strength standards across CoM				✓								
Identify high risk areas for rapid modifications (storm damage costs)			✓									
Broaden insurance cover to better protect council from sudden clean-up costs				✓								
Strategic priorisation and coordinated clean-up response to manage costs				✓								
Awareness campaigns to at risk businesses, preparation and insurance					✓							
Measures to strengthm trees, reduced risk of falling trees, branches: Increased 45˚ root watering, external supports, Looping - week branches						✓						

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 13: Adaptation measures: intense wind and rainfall - immediate and short term

9.0 Adaptation Actions for City of Melbourne

9.2.4 Adaptation measures – long term

The following potential long term adaptation measures are proposed for the City of Melbourne in managing the scenario of intense wind and rainfall event

Proposed potential adaptation measures	Risks influenced / controlled											
	RW 1	RW 2	RW 3	RW 4	RW 5	RW 6	RW 7	RW 8	RW 9	RW 10	RW 11	RW 12
Better drainage in low lying areas of transport system	✓	✓		✓						✓		
Widespread increase in stormwater capture and harvesting to reduce flood likelihood	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Progressive undergrounding of tram power supply	✓	✓										
Modernisation of train signaling system to improve system resilience and flexibility to individual breakdown	✓	✓										
More sophisticated use of exisiting network of City cameras to guide emergency vechicles, potentially from central control points		✓	✓									
Increase the extent of porous surfaces to reduce run off	✓	✓	✓	✓	✓				✓	✓	✓	✓
Improved drainage system for roads and around vulnerable buildings			✓	✓	✓					✓		
Ensure implementation of measures outlined under the Drainage Strategy, while also shifing focus, where required, to stormwater capture and harvesting to address other climate change risks	✓	✓	✓	✓	✓					✓	✓	✓
Continued roll-out of tree replacement program. Priorities replacement accounting to high risk locations	✓	✓		✓		✓			✓			
Increase building strength standards across CoM				✓								

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 14: Adaptation measures: intense wind and rainfall event - long term

9.0 Adaptation Actions for City of Melbourne

9.3 Heatwave

9.3.1 Adaptation responses- key themes

Actions undertaken by the City of Melbourne to adapt to extreme heatwave should be classified under the following strategy themes:

- cooler surroundings, inside and out, through improved infrastructure;
- better public knowledge and safe behaviour; and
- heatwave early warning system.

9.3.2 Actions

- Develop and implement the City of Melbourne Heatwave Response Plan.
- Liaise with adjoining municipalities to consider linkages in heatwave response plans
- Communicate with key stakeholders regarding the nature of heatwave risks and responses.
- Undertake scoping for wide ranging implementation of measures to gradually address the urban heat island effect.
- Investigate adjustments to transport interruption response plans to include heat relief (such as provision of water).
- Explore tiered warning system beyond main media outlets (for events such as Hong Kong typhoon warnings).
- Communications program to public and business to build capacity for dealing with transport delays in extreme events.
- Advise of safe shelter locations and function.
- Review transport upgrade recommendations for Melbourne to consider potential for inclusion of resilience measures.
- Undertake further communication with relevant stakeholders regarding the management of this risk.
- Review existing management plans for their adaptability to the need of managing infrastructure and assets in warmer temperatures.
- Liaise with relevant stakeholders regarding potential revision of engineering guidelines relevant to the City of Melbourne.
- Review adequacy of event planning and protocols to accommodate high temperature conditions.
- Identify priority public realm locations for modification over time to accommodate activity in higher temperatures.
- Incorporate consideration of rising temperatures into upcoming adaptation plans.
- Appropriate communication to at-risk groups to provide information regarding appropriate behaviour when extreme weather events occur.

9.0 Adaptation Actions for City of Melbourne

9.3.3 Adaptation measures – short term

The following potential immediate and short term adaptation measures are proposed for the City of Melbourne in managing the risks of extreme heat.

Proposed potential adaptation measures	Risks influenced / controlled													
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14
Implementation of detailed Heatwave Response Plan: active identification and care of at risk populations, measures to tackle high risk situation including events, transport breakdowns	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Public communication and awareness efforts regarding safety in hot conditions	✓	✓	✓	✓	✓			✓		✓	✓			
Provision of accessible safe locations	✓	✓	✓	✓				✓		✓				
Public steward education program (e.g. City volunteers)	✓	✓		✓				✓		✓				
Widespread and early Heat Wave Alert System, incorporating transportation system status information	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	
Increase police and security presence in hot conditions	✓			✓				✓		✓				
Improved shading at public events and key event venues	✓			✓			✓	✓						
More anti-violence outreach programs	✓			✓										
Training emergency staff to identify and manage situations in hot conditions	✓			✓										
Revise CoM asset management plans to include consideration of climate projections: application of contingency standard (strength) to soon-to-be constructed or refurbished key infrastructure ahead of revision of standards; critical asset augmentation; increased maintenance monitoring						✓								
Revised event protocols to enable safe, successful events in hot conditions: Improved communications with event attendees and organisers regarding precautions; water provision; event restriction over certain temperature thresholds; reduced alcohol provision							✓	✓						

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 15: Adaptation measures: extreme heat - immediate and short term

9.0 Adaptation Actions for City of Melbourne

9.3.4 Adaptation measures – long term

The following potential long term adaptation measures are proposed for the City of Melbourne in managing the scenario of extreme heat.

Proposed potential adaptation measures	Risks influenced / controlled													
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14
Implement changes to urban form to reduce heat island affect; urban and rooftop gardens; lighter building; roof and road colours; more extensive network of stormwater fed urban wetlands	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Revised building standards incorporating passive cooling, ventilation, and suitably rated materials	✓	✓	✓	✓	✓			✓		✓	✓			
Storm water street sprinkling/cooling mist facility	✓	✓	✓	✓				✓		✓				
Emergency/grid independent generation (e.g. solar) for ventilation	✓	✓		✓				✓		✓				
PT system improvements to reduce knock-on effects of individual breakdowns or service failures e.g. rail tunnel, bus service expansion	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	
Continued long term replacement of aged train/tram stock to provide greater resilience to hot conditions	✓			✓				✓		✓				
Development and implementation of revised engineering standards for infrastructure	✓			✓			✓	✓						
Ongoing efforts to redesign design public realm for comfort and enjoyment of all in hotter conditions: shading; cool places; public water facilities	✓			✓										

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 16: Adaptation measures: extreme heat - long term

9.0 Adaptation Actions for City of Melbourne

9.4 Sea level rise

9.4.1 Adaptation responses- key themes

Understanding the timing of sea level rise risks is critical to ensuring optimum management. Dealing with these risks requires maintaining a long term strategy to minimise cost and disruption. Decisions made today will directly influence the extent of vulnerability in future.

Actions undertaken by the City of Melbourne to adapt to sea level rise should be classified under the following strategy themes:

- Future proof planning, incorporating sensible precautions and contingencies for proposed future developments, or potentially restricting certain types of development in areas with a high risk of natural attrition due to sea level rise.
- Better protection for existing, low-lying developments.
- Better flood control through revised drainage planning.
- Measures to improve resilience to exposed infrastructure.

9.4.2 Actions

- Undertake scoping for the development of a sea level rise adaptation strategy to ensure adequately informed planning decisions for future developments, and timely introduction of protective measures for existing developments.

Areas for inclusion under such a plan include:

- Modelling of the altered flood risk and infrastructure impacts to low lying developments, in low lying areas in collaboration with the Department of Sustainability and Environment and Melbourne Water.
- Examining access and egress of at-risk residential structures and proposed future residential structures in the event of flooding.
- Development of suitable planning guidelines that reflect the findings of the modelling, and that minimise future vulnerability and maximise future resilience and adaptability to sea level rise.
- Appropriate stakeholder engagement including discussion of communication to raise awareness of adaptation actions for managing the impacts of sea level rise.
- A framework for the City of Melbourne to demonstrate reasonable decision-making in response to information that is available regarding sea level rise.
- Consideration of major adaptation decisions that may be required in future that will demand the involvement of the State Government and other impacted municipalities.

9.0 Adaptation Actions for City of Melbourne

9.4.3 Adaptation measures – short term

The following potential immediate and short term adaptation measures are proposed for the City of Melbourne in managing the risks of sea level rise

Proposed potential adaptation measures	Risks influenced / controlled																
	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16	S 17
Revised planning guidelines for habitable floor levels to better protect future development	✓	✓	✓		✓	✓	✓	✓	✓							✓	✓
More extensive stormwater capture and reuse infrastructure to decrease the potential flooding impacts of major events in the Melbourne City Council catchment	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓
Scoping of a more detailed Sea Level Rise Adaptation Action Plan, incorporating updated Australian Rainfall and Runoff data, that identifies a timeline of balanced and cost effective adaptation measures, and monitors changing knowledge in relation to projected sea level rise.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						
Documentation of processes and actions that demonstrate reasonable decision-making in light of information that is know in relation to SLR, potentially integrated with the delivery of a Sea Level Rise Adaptaion Action Plan								✓									

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 17: Adaptation measures: sea level rise - immediate and short term

9.0 Adaptation Actions for City of Melbourne

9.4.4 Adaptation measures – long term

The following potential immediate and long term adaptation measures are proposed for the City of Melbourne in managing the risks of sea level rise

Proposed potential adaptation measures	Risks influenced / controlled																
	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16	S 17
Application of infrastructure changes to protect areas from property damage from flood water. Such applications must be considered for their potential to increase safety risks and risks to other property by diverting and concertrating flood waters to more confined locations	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Include consideration of communication efforts regarding the risks of flood water, and safe behaviour in flooding events in scoping of Sea Level Rise Adaptation Action Plan				✓	✓		✓					✓					
Altered access and egress to at-risk residential buildings to provide safe transfer of people in the event of a significant flood				✓	✓	✓	✓										
Development of emergency evacuation procedures to quickly and safely remove at-risk residents and workers from buildings in the event of a flood				✓	✓		✓					✓					
Communication strategies will likely be required to inform investors and developers of the adaptation steps taken, particularly as awareness of the influence of sea level rise grows					✓	✓											
Direct liaison with at risk properties regarding appropriate insurance and preparation measures in the event of a flood							✓										
Documentation of processes and actions that demonstrate reasonalbe decision-making in light of information that is known in relation to SLR, potentially integrated with the delivery of a Sea Level Rise Adaptation Action Plan								✓									

Legend ✓ **Control Critical** ✓ **Active Management** ✓ **Periodic Monitoring** ✓ **No Major Concern**

Table 18: Adaptation measures: sea level rise - long term

10.0 High value adaptations

10.1 Expansion of stormwater harvesting and re-use

Among all of the adaptation options examined in this study, the expansion of stormwater harvesting and re-use is perhaps the highest value, highest priority adaptation action that can be undertaken by the City of Melbourne, for the following reasons:

- Harvesting and re-using stormwater effectively works to reduce likelihood and consequence of many risks, and addresses impacts and implications central to controlling the cascading effect of consequences. Harvesting and re-using stormwater:
  - diversifies the water supply to the City of Melbourne, reducing any impacts of drought and low rainfall, most notably in the maintenance of parks, gardens and sports fields;
  - helps to cool the urban environment by the proliferation of urban water bodies, contributing to the control of several extreme heat-related risks (when combined with greater efforts to tackle the urban heat island affect);
  - potentially reduces the likelihood of urban flash flooding in major rainfall events (further modelling is recommended to gain a better understanding of this), which works to control multiple cascading consequences;
  - improves water quality for rivers, contributing to greater river health and resilience of biodiversity in periods of low flow; and
  - can provide new, high quality amenity values through the creation of urban water features.
- The management of stormwater is one of the areas of greatest local government control.
- Risks relating to stormwater management are among the most foreseeable for local government, and hence potentially carry the greatest liability in relation to reasonable adaptation that is required to manage the impacts of climate change.

  The City of Melbourne is already actively engaged in stormwater harvesting and re-use, as highlighted both in the interactive *Water Savings Initiatives Map*, and the *Total Watermark - City as a Catchment* strategy reviewed as part of this study. This paper identifies that, "risks and opportunities for the urban environment and water management need to be considered on the basis of climate change impacts." The risk assessment work undertaken as part of this process has reinforced the relevance of the principles outlined in *Total Watermark - City as a Catchment* for managing the future impacts of climate change within the City of Melbourne.

10.0 High value adaptations

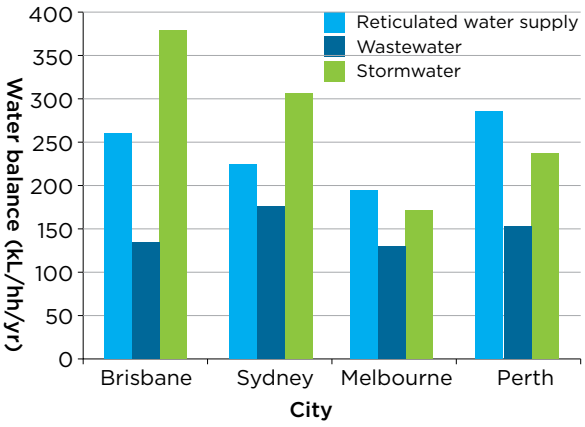

Figure 16: Average annual water balances from households (Brisbane, Sydney, Melbourne and Perth) (PMSEIC, 2007)

10.2 Develop and implement a heatwave response action plan

Research undertaken for this assessment has indicated that the risks posed from increasingly hot temperatures are real and significant in the immediate term. The City of Melbourne will develop a heatwave response action plan that will encompass various key areas including the following key areas:

- More detailed profiling of at-risk populations in the City of Melbourne, and means of providing aid during hot conditions. Key communication channels for reaching them.
- Revision of events protocols for hot weather conditions.
- Further investigation with a view to development of a heatwave alert system, to mobilise resources and trigger tiered responses.
- Education and capacity building among the City of Melbourne community.

The development and implementation of such a plan is important in both the short and long term. While improvements in the urban environment can help to control temperature (see 10.3 below), projections of rising temperatures suggest that active management and response, and safe behaviour of citizens during hot conditions will remain a key strategy to minimising risk.

10.3 Tackle the urban heat island effect

Temperatures within the CBD area can be up to 7°C higher than in less urbanised environments, due to the urban heat island effect. Action can be taken to mitigate the consequences of more frequent and severe hot conditions, through a range of design and infrastructure adaptations that provide cooling at the local level. While an extensive range of measures is likely to be required to achieve a municipality-wide effect, this is considered the most effective way for the City of Melbourne to control the serious consequences of rising temperatures.

10.0 High value adaptations

10.4 Heatwave alert system

A heatwave alert system issues a public alert when extreme heat events, with the potential to impact health, are forecast. These alerts can initiate timely public health interventions such as the provision of public information and the activation of heatwave response plans at a municipal level. Thresholds of a heatwave alert system will need to be specific to Melbourne with potential elements including maximum and minimum temperatures, relative humidity, duration of hot spell, cloud cover and air quality. Such a threshold should be established for Melbourne as a result of more comprehensive discussions and research among all stakeholders.

10.5 Actively plan to control the consequences of sea level rise

Effectively managing the risks of sea level rise, demands active planning today to reduce future vulnerability. This assessment has reported that the City of Melbourne should consider a 59cm rise in sea level by 2070. When combined with other flooding events or a storm surge, this has the potential to cause significant flooding. Modelling of the impacts of such a change should be considered as a priority to guide decision making into the future using guidelines that adequately reflect this change, and ensure that development planning in vulnerable areas is suitable for likely future conditions.

10.6 Develop more sophisticated communication and warning systems

Creating an informed and aware municipality is one of the best defences of public safety against climate risks. Empowering individuals and organisations to make better decisions in extreme circumstances goes a long way to controlling cascading consequences of climatic events.

Successful adaptation requires the development of communication and warning systems that are able to effectively reach both the resident and significant daily population of the City of Melbourne, as well as businesses and organisations that support the effective functioning of the City of Melbourne. These systems need to advise of the situation at hand, and serve as triggers for different tiers of response among stakeholders. Over time, such systems can develop a culture that more naturally and automatically responds to risks that are well understood.

10.0 High value adaptations

10.7 Monitor potential City of Melbourne liability in relation to responding to climate change

Recent literature indicates that local governments need to maintain vigilance in relation to the rapidly-changing space of reasonable action in response to climate change. As information about climate change grows in certainty, so too does the potential liability of local governments who respond inadequately or fail to respond to this information in areas where they assume high levels of control such as stormwater management. Liability and/or litigation can arise from two different sources:

- Failure to adequately plan for hazards associated with climate change which could have been reasonably anticipated and failure to communicate the risk of those hazards to stakeholders and the general public.
- Implementation of adaptation measures that are opposed by stakeholders or members of the community and subsequently challenged by the courts.

It is equally important that the City of Melbourne, in assuming a stewardship role for the municipality in responding to climate change, maintains clear demarcation of responsibility with partner stakeholders over appropriate response to potential climate change risk, to avoid assuming even greater liability.

10.8 Ongoing monitoring of risks

There is much uncertainty regarding the extent of future climate change and it is recommended that the City of Melbourne remain abreast of climate science on an ongoing basis. Risks will need to be reviewed in light of any changes made to projections and adjusted accordingly. As new control measures are developed (either by the City of Melbourne or other stakeholders) in response to a changing climate or other socio-economic pressures, risks and adaptation measures will need to be reviewed in order to ensure they remain appropriate.

11.0 Key Findings

As highlighted under the cascading consequence scenarios, the most successful climate change adaptations for the City of Melbourne are those that minimise the vulnerability of the City of Melbourne to the climate drivers outlined in section 4.0. Essentially, the City of Melbourne will adapt most effectively through measures that create a transition of the City of Melbourne toward an urban ecosystem that is an integrated part of the natural systems that influence it, rather than an urban anomaly that sits astride nature,

in separation from, and opposition to climatic forces. In this sense successful adaptation goes hand-in-hand with sustainability, provided adaptation is planned, proactive and tackles root causes.

Using the theme of urban ecosystem as the essence of the adaptation strategy, it follows that high value adaptation options will have the following characteristics:

- Address central impacts to controlling the cascading effect of consequences.
- Secure multiple adaptation benefits by the same action where possible, such as water harvesting for cooling, flood prevention, water system resilience and biodiversity protection.
- Align with climate change mitigation efforts within the City of Melbourne.
- Avoid significant climate shock through the development of diversity and resilience.
- Fosters a culture that understands and responds to climate risks through safe behaviour and care of self and fellow citizens, and supports broader adaptation measures.
- Promotes stakeholder partnerships, whereby all actors in the system contribute toward its harmonious functioning and allows the most appropriate focus of limited resources.
- Minimises urban development that will be adversely affected by changing climate conditions.

In addressing the four key climate change events likely to impact the City of Melbourne, high value adaptation responses should be aimed at achieving the following key aims:

- Control of the City of Melbourne microclimate in the face of rising temperatures.
- Increasing diversity of water supply and exploiting opportunities for water efficiency.
- Undertaking appropriate development planning that accounts for climatic changes, particularly sea level rise.
- Reduces the likelihood and consequences of urban flash flooding.
- Creates a cultural awareness of living safely within a changing climate.

To ensure the City of Melbourne's desired leadership position of stewardship of the city in responding to climate change is achieved, the City of Melbourne should engage with key stakeholders responsible for the relevant functions of the city to ensure a comprehensive and effective response. Significant capital investment and policy analysis will be required by the City of Melbourne to enable effective implementation of the adaptation options proposed in this report.

11.0 Key Findings

11.1 Common adaptations address multiple risks

It is evident that a number of high-value adaptation measures, when fully implemented, have the potential to reduce multiple risks across numerous scenarios. Examples include:

- stormwater harvesting and re-use;
- communication and warning systems for extreme events;
- measures to reduce the urban heat island effect; and
- community knowledge and capacity building.

Pursuing these high value adaptations should form the cornerstone of an action plan

11.2 Shared stakeholder responsibility

The unique characteristics of the City of Melbourne mean that effectively managing a number of the most significant risks is a shared stakeholder responsibility. Delivering on a leadership approach to climate adaptation will require engagement with key stakeholders to ensure climate change risks are incorporated into decision making that will affect the successful and safe functioning of the City of Melbourne.

11.3 Adaptation is under way

There is a great deal of work and effort underway by both the City of Melbourne and key stakeholders to adapt to climate change.

Part of the challenge is to ensure that efforts are consolidated under a framework of reducing climate risks, collaborative to deliver the greatest benefits at the least cost, and ensure that key areas of vulnerability are receiving due attention.

11.4 The current system state matters

The major risks to the City of Melbourne from climate change come from "shock" events. This assessment suggests that, in the near term, extreme heatwave and severe storms are the shock events that are most likely to deliver a number of serious risks. Where these shocks impact an already stressed system, it is clear that the consequences will be far greater. For the City of Melbourne, the transportation system is a key area of concern in this regard. All efforts to reduce everyday system stress will contribute towards adapting to climate change.

11.5 Background climate change cannot be ignored

While climate shocks are dramatic and attention grabbing, adaptation to climate change cannot ignore the subtleties of the everyday changes, such as overall higher temperatures and reduced rainfall. Such impact over time must be considered, particularly in the design and maintenance of infrastructure, parks and gardens.

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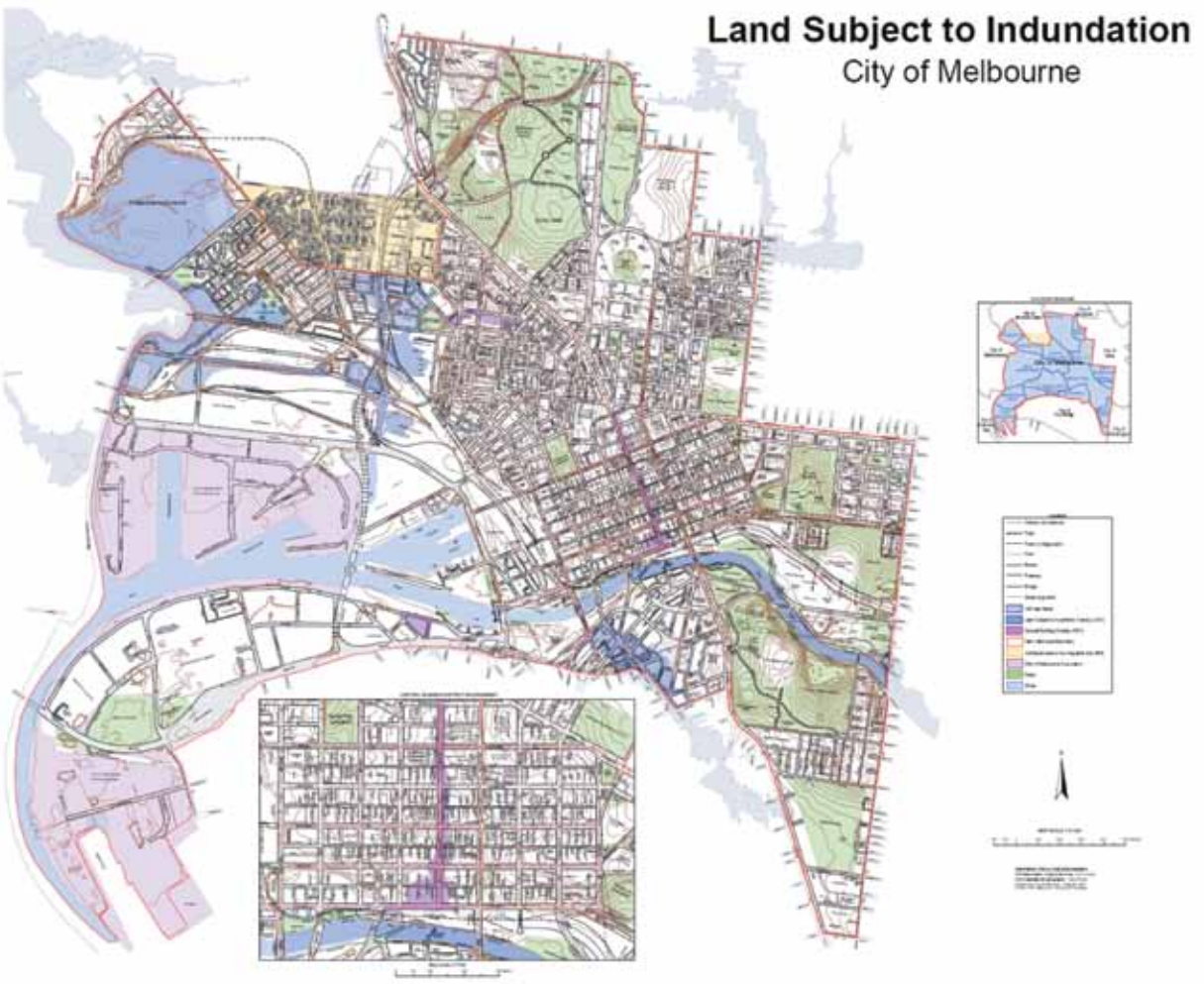
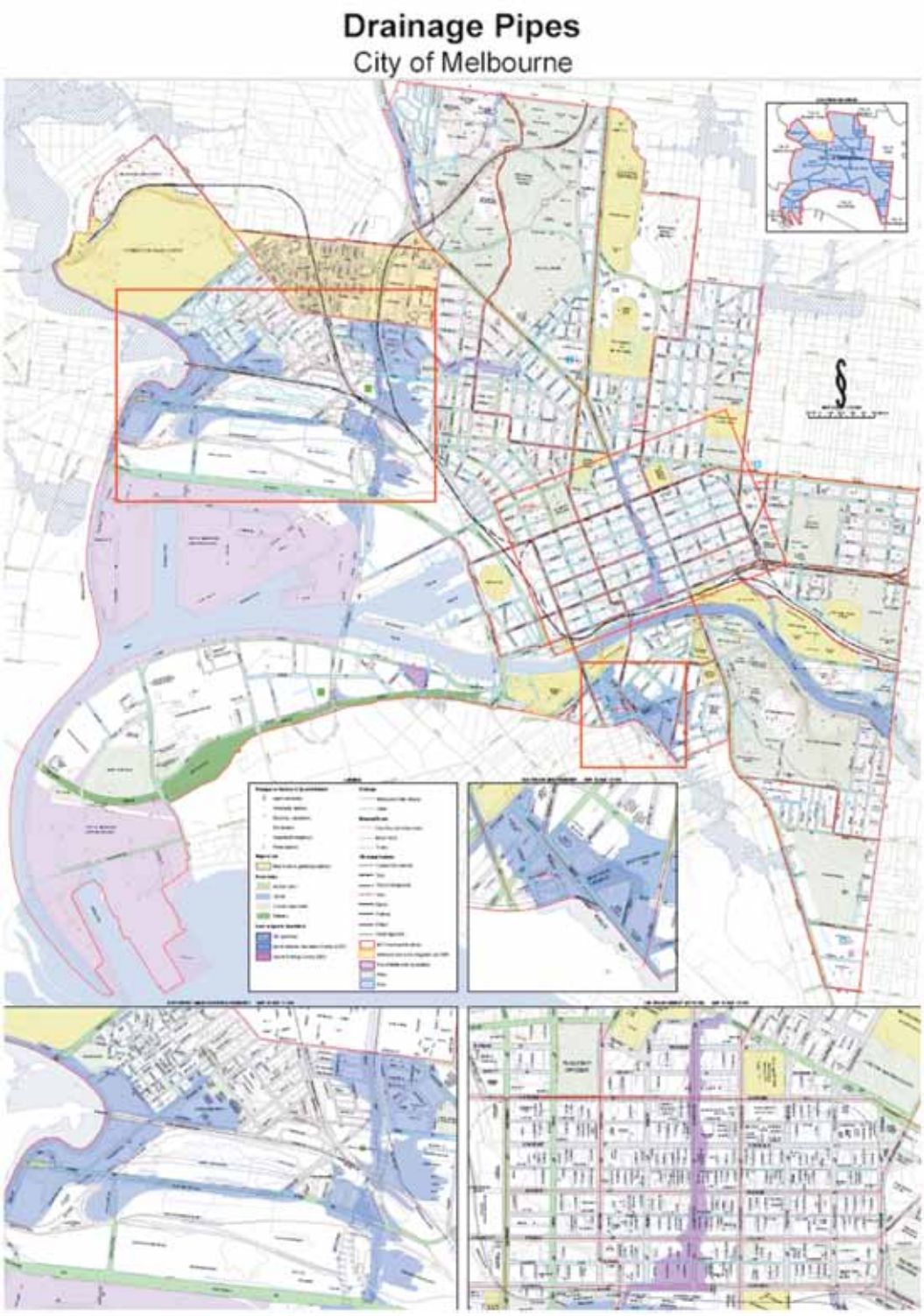
Appendix A
City of Melbourne Maps



Appendix A City of Melbourne Maps



Appendix B Methodology

Led by the City of Melbourne's sustainability team and guided by the project's Melbourne City Council Steering Group Committee, this project was undertaken in three phases: **Phase One, Risk Identification; Phase Two, Risk Assessment;** and, **Phase Three, Adaptation Action Plan**. Phases one and two included extensive consultation with external stakeholders responsible for aspects of city management and function. These included representatives from sectors in the integrated assessment framework (refer section 0) including water, transport and mobility, buildings and property, social health and community, business and industry, energy and communications and emergency services, to identify or affirm risks and current control measures.

These phases also included workshops with the Council Steering Group Committee to identify and build awareness of risks, assess potential consequences and current control measures, and build an understanding of climate change adaptation and resilience concepts. The process was closely aligned, where possible, with the City of Melbourne's risk management framework and benefited from the input of the City of Melbourne's risk management team.

Phases one and two of the project asked, "as a result of the projected climate change impacts for the City of Melbourne now, in 2030 and in 2070, '*what can happen?*', '*when and where?*' and '*how and why?*'". Phase three asked '*what can be done to avoid or mitigate it?*' Current control measures were considered when developing likelihood and consequence scores for present, 2030 and 2070 timeframes – these are defined as control measures that have already been implemented or those which have been committed to. Potential controls (such as those that are likely to occur) were not included in the risk ratings, but were considered in discussions regarding 'changes over time'.

Exploring these questions through stakeholders, research and expert analysis, allowed a range of informed possible outcomes and event scenarios to be developed and contextualised for Melbourne, from now to 2070. Potential cumulative circumstances, varying timing and hypotheticals were also contemplated for these scenarios to identify all potential, material risks.

Appendix B Methodology

To gain insights into the full range of potential system risks and influences, the cascading consequences of each event scenario were mapped. This systems view provides an appreciation for the inter-relationships of event impacts and implications and can help identify factors currently enabling a flow-on effect, that if adjusted may limit or disable the effect, and thus also any flow-on effects that the impact caused. These constraints to consequences reduce the overall event damages, and therefore the required adaptation response, by limiting the event's potential impact range. High value adaptation measures affecting multiple risks or consequences in a single initiative are of significant value to any adaptation program and can also be identified in this systems approach (see section 1.0).

Beyond looking at causal relationships and systems analysis, chaos theory states the outcome is based on initial conditions. Thus, the current condition of the urban systems likely to be affected by or required to respond to, climate change impacts is a key determinant in the outcome and must be considered as part of Melbourne's vulnerability assessment.

Melbourne's system state included in the integrated assessment framework were water, transport and mobility, buildings and property, social health and community, business and industry, energy and communications and emergency services sectors. These were all assessed based on consultation and research.

The analysis considered the condition and capacity of the system and whether its current status is one of stress or resilience (for detailed system state evaluations refer to 0). This allowed for a contextual evaluation and sensitivity analysis of whether a climate change impact would have particular influence on a system or would be easily absorbed. The analysis also allowed understanding of any particular pressures or processes of current relevance to a system that might provide opportunities for better alignment and collaboration for adaptation by the City of Melbourne with stakeholders.

Climate change will not happen in a vacuum and for its potential impact to truly be understood in a city context, risks must also be assessed in combination with current and changing city attributes such as socio-economic and sensitivity factors for a city. These factors include population and demographics, infrastructure condition and capacity, institutional control measures, community knowledge and skills and emergency services capacity. These sensitivity factors are key indicators of whether climate change impacts will be nullified or amplified in a given city context (IPCC 2004). They give weighting to the likely consequences of risks in local circumstances and provide further insights into how certain dynamics may be fine-tuned to contain the ramifications of particular impacts (see section 0).

Appendix B Methodology

After undergoing this multi-faceted analysis, all risks were provided a reference number and noted on the City of Melbourne climate change risk register. Each risk was given a combined risk rating based on a 1 to 5 assessment of its likelihood of occurring plus a 1 to 5 assessment of its consequence if it does, giving a combined rating out of 10 (refer to section 7.3.1 on page 31 for rating criteria). Given the City of Melbourne's risk management framework does not yet have consequence rating criteria for municipal risks (only council risks), ratings for municipal risks were given comparative ratings by the Maunsell risk assessment team based on the council consequence criteria. It is recommended these consequence criteria be further reviewed and defined with all stakeholders.

With combined ratings of likelihood and consequence, risks were then assigned a one to five rating for the known control measures currently in place to monitor or mitigate their occurrence. One is considered well controlled and five is considered uncontrolled. While further discussion with the City of Melbourne is required, a combined risk tolerance of six is recommended, meaning all risks rated seven and above are considered 'critical'.

Those critical risks with control measures rated one or two were considered 'control critical' and require strong management, ongoing monitoring and auditing of the control measure.

Those critical risks with control measures of three or higher are considered to be in 'active management' and require priority assessment and active response by the City of Melbourne and stakeholders.

It should be noted that the risk scores do not imply value judgements about the importance of one impact versus another. The risk rankings appearing in the report are for the purpose of identifying issues that require treatment or the attention of the City of Melbourne, rather than being value statements indicating the importance of one risk relative to another.

Risk ratings may change over time due to increased likelihood, consequences or controls and should be reviewed regularly. These likely changes have been reflected in the risk matrices for each time period (refer to sections 8.1.3, 8.2.3, 8.3.3, 8.4.3). While treatment has not been detailed in this assessment, risks rated below the tolerance threshold should also be reviewed by the City of Melbourne and control measures assessed and reviewed if necessary. A listing of these risks with brief sensitivity and adaptation advice is in Appendix C Non-Critical Risks.

Appendix C Non-Critical Risks

Risk	M/C?[5]	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Insufficient urban water supply										
W4- Increased health problems related to declining water quality	M	6	6	6	• Dependence on piped potable water supply	• Existing testing and monitoring of water by Melbourne Water	3	• Provision of bottled potable water	• Expanded testing, monitoring and (if required) treatment	• Melbourne Water • City West Water
W6- Social inequity and public conflict due to prolonged water restrictions	M	5	6	6	• Number of homes with gardens • Extent and duration of water restrictions • Availability and access to water alternatives	• Restrictions and enforcements • Public awareness campaigns	3	• Report infringements • Higher profile enforcement • Limit bore permits	• Shared garden co-ops with alternative water supplies • Rainwater tank inclusion in all new buildings or renovations encouraged • Encourage development of native gardens	• City West Water
W7 – Loss of revenue due to forced suspension of sports and events due to inadequate irrigation	C	5	6	6	• Sport events • Number events that provide revenue	• Lawn replacement to drought tolerant species • Use of reclaimed water e.g. Royal Park Wetland • Increased water efficiency practices	3	• Prioritisation of ground maintenance to enable maximum revenue	• Storm water harvest reuse • Recycled water uptake	• Melbourne Water • City West Water • Parks Victoria
W8 – Reduced public amenity on waterways	C	5	5	5	• Current water availability • Current use of waterways public amenity	• Environmental flows • Ongoing maintenance of banks and amenity works • Water sensitive urban design features for water cleaning, habitat protection such as ponds and tree pits	3	• Alternative public realm • Increase environmental flows • Increased frequency of organic matter cleanup	• Revegetate and landscape riverbanks to make more suitable for lower water levels • Implement proposed Water sensitive urban design projects	• Parks Victoria

5. Note: M=municipal risk and C=council risk

Appendix C Non-Critical Risks

Risk	M/C?[5]	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Insufficient urban water supply										
W9 – Loss public amenity reduced quality of public gardens	C	5	5	5	• Number of gardens using potable water (what is the makeup of the City of Melbourne water supply – potable/ recycled?). • Non-indigenous / sensitive plants • Geom-orphology of gardens • Shading exposure	• Alternative watering systems e.g. subsurface irrigation extension • Purchase of recycled water • Watering trees at 45 degrees angle • Wetland – Royal Park • Other re-use projects outlined in Water Savings Initiatives Map	3	• Turnover to water efficient plants • Reused water supply	• Implement proposed water re-use projects • Investigate further storm water reuse • Integrate wetland • Re-landscape gardens to indigenous gardens	• Parks and Recreation • Gardens Managers • Melbourne Water • Private project partners
W10 – Increased liability costs due to declining quality of water leading to public health issues	C	5	5	5	• Health issues • Current treatment costs	• Monitoring • Standards for quality	2	• Lobby for staggered pricing – so costs do not hit the most vulnerable	• Water us efficiency – shower heads, rainwater tanks and better water use	• Melbourne Water
W11 – Declining public health due to inability to access sports grounds	M	4	4	4	• Number of people dependant on grounds for activity • Number of substitute activities and alternative locations	• Drought resistant grass • Wetland water use • Dripper systems	2	• Communi-cation of alternative activities and areas available	• Further development of non irrigation dependant activities	
W12 – Future liability and reputation damage relating to construction dwelling unsuited to climate change	C	3	6	6	• Number of new dwellings to be constructed • Building standards not incorporating climate change consider-ations		4		• Update the building standards regularly to reflect climate change • Evolution of insurance products to offer financial protection from liability	

Appendix C Non-Critical Risks

Risk	M/C?	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Intense rainfall and wind event										
RW8 – Burst water supply pipes	C	6	5	5		• New pipes being laid are more resilient to ground movement	3			
RW9 – Health risk sewer inundation	M	5	6	6	• Where are the sewers? • Which sewers are prone to flooding? • Proximity to homes / schools / shops • How many failures of the sewage emergency overflow structures are known?	• Sewage emergency overflow structures (1:5 ARI event design)	3	• Communi-cation and evacuation plan – how to avoid the contaminated area • Develop more sophisticated clean up programs	• Increase sewage / emergency overflow capacity • Increase peak volume capacity • Manage-ment procedures	• City West Water
RW10- Cleanup cost from damaged/ stranded cars	M & C	5	6	6	• Cars in flood risk zones • Availability of towing services		3	• Secure contracted services to rapidly respond to events	• Minimise flood risk through storm water capture and water sensitive urban design	• Contractors
RW11 – Increased public health risk from waterways	C	5	5	4	• Number of waterway activities • Degree of community knowledge and awareness	• EPA and Melbourne Water monitoring	3	• Communi-cative strategies • River users • Education campaign	• Litter and pollutant control measures	
RW12 – Public discontent reduced access to river amenity	C	4	4	4		• Erosion protection	2	• Complaints management, prepare responses	• Slow storm water flow, develop storm water and water sensitive urban design	

Appendix C Non-Critical Risks

Risk	M/C?	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Heatwave										
H5- Increased prevalence of food-borne disease	M&C	6	6	6	• Number of high risk food vendors • Behaviour of population in transporting and storing food	• Activities undertaken by the Health Services branch of the City of Melbourne, enforcing the Food Act 1984 • Food safety programs for registered food businesses • Food safety program template for events	2	• Expanded education and communi-cation regarding safe food storage and handling	• Assessment of th e need for revisions to food safety standards	• The City of Melbourne • Department of Human Services/ Food Safety Victoria • Food retailers.
H9 – Business interruption due to electricity blackout	M	6	5	5	• Number of businesses without interruption cover	• Increased network security measures • Business contingency plans, back up generation, distributed network	3	• Communi-cate importance of interruption cover and management plans	• Run events scenarios with businesses to test management plans	• Small and medium Enterprises • Victorian Employers Chamber of Commerce and Industry • Retailer and Hotel Association
H10 – Increased stress related death/ injury due to elevated temperatures (City of Melbourne workers)	C	6	6	6	• Outside workers • City of Melbourne owned buildings	• Heat wave alert system • Air conditioning • Heat wave response plans for events • Implement Heatwave Management Plans (issued by Department of Human Services) • Occupational Health and Safety procedures for outdoor work	4	• Heat wave alert system • Public communi-cation and awareness • Heightened care • Temporary relocation • Public steward education program	• Building standard passive cooling – ventilation – rating materials • Urban gardens • Paint roofs white • Storm water street sprinkling • Solar power ventilation • Systems/ generator	• Outdoor workers/ contractors • Unions • Emergency Services • Medical services • Power companies

Appendix C Non-Critical Risks

Risk	M/C?	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Heatwave										
H11 – Respiratory illness and social disruption due to poor air quality	M	5	6	6	• Number of elderly people, asthmatic people and those with other respiratory illnesses	• Environ-mental Protection Authority monitoring and warning • Media warnings	3	• Additional risk communi-cation through City of Melbourne channels		• Health Services • Hospitals • Schools
H12 – Passengers injured due to derailment	M	5	5	6	• Number of people using trains/trams • Weekdays and events • Number of expected hot spells • Transport infrastructure temperature thresholds	• Connex and Yarra Trams response protocols • Rescue plan • Slow down orders from monitoring tracks • Buses – alternative modes of transport • Progressive replacement of aged train/ tram stock	4	• Planned emergency response	• Continued rail maintenance/ inspections • Continued / accelerated investment in newer train/ tram carriages	• Connex • Yarra Trams • Emergency services
H13 – Increased closure of schools due to poor air quality	M	5	5	5	• Schools within boundaries • Ability of school buildings to function in bushfire conditions	3				

Appendix C Non-Critical Risks

Risk	M/C?	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Sea level rise										
S3- Environmental damage due to flooding of industrial areas in expanded flood zones	M	4	6	6	• Number of facilities posing an environmental risk if flooded • Number of these facilities in potential expanded flood zones	• Existing storage and containment guidelines for environmentally hazardous substances	3	• Identification improved containment of hazardous substances at risk of flooding impact	• Improvement of flood protection infrastructure	• The City of Melbourne, Environmental Protection Authority, Parks Victoria, potentially impacted businesses
S9 – Damage to business due to expanded flood zone at fisherman's bend	M	3	6	6	• Number of businesses in expanded flood zone • Value of businesses • Level of insurance against level of flood	• Business contingency insurance	3	• Communicate regarding changed flood risk in the City of Melbourne • Liaise with business regarding adequate protection	• Water sensitive urban design and storm water capture • Increased drainage capacity	• Affected businesses • Insurers
S10 – Damage to road and rail infrastructure due to expansion of flood zone	M&C	3	6	6	• Dependence on at risk road and rail • Availability of substitutes	• Road Management Plan	4		• Progressive infrastructure strengthening as changed flood zone becomes known and risk increases	• VicTrack • VicRoads
S11 – Interruption of freight movement due to expansion flood zone	M	3	6	6	• Extent of financial loss from cessation of freight movement • Dependence on key routes		4		• Identify and improve alternative freight routes • Develop freight movement plan in case of emergency	• VicRoads • Police • VicTrack
S12 – Mass stranding of workers due to flooding at Fisherman's Bend	M	3	6	6	• Size of the workforce • Substitute modes of transport • Substitute routes		4	• Encourage transport alternatives where available	• Provide improved alternative public transport, bicycle services to the district • Priority storm water capture to keep key routes clear	

Appendix C Non-Critical Risks

Risk	M/C?	Now	2030	2070	Sensitivity	Control	#	Reactive	Proactive	Stakeholder /s
Sea level rise										
S13 – Decreased waterway activity and loss of major events due to reduced bridge clearances	M&C	2	5	6	• Current margins of clearance for different boats and activities • Dependence of the City of Melbourne and Docklands on events		5		• Local water events • Smaller water craft • Raise bridges	• Boat business operators • VicRoads
S14 – Increased maintenance of marine structures due to higher water levels	C	2	5	6	• Value of exposed assets	• Asset management plans for bridges, roads and other	2		• Revise maintenance needs • Phase in more advanced materials, paints, protections and reinforcement	
S15– Decreased use of boating facilities due to increased flood return	M&C	2	5	6	• Number of boat movements at different times • Reliance on boats for economic activity		5		• Communi-cation system to advise users of down time • Modified marinas and berthing	
S17 – Decreased use of public realm due to increased flood return	M&C	2	5	6	• Reliance, use levels of at-risk public realm	• Extensive and ongoing program of improvements to provide diverse, high quality public realm	2		• Storm water collection	

Appendix D Likelihood, Consequence and Risk Rating

Likelihood	Number	Description
Almost Certain	5	The event is expected to occur in most circumstances
Likely	4	The event will probably occur in most circumstances
Possible	3	The event should occur at some time
Unlikely	2	The event could occur at some time
Rare	1	The event may occur only in exceptional circumstances

Table 19: City of Melbourne risk likelihood ratings

Consequence	Category	Business Continuity	Environmental	Financial and Economic	People and OHS
Catastrophic	5	The continuing failure of the City of Melbourne or major service providers to deliver essential services. The removal of key revenue generation.	Catastrophic and irreversible environmental damage attributed by the courts to the negligent or incompetent actions of the City of Melbourne.	Above $20,000,000 (calculated as approximately 10% of the City of Melbourne's annual revenue before tax)	Multiple fatalities (more than five persons) and significant irreversible disabilities.
Major	4	Widespread failure to deliver several major strategic objectives and service plans. Long-term failure of major service provider causing lengthy service interruption.	Long-term and widespread environmental damage taking greater than 5 years to recover and requiring significant restorative work.	$2,000,000 to $20,000,000	Single or multiple fatalities and multiple irreversible disabilities.
Moderate	3	Failure to deliver minor strategic objectives and service plans. Temporary and recoverable failure of service provider causing intermittent service interruption for a week.	Significant environmental damage taking several years to recover and requiring moderate restoration work.	$200,000 to $2,000,000	Multiple irreversible disabilities and/or critical long-term injuries.
Minor	2	Temporary and recoverable failure of service provider causing intermittent service interruption for several days.	Minor environmental damage such as remote temporary pollution.	$20,000 to $200,000	Single or multiple disabilities requiring short to mid term hospitalisation/ medical aid.
Negligible	1	Negligible impact on business processes, brief service interruption for several hours to a day.	Brief, non hazardous, transient pollution or damage.	Up to $20,000	Injuries requiring minimal temporary first aid.

Appendix D Likelihood, Consequence and Risk Rating

Consequence Category		Reputation	Infrastructure and Assets	Political	Liability
Catastrophic	5	Loss of support of the State Government with scathing criticism and removal of the Council. International media exposure.	Long-term loss of Town Hall, CH1, CH2 or CBB, including damage to the City of Melbourne assets such as IT infrastructure etc.	Loss of power and influence restricting decision making and capabilities. Dismissal of the Council by State Government.	Regulatory or contract breaches causing very serious litigation, including major class action. Significant prosecution / fines for the City of Melbourne and individuals.
Major	4	Public and National media concern / exposure with adverse attention and long-term loss of support from the City of Melbourne residents.	Short to mid term loss of Town Hall, CH1, CH2, or CBB. Damage to the City of Melbourne assets.	Major adverse impact and intervention by Common-wealth and State Government.	Major regulatory or contract breaches and litigation. Liability implications and fines for Directors/ Managers.
Moderate	3	Significant statewide concern / exposure and short to mid term loss of support from the City of Melbourne residents.	Damage to one part of a major facility or many parts / all of a small facility.	Moderate adverse impact and intervention by State Government.	Regulatory or contract breaches causing investigation / report to authority and prosecution and moderate fines.
Minor	2	Minor local community concern manageable through good public relations.	Damage to internal assets, system etc. Isolated to a part of a facility.	Minor adverse impact and intervention by Local Government Authorities and Municipal Association of Victoria.	Minor regulatory or contract breaches causing likely prosecution and minor fines.
Negligible	1	Transient matter, such as customer complaint, resolved in day-to-day management.	Minor property damage such as storm, criminal, accidental, no internal asset damage.	Negligible impact from one Local Government Authority.	Negligible regulatory breaches that are detected early and rectified. Insignificant legal issues and non compliance.

Table 20: City of Melbourne risk consequence ratings