OCCASIONAL PAPER 27

Climate Change Adaptation and the Australian Urban Water Industry

MARCH 2012

WATER SERVICES ASSOCIATION OF AUSTRALIA

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Overview of WSAA

WSAA IS THE INDUSTRY BODY THAT SUPPORTS THE AUSTRALIAN URBAN WATER INDUSTRY

Its members and associate members provide water and wastewater services to approximately 16 million Australians and many of Australia's largest industrial and commercial enterprises.

The Association facilitates collaboration, knowledge sharing, networking and cooperation within the urban water industry. It is proud of the collegiate attitude of its members which has led to industry-wide approaches to national water issues.

WSAA can demonstrate success in the standardisation of industry performance monitoring and benchmarking, as well as many research outcomes of national significance. The Executive of the Association retain strong links with policy makers and legislative bodies and their influencers, to monitor emerging issues of importance to the urban water industry. WSAA is regularly consulted and its advice sought by decision makers when developing strategic directions for the water industry.

ACKNOWLEDGEMENTS

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About Elements Strategic & Risk Management

Elements SRM offers a range of sustainability, environmental, climate change and climate variability related services. Elements SRM engages businesses in the public and private sector to help adapt to a changing climate, manage the risks of extreme climate variability such as floods and drought, develop strategies to help reduce greenhouse gas emissions and energy management and reduce environmental impacts and improve sustainability. Let us help you 'Manage the Elements'.

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Foreword

Growing evidence indicates that the water and wastewater sector will not only be affected by climate change, but that many of the impacts of climate change will be delivered through floods, droughts or severe storms. Water resources will change in both quantity and quality, potentially requiring investments in new source developments; whilst existing water, stormwater and wastewater facilities infrastructure will face a greater risk of damage. At a time when society's capital and financial resources are already strained, and the community is already sensitive to the devastating impacts of recent natural disasters, continuing climate change presents a significant strategic challenge for our industry,

This emerging realisation is echoed by the Intergovernmental Panel on Climate Change's report, Managing the Risks of Extreme Events and Disasters to advance Climate Change Adaptation which states that "where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase, and these increases will be substantial in the areas most directly affected. Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages."

While certain actions being taken by urban water utilities may help to reduce their exposure to climate change, there is an evident need to address climate vulnerability more systematically.

Some of the measures currently being implemented primarily address short-term concerns. For many utilities longer term actions may often appear to be unaffordable or unfeasible given perceived complexity, a lack of scientific information relevant to the urban environment, or a lack of coordination with other authorities related to issues such as resource protection and flooding.

Many WSAA members have been focusing on climate change adaptation over and above traditional water supply issues as they will need to adapt their infrastructure and operations to cope with the future impact of climate change.

These analyses have been developing around the key elements of the business model i.e. (strategic and tactical) planning needs, design and installation, operations and maintenance, customer service, business continuity and so on. The focus has been on identifying what climate change might mean for these elements.

In response to these analyses, the water industry is developing an adaptation tool specifically for water utilities. "AdaptWater" will capture and quantify the complexity of modern utilities economic, social and environmental performance requirements and integrate the effects of evolving direct and indirect climate change hazards.

The next stage of the water industry's adaptation work will need to include consideration of how the urban water sector can contribute to the overall community response/adaptation to climate change, especially in relation to:

> **Asset management and maintaining built infrastructure:** the large asset base and long-term horizons for decision-making make asset management and maintenance key issues for water utilities owner/operators. This is compounded by the ageing of infrastructure

> **Water quality and quantity:** new climate conditions and changed infrastructure configurations will require innovations in water treatment

> **Cities of the future:** our urban and social resilience – particularly in the face of population growth and changing demographics – will be a result of integrated and comprehensive planning.

To assist the water industry in this task, WSAA held a climate change adaptation workshop. The key objective of the workshop was to spell out the major gaps, current approaches/tools, future needs for tools and finally to develop some processes and frameworks as to how we might close those gaps and provide opportunities for improvements to decision making. The desired outcomes of the workshop were to transfer information and approaches in order for WSAA members to develop a common understanding and consistent approach, and to identify relevant issues to take forward for positioning, research and action.

From the information presented in this report there are seven key messages that were identified as important for WSAA and our members going forward. These key messages are mainly focused on keeping an open dialogue with government departments and regulators, the significant relationship between energy and water, and to ensure cross sectoral planning.

The key priority actions in this paper are also crucial to assisting the water industry in its response to adapting to climate change. These actions are mainly focused on stakeholder engagement and collaboration to leverage what we can and share this with the international water industry community.

There remain some important areas for research so it's important that the urban water industry is proactive in this area given the risk to water security and quality, water and sewer assets, and community concerns over climate change.

WSAA will continue to work with its members to improve its understanding of how the industry can contribute efforts to adapting to climate change. WSAA will be developing a Climate Change Network in which members will be communicated with on an ongoing basis and updated on relevant research and projects via WebPages on the WSAA website. These WebPages will also include a Climate Change Clearinghouse where members can download information and upload reports to share with other members.

I would like to thank the WSAA members who attended and contributed at the October workshop and in particular the small steering committee formed to review the paper along its development. I would also like to thank Mark Burford (Nous Group) and Carolyn Tsioulos (Elements Strategic & Risk Management) for their contributions to preparing the final paper.

Adam Lovell, Executive Director, WSAA

Executive summary

Climate change projections for Australia suggest a hotter, drier climate, rising seas and more intense fires and floods (BOM 2010). These projections will be critically important to the management of water services across the country because the water cycle is highly sensitive to climate. Therefore, the water industry in Australia is facing an unprecedented challenge, with implications for all facets of the urban water cycle from water supply, sewerage transfer and treatment and infrastructure, to river health, drainage and flood management.

The Australian water sector has already been exposed to the extreme variability and long term changes that the climate can bring. 'Natural disasters' such as floods, droughts and bushfires are some of the issues the country has faced in the last 10 years, many arising from record breaking extreme rainfall (Mullen 2009) and extreme temperatures respectively (BOM 2011). Events such as these have had enormous impact on the water industry across Australia and the way they do business.

Collaboration and engagement across the water sector will be critical to ensure continuing successful adaptation to a changing climate. Such collaboration has been demonstrated through events such as the Water Services Association of Australia (WSAA) Climate Change Adaptation workshop.

This report draws upon the findings and discussions arising from this workshop, and organised into three key themes. Within each theme, the risks and key challenges are identified, as are the adaptation actions that have already been initiated. This report summarises those activities, and highlights opportunities to further enhance the Australian urban water industry's preparedness for both current and future climate change.

BUILT AND SOCIAL ENVIRONMENT

The impacts on the built and social environment are complex and far reaching. Customer service standards for water, sewerage and drainage all have the potential to be affected. These changing levels of service could give rise to social implications particularly in response to changing flood levels and sea level rise.

Whilst there is clear scientific consensus that anthropogenic climate change is now occurring, and a broad agreement on the general nature of this change, there is still a degree of residual uncertainty around the exact scale and timing of these effects. (Recent observations suggest a trajectory at the upper end of IPCC forecast ranges), The secondary impacts of these climatic changes and the consequences for human behavioural, social, technological and economic systems are further mediated by a complex set of interrelationships and interdependencies, and are even harder to predict. Uncertainty is thus an inherent feature of the climate change challenge, and will never be resolved simply by waiting for more information. Investment decisions water utilities will face have costly implications for both current and future generations, with increased risks of wrong decisions, poor allocation of capital, potential for stranded assets, and/or missed opportunities for efficiencies.

Despite these inherent uncertainties, some long term investment decisions have already been necessary to meet immediate needs, particularly to secure water supplies in areas that have experienced drought in the last ten years. Whilst this does represent some form of progress on climate change adaptation, it is still based upon shoring up the traditional large scale, centralised urban water supply model based upon long lived permanent assets against the increased risks of (possibly) short term supply shortages. It is not certain that such assets will be fully utilised throughout their life, or deliver the level of benefits that were assumed in making the investment decision.

The actions to increase the robustness of existing systems is a reasonable first step in climate change adaptation, but the efficacy of this approach is ultimately limited if the scale of climate change extends again beyond the range of scenarios anticipated in the design, or if the nature of change flips to a different state (e.g.: from persistent drought to increased flooding), or if the broader social and urban systems themselves change in response to climate change (e.g.: human settlement patterns, urban form, behaviours and cultural norms, social attitudes and values, etc). Indeed, different approaches based upon 'soft fail' alternative operating modes, multiple-redundant or decentralised systems, community resilience, adapting urban form, and active engagement to re-prioritise community expectations may provide our society with more productive and cost-effective adaptation pathways over the longer term.

These more mature systems-based approaches are beginning to emerge, with significant potential to provide increased resilience and preparedness for future climate change at reduced societal cost. Initiatives such as 'Cities of the Future' are starting to see a change in thinking about the future of water in the urban environment that will provide multiple benefits and greater surety in a changing climate.

BIO-PHYSICAL ENVIRONMENT

The second theme of our analysis is the biophysical environment, encompassing climate change impacts related to public health, water quality, source water, catchments and river health and receiving waters. These impacts may be highly localised and non-uniform across the water industry, as each environment, catchment, water source and receiving water will respond in different ways to a changed climate, and because of differing pre-existing pressures on these natural environments.

The WSAA workshop identified a need for deeper understanding of bio-physical dynamics, and recognised that they are likely to be different for each catchment or region. An example of such region-specific research is the Wungong Catchment Management Trials (forest thinning) in south west Western Australia, South Eastern Australia Climate Initiative (SEACI) and Geosciences Australia's national vulnerability assessment.

A need for research into the responses of various micro-organisms (pathogens, cyanobacteria, etc) to changed climate regimes, and potential public health considerations for management of water supply and wastewater systems was also recognised. Such research would be more universally applicable across the industry, and of relevance to all water utilities and public health regulators.

Other adaptation actions relate to monitoring systems and data capture to provide continuous assessment of biophysical factors (concentration of pollutants and pathogens in water sources, soil characteristics etc), and the development of associated tools and organisational learning processes to feed this information back into design and asset planning processes, and to develop models of how climate change can affect these biophysical and microbiological process in the environment.

Modelling, monitoring and learning processes such as this can build an inherent adaptive capacity into the industry, which allows new approaches to continuously evolve apace as different climate change effects unfold. Similarly, innovative research catchment trials and new monitoring and response systems extend beyond traditional approaches to include the interrelationships between urban water and contextual biophysical systems, and represent the beginnings of more comprehensive and systems based approaches to adaptation and the management of climate vulnerability.

INFRASTRUCTURE

Water infrastructure is recognised widely as being at risk from climate change. The implications for asset failure and reduction in asset life will cost water utilities and the paying community. Asset failure can be a catastrophic failure or the inability of an asset to perform its functions properly: either affects the ability of the water utility to perform its role. Asset failure due to fatigue or ongoing degradation of an asset may lead to catastrophic failure or alternatively increased renewal and replacement cost.

Table 1 illustrates the variability of average replacement costs to water and sewer network infrastructure in Australia.

	Mains (km)	Low Complexity Replacement Cost ($b)	High Complexity Replacement Cost ($b)
Water	146,000	40	175
Sewer	123,000	34	148

Table 1: Australian water and sewer network replacement costs

Resilient infrastructure design that allows for redundancy, 'soft fail' options, and alternative operating modes is already applied by many water utilities. In anticipation of future climate change and in response to early warning signs such as a decline in rainfall over south west Western Australia there have been moves across Australia by water utilities to:

> diversify water supply;

> create interconnected water supply grids or systems;

> build redundancy into sewerage systems to cater for increase peak flows; and

> understand other potential impacts on infrastructure such as odour and corrosion.

In general the risk management systems adopted by water utilities manage the risks and hazards to water infrastructure very well. These systems now need to be adjusted to further account of climate change and could be done in collaboration with national programs such as National Climate Change Adaptation Research Facility (NCCARF) Settlements & Infrastructure Program and Critical Infrastructure Program for Modelling and Analysis (CIPMA).

It is evident from the discussion that the Australian urban water industry has been amongst the first built environment system to be affected by climate change, and amongst the first industries globally which has had to develop an adaptation response. These early responses have been positive, but there is opportunity to improve upon these approaches, and much more that will need to be done as further climate change takes place. There is still much to learn from water agencies and utilities overseas, and from vulnerability and resilience approaches being developed by various research institutions and organisations.

CONCLUSIONS

KEY MESSAGES

From the information presented in this report there are seven key messages that have been identified:

The Federal Government has good existing programs to assess the vulnerability and risks to infrastructure of climate change and associated extreme events: the potential bill for replacement of water assets is huge and enough to warrant the government to show a greater urgency in preparing for these risks.

The report clearly shows that Australian cities and towns need more resilient and climate independent sources of water. Current policy bans in place around the states inhibit that resilience and removal of policy bans, including the rural – urban trading and potable recycling and in some cases dams is a top priority

> Climate ready regulators: clearly the impacts of short sighted and non-complementary regulation under climate extremes and variability could generate significant costs for water utilities and these costs would be passed onto customers. Ensuring health, environmental and economic regulators are collaborating to achieve optimal outcomes for water utility customers is critical. With a replacement or rehabilitation cost as shown in Table 1 increasing water

quality challenges for both drinking water and environmental water, the heavily regulated water industry needs regulators to be as adaptable as the utilities will need to be, to invest in more complex, expensive and potentially shorter lived assets.

> The energy-water nexus is now a vital issue as pressure increases on ways to increase supply of water independent of rainfall, to manage power and water supplies during catastrophic events, to develop energy supplies not dependent on coal and to reduce both water and energy use in businesses and homes. All levels of government must act now to ensure decisions on refurbishing or planning new infrastructure, and on encouraging resource efficiency, strongly consider the energy-water nexus.

> Utilities will need to consider the 'retreat' option in some circumstances. Utilities will look for opportunities to move crucial equipment, including pumps and other important assets out of low lying areas. And assets now need to be viewed as having multiple uses throughout their long lives. For example some dams and aquifers may need to play a bigger role as storage reservoirs for climate-independent (e.g. desalination and recycled water), year round water production.

> The extreme drought across the eastern seaboard in the mid-2000's ignited the debate around the role that water restrictions should or should not play in the efficient management of urban water. This debate has now matured in the industry to an acceptance that low level (common sense), permanent water saving measures do make a valuable contribution to the long term efficient use of water by our customers.

> Australian cities, towns and communities of the future will be technically and socially more complex, infrastructure will be more interconnected and resources such as energy and water will be more expensive. The reduce the cost pressures to the community, a much greater urgency needs to be placed on cross sectoral planning so that all Australians can enjoy healthy, liveable cities that will stand the test of time the extremes of climate change.

PRIORITY ACTIONS

Research and adaptation opportunities are identified in the report for each theme as well as enabling actions that will assist water utilities in the areas of:

> climate science, hydrology and uncertainty;

> decision support; and

> collaboration

Issue	Key Priority Action	Outcome
Identifying key stakeholders	Identify stakeholders (including international organisations) with *strong interest and involvement* in climate change adaptation to clarify and prioritise opportunities for collaboration in both policy and science.	A mud map of key stakeholders that can form the basis for the National conversation, and help in developing and delivering on the roadmap.
National conversation	WSAA to lead a national conversation with its members on the topic of climate change in the context of the 2009 Victorian bushfires, the 2011 Queensland floods, the 2010 record dry winter in Perth and the pending carbon tax.	A roadmap that provides clear research and policy direction to Government, research institutions and customers on what is necessary to ensure essential water services are protected from climate change.

Engagement with regulators	Engage with economic, public health and environmental regulators to encourage them to become 'climate ready.'	Regulators have a deep understanding and appreciation for climate change issues, the impacts for future decision-making frameworks and the likely trade-offs required in investments in infrastructure.
Collaboration with National scientific institutions	Collaborate to leverage access and potentially influence climate change modelling and adaptation work undertaken by CSIRO, BOM and the Centre of Excellence for Climate System Science	Climate Change modelling and adaptation science at the National level has relevance to the real issues facing water utilities, and significantly assists the industry in managing for climate change.
Collaboration with International scientific institutions	Collaborate with the US based Water Utility Climate Alliance (WUCA) and utilise existing WSAA relationships with the Water Research Foundation (WaterRF) and the Water Environment Research Foundation (WERF) in priority areas, developing, trialling and documenting case studies of decision-making tools	Climate Change research at the International level covers decision-making tools which can be applied in the Australian context.
Conceptual models	Develop a suite of conceptual models, incorporating a 'model business case' and including CIPMA overlays, to identify vulnerable assets, infrastructure and communities. Develop a 'model business case' for investment (in infrastructure or a program) that incorporates a climate change adaptation perspective – for use in sector capacity building and for engagement with industry regulators.	People and assets in vulnerable areas are protected from climate change impacts or moved away if protection is not possible. The urban water industry and regulators understand the scale of what is required to adapt to climate change from an economic, financial, health and wellbeing perspective. And appreciate the flow on effects that catastrophic events can have in the community, natural environment and economy.
Knowledge sharing	Build and share knowledge on water utilities' responses to record-breaking events.	All water utilities have a good understanding on how to plan for, manage and continue to meet customer needs in the face of events which may affect them like catastrophic storms, floods, heatwaves, drought or bushfires.
Climate Change Adaptation Network	Develop a Climate Change Network in which members will be communicated with on an ongoing basis and updated on relevant research and projects via WebPages on the WSAA website. These WebPages will also include a Climate Change Clearinghouse where members can download information and upload reports to share with other members.	All members have a 'one stop shop' for climate change issues (particularly adaptation issues) to encourage sharing of information and ideas, and to ensure doubling up of work is avoided where possible.

Whilst the early responses of the water industry were simply an incremental extension of risk mitigation applied to traditional approaches, more mature and broader systems based approaches are emerging to build resilience and enhance the adaptive capacity of our urban water systems. These approaches are better able to deal with the uncertainties of future climate change, improve overall preparedness at a lower societal cost, and reduce vulnerability of our critical infrastructure services.

What has become clear through the actions identified is that there is still a large amount of work to be undertaken in all themes and that the science continues to play an important role, whilst collaboration is emerging as a cornerstone to successful adaptation by enabling all areas of the community, government, sectors and utilities to work together on moving towards water sensitive cities.

1.0 Background

1.1 CLIMATE CHANGE AND VARIABILITY

Climate change and the risks it presents has become one of the biggest and most confronting issues in recent times. The climate is the most critical chemical and physical factor influencing human settlement and its survival. Communities, businesses and governments worldwide rely on the climate among other things for; providing water to drink, providing optimal conditions for agriculture to supply food and maintaining the temperature range and ecological conditions suitable for habitation. Climate change puts at risk the world we know today and projections for the future paint a worrying picture and even if the world takes action now to reduce greenhouse gas emissions that influence climate change, there is still likely to be an unavoidable change due to past and imminent future emissions to which the world must adapt.

Australia experiences wide climate variability; from the hot tropics in northern Queensland and the Northern Territory to the wetter climate of Tasmania, and the dryness of central Australia. Communities living in these areas and across the rest of the country have historically adapted to these varying conditions. However, changes to the 'normal' range of climate and weather conditions in the different regions of Australia are becoming a reality.

Climate change projections for Australia suggest a hotter, drier climate, wetter tropics, rising seas and more intense fires and floods (BOM 2010). These projections will be critically important to the way water services are managed across the country because the natural water cycle is highly sensitive to climate. Therefore, the water industry in Australia is facing an unprecedented challenge, with implications for all facets of the urban water cycle from water supply, sewerage transfer, treatment and infrastructure, to river health, drainage and flood management.

1.2 IMPACTS OF NATURAL DISASTERS

The Australian water sector has already been exposed to the consequences of climate change. 'Natural disasters' such as floods, droughts and bushfires are some of the serious issues the country has faced in the last 10 years. These disasters cost lives and significantly impact on community well-being, as well as having financial and environmental impacts.

In 2009, devastating bushfires cost 173 Victorian lives and over $4 Million in economic costs (Victorian Bushfire Royal Commission 2010). The cost of rebuilding infrastructure alone in response to the severe floods in late 2010 and early 2011 on the east coast and Cyclone Yasi in Queensland alone has been estimated at $6.8 Billion (Fraser 2011).

The conditions that led to both of these extraordinary events arose from record breaking rainfall (Mullen 2009) and extreme temperatures (BOM 2011). Events such as these and long term drought (as experienced particularly in south west Western Australia but also the east coast)has had enormous impact on the water industry and the way they do business.

1.3 RESPONSES FROM THE URBAN WATER INDUSTRY

In response to arising climate-related issues already facing the water industry there has been action by the water utilities across Australia to adapt as necessary to ensure public health security of supply are maintained. Adaptation to climate change means re-examining many of the underlying planning, design and operational principles and assumptions across the water cycle as well as how the water sector interacts with other sectors of government and utilities.

In recent years, significant emphasis has been placed on the security of water supplies and their augmentation through means such as desalination and other alternative water sources. Water conservation efforts have also contributed to what may be described as a step change in water using habits, reflected now in the absence of a bounce back in demand following the lifting of restrictions in Melbourne and Sydney. For example Melburnians continue to demonstrate a sustained commitment to using water efficiently with per person water use currently at record lows. Despite continuing growth in population and the relaxation of restrictions from Stage 3 to Stage 2 in 2010, Melburnians continue to reduce their water use (eg from 349GL in 2009/10 to 343 GL in 2010/11).

However, there is recognition that different and new issues due to climate change will emerge in the future and the urban water industry must be prepared. Whilst many of the emerging issues surround understanding the potential impacts of climate change, the extent of these impacts is subject to a range of uncertainties and managing for these uncertainties presents significant challenges in planning for water services.

The water industry must take action to prepare for these impacts including::

- diversifying water sources in our cities;
- reducing water use (both our own and customer use);
- improving the way we plan and manage waterways and wetlands;
- planning to better manage potential impacts on sewage i.e. wastewater quality;
- changing the way we make decisions;
- rethinking the way we provide advice for development in flood prone and vulnerable coastal areas; and
- planning for the risk of not meeting levels of service in circumstances of asset failure.

Most of these actions are in line with recommendations in the recently released Productivity Commission inquiry into Australia's urban water sector and the National Water Commission's review of urban water.

1.4 COLLABORATION AND ENGAGEMENT

Collaboration and engagement across the water sector will be critical to ensure successful adaptation to a changing climate. Such collaboration has been demonstrated through events such as the Water Services Association of Australia Climate Change Adaptation Workshop held in October 2010.. Collaboration with other sectors will also strengthen the ability of the water sector to be integrated into all aspects of urban planning, transport, energy, communications, health, education and resources issues.

There are other influencing factors that will encumber the ability of water utilities to adapt to climate change such as population growth, lifestyle changes, demographics, customer expectations and carbon pricing. These factors and everyday business accountabilities present a challenge of balancing response to short term issues and planning for long term security.

Regardless of the timeframe or onset of impacts, climate change adaptation will become a necessity and the 'business as usual' assumptions under which water utilities have been planning are changing. Now is the time to develop a new water working paradigm and plan for our water future.

1.5 PURPOSE OF THIS DOCUMENT

The key objective of the WSAA Climate Change Adaptation workshop was to identify the major gaps, current approaches/tools, future needs for tools, information gaps and finally to develop some processes and frameworks as to how we might close those gaps and provide opportunities for improvements in decision making. The desired outcomes of the workshop were to transfer information and approaches in order for WSAA members to develop a common understanding and consistent approach, and to identify relevant issues to take forward for positioning, research and action.

The purpose of this document is to highlight the impacts the Australian urban water industry are facing due to climate change and how the industry has adapted. Furthermore this report identifies how the urban water industry could be doing it better and sets out a list of priority actions (as well as enabling actions) to ensure it does respond adequately to meet regulator and customer needs.

Climate change is a significant issue facing the urban water industry and cuts across a number of the five key recommendations in WSAA's 2011 Report Card:

- planning for sustainable urban communities – Cities of the Future designs and plans need to be climate resilient and cater for uncertainties in urban water services;

- building capability in technology and our people – water utilities should aim to be net producers of energy and resources from sewage;
- providing value for money for water services – there is a refocus on water efficiency to ensure not a drop of water is wasted and water restrictions are used for emergency measures only;
- implications of the carbon tax (pricing mechanism) on the urban water industry - water utilities use the Cost of Carbon Abatement tool to identify carbon emission reduction opportunities.

There is already work being completed by WSAA and its members to address the gaps identified in this report. This work will be released in the coming months in the form of a number of reports addressing tools, energy use in the industry and the exciting new ways of designing our cities to ensure they incorporate water sensitive urban design.

2.0 Australia's Changing Climate

KEY POINTS

- The trend in annual rainfall for the period 1970-2010 (Figure 1) demonstrates quite a significant decline in annual total rainfall along the east coast and southern Australia as well as central and south west Australia.
- There has been an increase in the extent of wet extremes and a decrease in the extent of dry extremes annually and during all seasons from 1911 to 2008 at a rate of between one per cent and two per cent per decade.
- Recent projections indicate that sea level rise may well exceed 1m by 2100 with a possible upper limit of 2 metres.
- It has also been determined that storms with heavy rainfall will become more intense due to the wetter warmer atmosphere.
- The intensity of the strongest cyclones is also predicted to increase.
- Increases are expected in:
  - maximum and minimum temperatures and the number of hot days and nights;
  - wind speed; and
  - the number of days when the Forest Fire Danger Index is very high or extreme.

Implications for the urban water industry are:

- Increased challenges to service delivery i.e bushfires, floods and sewer spills
- Urban heat island effect
- Decreased water availability in the heavily populated areas of southern Australia
- Increased stress on the community from floods and coastal inundation
- Increased insurance costs
- Peak demand changes & infrastructure sizing
- Salt water intrusion, changing sewage concentrations, coastal groundwater quality impacts and increased corrosion rates

2.1 OUR CURRENT CLIMATE

The Australian climate influences the way in which water is sourced and distributed for consumption, and the manner in which stormwater and waterways are managed, and sewage is treated. What can seem to be relatively small changes in climate over the natural climate variability can result in short term (e.g. floods) and long term impacts (e.g. drought) and can also have devastating and lasting effects on Australia's water resources and their management.

The Australian climate is both diverse and variable (Table 2). These climates define the way communities live and the attitudes to water in the different regions.

The arid climate of central Australia lends itself to high mean temperatures and low rainfall while the temperate climate of Hobart in the south of Australia experiences much lower mean temperatures and moderate rainfall. Darwin in the tropical north of Australia has both high mean temperatures as well as high annual rainfall.

	Mean Temperatures (°C)				Rain
	January		July		(mm)
Location	Max	Min	Max	Min	Annual
Adelaide	28.5	16.6	14.9	7.5	553
Alice Springs	36.1	21.2	19.5	4.0	274
Brisbane	29.2	21.0	20.6	9.5	1189
Canberra	27.8	12.9	11.1	-0.2	631
Darwin	31.8	24.8	30.4	19.3	1666
Hobart	21.5	11.7	11.5	4.5	624
Melbourne	25.7	14.0	13.3	5.8	661
Perth	31.5	16.8	17.7	8.1	869
Sydney	26.3	18.5	16.9	6.7	1220

Table 2: Key climate elements at Australian capital cities (Source: Bureau of Meteorology)

This diversity of climates means that water must be managed in different ways. For example flood management in tropical regions may need to cater for larger flow volumes, while in central Australia, low rainfall means water supply is precious and needs to be conserved.

2.2 CLIMATE OBSERVATIONS

In Australia, we have observed a potential climate shift over the decade 1997 – 2006. Hence, there is a need to better understand where we are headed and the changes and impacts we could be facing if we are to be adequately prepared and adaptable. Observations analysed by the Australian Bureau of Meteorology conclude that the decade 2000-2009 was Australia's warmest decade on record (State of Climate 2010). The trend in annual rainfall for the period 1970-2010 (Figure 1) demonstrates quite a significant decline in annual total rainfall along the east coast and southern Australia as well as central and south west Australia. This has led to a drying trend in these areas for over a decade putting pressure on the agriculture industry as well as the urban water industry to supply drinking water for consumption. The decrease in rainfall across the various regions of Australia appears to be generally seasonal. For example south west Western Australia has experienced its greatest decline in rainfall in winter, with averages down by around 15%, whereas the Murray Darling Basin region experienced rainfall reductions in autumn and winter. (CSIRO 2011b)

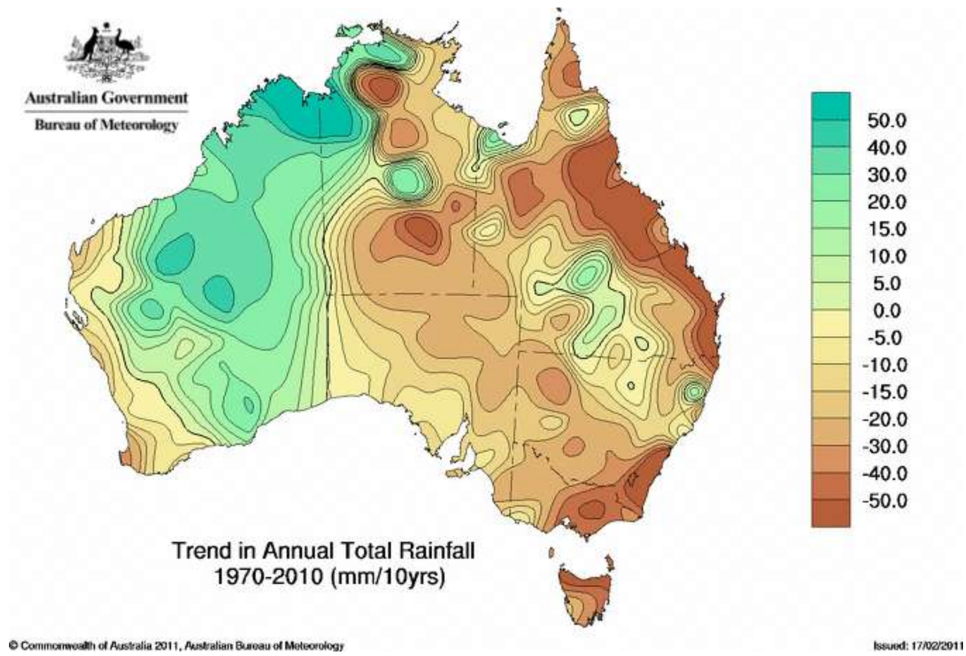


Figure 1: Australian Annual Rainfall Trend (Source: Bureau of Meteorology 2010)

However whilst some parts of Australia have been in drought, other areas have been receiving greater average rainfall, particularly north west Australia (Figure 1). This highlights the extremely variable climate of Australia and the changing climate conditions to which the water industry has had to adapt.

Australians are not strangers to the devastating bushfires and flooding that climate variability can bring. Gallant and Karoly (2010) concluded that for Australia as a whole (but not at all locations) there has been an increase in the extent of wet extremes and a decrease in the extent of dry extremes annually and during all seasons from 1911 to 2008 at a rate of between one per cent and two per cent per decade. (CSIRO 2011a)

As global and local temperatures rise, the oceans warm. This results in thermal expansion that causes sea levels to rise. Climate science is a rapidly moving field. Since the IPCC 4th Assessment Report was released in 2007, new scientific developments have occurred that indicate climate impacts may be even greater than previously thought. Recent projections indicate that sea level rise may well exceed 1m by 2100 with a possible upper limit of 2 metres. (Maddocks 2011).

2.3 CLIMATE CHANGE PROJECTIONS

The IPCC Fourth Assessment Report (IPCC 2007) and its SRES emission scenarios have formed the basis of the regional models and emission scenarios used to develop climate change projections for Australia (CSIRO 2007). The projections for the nation are increases in:

- maximum and minimum temperatures and the number of hot days and nights;
- wind speed;
- annual rainfall in the north, and decreases of 2-5% across the rest of Australia by 2030; and
- the number of days when the Forest Fire Danger Index is very high or extreme (CSIRO 2007).

2.4 CHANGES TO THE AVERAGE AND EXTREMES IN TEMPERATURES AND RAINFALL

2.4.1 TEMPERATURE CHANGES

The average annual warming of Australia by 1oC by 2030 can be further broken down as a 0.7oC-0.9oC average warming in coastal areas and a 1-1.2oC warming across inland areas. By 2050, projections estimate an annual warming range for Australia between 1.2oC for the B1 scenario (where the world moves to a more sustainable future) to 2.2oC for the A1F1 scenario (where the world continues its reliance on fossil fuels). By 2070 projections estimate an annual warming range for Australia between 1.8oC for the B1 scenario to 3.4oC for the A1F1 scenario. (CSIRO and BOM 2007)

The number of days over 35oC is expected to increase across all regions (CSIRO and BOM 2007); as is the number of warm nights. And in winter, minimum temperatures with fewer frost days and fewer extreme low temperatures are predicted (CSIRO 2011a). Increases in the number of and severity of bushfires are also expected. (CSIRO 2011).

2.4.2 RAINFALL

Rainfall projections for the different regions are variable with small increases in average annual rainfall predicted for the north of Australia and larger decreases in average annual rainfall in the south (CSIRO and BOM 2007). Southern Australia could receive up to 10% less rainfall by 2030 and up to 20% by 2050. And areas of northern Australia may receive changes of -10% to +5% by 2030 and -20% to +10% by 2050 (CSIRO 2009). Exceptionally dry years are expected to occur more often (CSIRO 2011a) which would contribute to drought conditions, length and frequency.

It has also been determined that storms with heavy rainfall will become more intense due to the wetter warmer atmosphere (CSIRO 2011a). A study by Rafter and Abbs (2009) showed that there was a tendency for storms to increase in intensity for all regions across Australia. Also storms that come and go quickly and often lead to urban flash flooding are more likely to change rapidly than the longer-lasting storms that lead to widespread riverine type flooding (CSIRO 2011a). In some areas such as southern Australia, the intensity of storms will increase in summer and autumn, and in northern Australia, in the winter and spring (CSIRO 2009).

2.4.3 CYCLONES

According to work undertaken by Abbs (2009), model simulations showed an average decrease in the number of tropical cyclone (TC) days. These results are consistent with other studies published internationally, however a report released by CSIRO (2009) indicated that TC days are projected to increase in the north east, but decrease in north western Australia.

The intensity of the strongest cyclones is also predicted to increase (CSIRO 2009). Abbs (2009) reports model results showing a southward movement in the creation and decay of cyclones, with more southward movement in cyclones on the east coast of Australia than the west (CSIRO 2011a).

IMPLICATIONS FOR THE URBAN WATER INDUSTRY

- Increased challenges to service delivery i.e bushfires, floods and sewer spills
- Urban heat island effect
- Decreased water availability in the heavily populated areas of southern Australia

2.5 SEA LEVEL RISE

Sea levels are projected to continue to rise over the next century and beyond due to both thermal expansion and melting of glaciers and ice sheets. Plausible estimate for sea level rise based on the modelling of thermal expansion and sea ice indicate that seas are expected to rise by up to 0.8m by 2100 (CSIRO 2011a). The understanding of how much ice sheets will contribute to sea level in the future is limited and therefore difficult to predict but could contribute to further rises this century. Figure 2 provides the indicative projections for sea level rise in the 21st century (CMAR 2011).

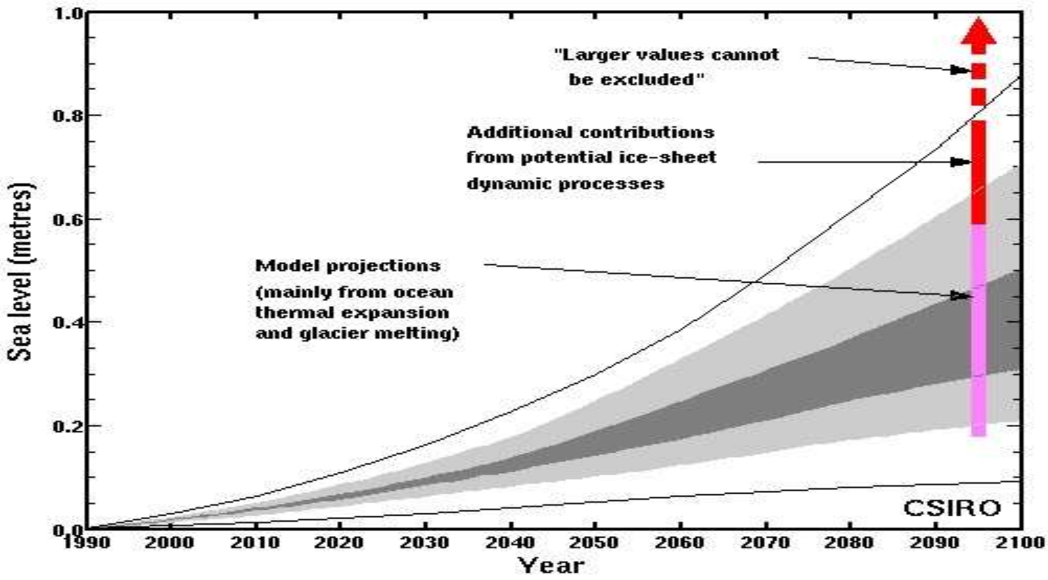


Figure 2: Projections for sea level rise

These levels are for sea level rise alone and do not consider the additional extent and destructiveness of storm surge (extreme high sea levels brought about by storms and weather phenomena such as high winds, tropical cyclone and/or low pressure systems). With projections for an increase in the frequency and intensity of storm surge events, a storm tide could add a further 82cm on to mean sea level and a 1 in 100 year extreme storm surge event could occur as often as once every 30 years in 2030 and once every 5 years in 2070 (DCC, 2009.)

IMPLICATIONS FOR THE URBAN WATER INDUSTRY

> Increased stress on the community from floods and coastal inundation

> Increased insurance costs

> Peak demand changes & infrastructure sizing

> Salt water intrusion, changing sewage concentrations, coastal groundwater quality impacts and increased corrosion rates

2.6 IN SUMMARY

The following Figure (2) summarises the key climate variables and the resulting impacts on the water industry. The next three chapters of this report will identify how these variables and impacts will (and already have) influenced the water industry's response to climate change across the following key themes:

> built and social environment;

> biophysical environment; and

- management and protection of vital infrastructure.

Each of the three chapters is structured to present the:

- key implications of climate change relevant to the theme;
- current adaptation practices and research; and
- research and adaptation opportunities.

CLIMATE VARIABLES

Increased average annual temperature

Increased extreme heatwaves

Decreased average annual rainfall

Increased intensity of extreme storms

Sea level rise

Increase intensity and frequency of extreme storm surges

CLIMATE IMPACTS ON WATER INDUSTRY

Decreased streamflow (not in northern parts of Australia)

Lower groundwater tables

Increased extreme hot days and bushfires in catchments

Increased land inundation – community and treatment plants from rising sea

Increased flooding from extreme storms

Increased sewage spills

Increased demand for water during extreme heatwaves

Increased water temperature

Decreased water quality

Decreased environmental flows

Increased peak flows

3.0 Theme 1 Built and Social Environment

The theme built and social environment covers customer service standards for water, sewerage and drainage, and highlights considerations relating to the economic, social and environmental impacts through which services are delivered.

Climate variability alone creates a number of water servicing issues for the built and social environment. Changing the ranges of variability and climate extremes within which the water industry operates, and adding greater uncertainty about what the climate future may bring, means water utilities will be operating in an increasingly challenging and complex environment.

Planning and investment in water infrastructure is centralised in most jurisdictions. This has resulted in investment in large, lumpy and expensive infrastructure projects such as dams and desalination plants. While these forms of alternative supply may prove necessary and useful, sometimes a more decentralised approach may be preferable from a cost and efficiency perspective. When investing in these projects planners and decision-makers need to consider how infrastructure such as dams may be adapted for other purposes i.e. storage for recycled water, so that the investment is not lost.

KEY POINTS

> Decreased annual rainfall in the southern, heavily populated areas of Australia has led to a drying trend, particularly in the SW of WA. While this has meant customers have been on outdoor water restrictions for some time over the past 5 – 10 years, water utilities and governments have acted to diversify water sources to move away from dams to climate independent sources such as recycled water and desalination plants. This provides long term security under climate change.

> Service delivery standards to customers can be impacted by catastrophic events like storms, bushfires, high winds and heatwaves. By building interconnected (and diverse) supply networks, utilities do not have to rely on the one source should a source be compromised by an event. The urban water industry will continue to learn from these events; sharing knowledge, talking to and understanding the community's issues and building capacity to better respond to customers and protect assets as far as is practicable.

> Water Sensitive Urban Design is a way for utilities to influence the shape of our cities to ensure all sources of water (for 'fit for purpose' use), are considered when planning a new (or redefining an existing) neighbourhood. The contribution that water in the urban landscape can make to community well-being (beyond essential needs) is also a key concern for utilities who are happy to collaborate with other agencies.

> Water prices have increased in recent years with the establishment of new, climate independent sources such as desalination. Other impacts on prices may result from increased insurance premiums and claims affecting water utilities. Ways to better manage water pricing and its impacts are being explored by the utilities and could include providing greater customer choice in products and hence, pricing.

> Decision-making in the face of climate change is complex and requires the input of new tools. Water Utilities have responded through the development of tools such as AdaptWater and the Socio-Environment tool. However, better decision-making could be achieved through the development of model business cases that specifically take climate change adaptation into account

3.1 CLIMATE CHANGE RISKS AND CHALLENGES

IMPLICATIONS FOR THE BUILT AND SOCIAL ENVIRONMENT

- Decreased water availability in the heavily populated areas of southern Australia
- Urban Heat Island effect
- Increased challenges to service delivery ie.bushfires, floods and sewer spills
- Increased odours form sewerage network and treatment plants
- Potential increase in breach of obligations and regulations
- Increased insurance costs
- Reduced income/revenue
- Increased peak demand
- Willingness to pay issues
- Investment decisions / budget considerations.
- Changing customer expectations.
- Increased stress on the community from acute water shortages, floods and coastal inundation

As detailed above, climate change will have implications for the urban water industry in servicing the built and social environment. These key implications, the current adaptation practices (including research) and the potential opportunities are discussed in further detail below. They cover the five broad areas of:

- customers and regulators (particularly service delivery standards);
- urban planning and form;
- community well-being;
- economic and financial considerations; and
- triple bottom line (sustainability) and decision making.

3.2 CUSTOMERS AND REGULATORS

3.2.1 DECREASED WATER AVAILABILITY IN THE HEAVILY POPULATED AREAS OF SOUTHERN AUSTRALIA

A decrease in average annual rainfall in the heavily populated southern areas of Australia combined with increasing average temperatures has already caused and will continue to see a decline in water availability. Increased pressure on water availability may result in greater periods of time on water restrictions (possibly including total bans on outdoor drinking water use). These measures can often be met with criticism or resistance by the community, regulators and politicians. They may also contribute to stress and discontent, particularly in vulnerable areas of the community and in those businesses and industries that have a heavy reliance on water for productive uses e.g. agriculture and electricity generation.

3.2.2 CUSTOMER EXPECTATIONS

Customers expect a certain level of service in return for paying their rates to local water utilities. If water prices are rising, the customer will expect to continue to get the safe, clean drinking water that they paid for. As water availability decreases, there may be a number of issues around drinking water quality that arise including potentially increasing:

- algae and pathogen levels;
- turbidity following bushfires; and
- salinity levels in groundwater.

Water utilities are likely to face greater pressure to maintain the quality of drinking water and overcome these issues.

3.2.3 SERVICE DELIVERY STANDARDS - SEWERAGE

Under climate change, increased storm activity could affect the service delivery standards for sewage collection and treatment. Under heavy rainfall, flows in sewage systems are exacerbated by infiltration from surrounding sub-soil geology and illegal connections from stormwater drains. These excess flows often are released through emergency relief structures (ERS) and flow into waterways. This prevents them from back up in the sewer network and potentially people's homes. These structures have design and operational standards that must be met for health and environmental purposes; however changes in volumes of sewer flows could have an impact on the frequency of spills from the sewerage system and potentially breach environmental regulations and place a risk on public health.

Customers also expect their waste water to be removed as quickly as possible with minimal odour and mess. The sewage collections and treatment systems across Australia generally provide secondary or tertiary treatment and disease has been completely eradicated. Odour however can still be a problem around sewers and at treatment plants. Projected increasing temperatures and reduced inflow to sewers may contribute to increased odour issues associated with chemicals such as hydrogen sulphide. Water utilities often have a licence and obligations to control, monitor and report on odour to protect the community's health and well-being. Therefore an increase in odours could result in greater odour issues and more customer complaints.

3.2.4 SERVICE DELIVERY STANDARDS - WATER SUPPLY

The supply of drinking water for consumptive purposes must meet various public health criteria and regulations that may differ in each state to some extent. Measures taken to ensure appropriate standards are maintained require methods such as disinfection, filtration and treatment. The effectiveness of these processes may be compromised as a result of extreme wind, electrical storms, heavy rainfall, bushfires or heatwaves. Such events have the potential to interrupt power supplies and treatment of water or delivery of water for distribution. This could in turn affect the continuity of supply. These scenarios would also affect the ability to remove sewage from the homes of customers, and its treatment. There is also increasing pressure to improve treatment methods to respond to declining quality of water due to algal blooms with increased temperature and increased turbidity due to a) runoff in extreme rainfall events, b) runoff post-bushfire or c) increased wind action in drawdown reservoirs with exposed banks.

3.2.5 SERVICE DELIVERY STANDARDS - RECYCLED WATER

Recycled water is a relatively new source of water as an alternative to drinking water for non-consumptive purposes. Recycled water can be supplied by water utilities following appropriate treatment to ensure it meets the guidelines and regulations in each state. Recycled water is treated wastewater that comes from either an individual source or combination of residential, commercial and industrial waste. Recycled water can also be used to replenish drinking water aquifers as in the case with the Perth groundwater replenishment trial. The trial is part-funded by the Australian Government's Water for the Future initiative. The trial involves further treating secondary treated wastewater to drinking water quality and recharging it to the groundwater. The benefits of the trial are twofold: to top up decreasing groundwater tables and to supply drinking water to the community.

Increased average temperatures and increasing usage of water efficient appliances will result in more concentrated sewage inflows that will potentially change the quality of recycled water and the treatment requirements. Extreme heatwaves over summer associated with a changing climate also have the potential to cause increased algal outbreaks which may affect the quality of recycled water and it's fit for purpose use.

CUSTOMERS AND REGULATORS – CURRENT ADAPTATION PRACTISES AND RESEARCH

Diversifying water sources to avoid water restrictions

> This includes moving to less climate dependent sources such as greywater and blackwater recycling, stormwater harvesting and rainwater tanks, aquifer storage and recovery, and desalination of sea water.

> In Perth, the Water Corporation developed a 'Security through Diversity' approach to the 30 year drying trend facing the city and South-West. This culminated in the significant development of groundwater sources, Australia's first major desalination plant for drinking water supply, Australia's second major recycling plant to supply industry and significant investment in water efficiency measures to reduce demand. The result of this is a 50 year plan, *Water Forever*, focussing on recycling wastewater (including the development of Australia's first groundwater replenishment trial), reducing demand for water and developing new sources such as deep groundwater and more desalination.

Network interconnectivity to share and trade water to maintain supply

> Construction of water supply pipelines and networks connected to external supply networks to enhance opportunities for sharing and trading of available water resources. The Seqwater Water Grid is such an example of this. The grid comprises of an infrastructure network of treatment facilities and two-way pipes that move water from new and existing sources across the region. Further details are found in the case study at the end of this chapter.

> The Integrated Water Supply Scheme (IWSS) for Perth links groundwater, surface water, recycled wastewater and desalination sources.

Strategic plans to ensure public water services are resilient to climate change

There has been an increased focus on strategic planning for securing future sources, assessing available and potential supply from current infrastructure, demand analysis, improving efficiency of operations of water supply networks and sewerage strategies. For example Perth's *Water Forever* (as noted above), the 50 year Water Supply-Demand Strategy for Melbourne and the NSW Government's Metropolitan Water Plan.

Water Conservation and Efficiency

> Adoption of permanent water saving measures (low level, common sense restrictions)

> Setting of water use targets and implementation of water industry programs to promote demand management and reuse.

> Most governments or water utilities also offer some sort of subsidy or 'reward' for using water efficient appliances or for the installation of rainwater tanks.

> Introduction of leakage reduction programs in water supply networks and construction of pipelines to reduce numbers of open water channels that have a high incidence of evaporation.

> Smart metering is also gradually being introduced across Australia, with projects and case studies in Victoria, New South Wales, Western Australia and Queensland. Smart meters provide real time continuous monitoring of water consumption that will provide valuable information to customers and utilities such as understand when, how and why water is used; and more readily and quickly identify leakages to improve water conservation.

3.3 URBAN PLANNING AND FORM

3.3.1 URBAN HEAT ISLAND

In the hotter, drier climate of the future, water will be an important element for keeping cool and managing liveability. The urban heat island effect is reduced through use of water sensitive urban design and gardens. These gardens and water systems often rely on stormwater to survive, however reduced rainfall may lead to deterioration of green spaces. This then reduces the benefits of these areas on the urban heat island effect.

In Perth and the eastern states increased use of paving and synthetic lawn (as a means of reducing water consumption), can increase the heat island effect and hence the greater use of air conditioning. This effect can also be enhanced by the increased loss of street trees in new suburbs due to water restrictions. The relationship between water efficiency and energy efficiency is not always balanced or complementary and needs to be carefully considered. Maintaining sensible, well-planned and watered areas of urban greenery is a legitimate use of water, and is important for many other reasons than simply reducing the heat island effect.

3.3.2 FLOODING AND DRAINAGE

There can be a thing as too much water in an urban setting even in times of declining rainfall. Projections for an increase in intensity of storms above and beyond that for which the urban drainage systems have been designed, may see increased intolerable flooding affecting property and buildings. For example the Queensland flood disaster that impacted 70 per cent of the state in 2010-11.

Planning and development guidelines exist in many regions to set floor levels and safety measures to minimise the impacts of flooding on new development, however existing development in areas that previously were not affected by flooding, may now face inundation. Properties in low lying areas will be particularly vulnerable, especially those along the coastline that may also be subject to sea level rise and storm surge inundation. Projects such as AdaptWater may be useful in influencing planning and building regulations so that infrastructure can be built and managed to prevent inundation of low lying areas.

URBAN PLANNING AND FORM – CURRENT ADAPTATION PRACTICES AND RESEARCH

Water Sensitive Urban Design

Planning for urban development necessitates consideration of emerging future issues because some elements of urban landscapes and suburbs endure up to and beyond a century e.g. infrastructure and roads. Given the increasing urgency and attention to climate change, urban planners are now starting to consider the impact of climate change in their planning. What started out as an urban design to primarily treat stormwater runoff and manage other peripheral issues, water sensitive urban design (WSUD) has transitioned into a type of design that is being considered as a tool to help cities adapt to a changing climate. WSUD may also reduce the impacts of the urban heat island effect and provide stormwater harvesting and alternative sources of water at local and regional scales. Integrated water management and projects such as Cities of the future (see case study on Page 25) may also have the potential to influence urban planning to enable better integration of water planning in future urban development.

Assessing and planning for climate change impacts on the Australian coastline

Continuing sea level rise and extreme storm surge events over the last century have already seen a number of changes in the Australian coastline. These changes have contributed to a greater acceptance of climate change induced sea level rise than most other climate change projections. The report on Climate Change Risk to Australia's Coast by the Commonwealth Government (DCC 2009) is a first pass national assessment investigating the risks of climate change to the coastal environment, human settlement and industry. Other state and local governments have also undertaken risk, hazard or vulnerability assessments and developed policies and strategies for adaptation.

Planning panels and the legal system are also starting to recognise the gravity of the risk that existing coastal development now faces and have in some instances restricted or prohibited development in an area identified for future potential coastal inundation. Governments and planning authorities have also taken, or are taking, the steps to produce guidelines for future development that may be subject to inundation from either sea level rise or from increased flood reach due to increased storm intensity.. The New South Wales Government have produced *Coastal Planning Guidelines: Adapting to Sea Level Rise* and Melbourne Water has released interim guidelines for assessing development in areas prone to tidal inundation from sea level rise in the Port Phillip and Westernport Region called *Planning for Sea Level Rise*. The Victorian Government is also due to release *Victorian Coastal Climate Change Hazard Guidelines* for coastal management authorities to use in their assessments of coastal development proposals.

3.3 COMMUNITY WELL-BEING

3.3.1 FLOODING AND INUNDATION

Increased storm intensity would mean greater volumes of runoff and flow within a catchment. Reservoir levels will in turn rise and may result in spill and disruption to reservoir operations. Side entry pits and underground drains may not be able to cope with these volumes of water which will result in greater overland flows and potentially increased flood reach. The potential flood depths of properties with existing flood risk may rise or be flooded more frequently by smaller more frequent and more damaging storms. This may result in more flooding above existing floor levels.

Uncertain results from modelling could lead to overinvestment in flood protection if flood reach is overestimated or inadequate flood preparedness and protection if flood reach is underestimated.

Underestimating flood reach would produce the greater social impacts and stress on the community. Damage to property, interruption to business, loss of memorabilia and death and injury are major stress factors. But the social impacts of flooding are increased also by 'outrage factors' (Sandman 2011), which would be more apparent if there is inadequate education, preparedness and flood warnings. There is also a current state of distress amongst the population in Queensland, Western Australia and Victoria over the poor state of flood insurance and the lack of willingness of some insurers to cover some types of flood risks to avoid payouts.

As the owner and operator of Wivenhoe, Somerset and North Pine Dams, Seqwater had an integral role to play in managing and responding to the recent 2010/11 flood event. Seqwater is already well advanced in its preparations for future wet seasons.

3.3.2 SEA LEVEL RISE

The greatest risk to the community associated with sea level rise is that of permanent inundation, which would be further exacerbated by increases in intensity of storm surge inundation of existing property, land, infrastructure and services. Some water utilities have new or emerging or altered responsibilities that require the consideration of the requirements or conditions for future development in these flood affected areas in particular. Such a concern is the siting of wastewater treatment plants which are generally located along or in close proximity to coastlines for to allow for ocean outfall of treated wastewater.

The occurrence of salt water intrusion will further damage low lying assets and salinate the water table and soil possibly destroying ecosystems.

3.3.3 REDUCED RAINFALL AND IMPACTS ON GARDENS

During the last 10 years or so, gardening in much of Australia has become more difficult. Water restrictions have progressively become more severe as prolonged dry periods impact on our largest cities. The most common type of restriction is limitation or prohibition of outdoor water use in gardens, upsetting many domestic consumers who value their gardens.

It is likely that permanent water savings measures will be part of the portfolio of long term regulatory responses to climate change. In short term drought temporary water restrictions may be required depending on the success of alternative strategies (e.g. rainwater tanks, garden bores or greywater recycling systems, and installing efficient irrigation systems and low water using plants) that may be adopted by consumers if they want to have the many benefits that gardens provide.

COMMUNITY WELL-BEING – CURRENT ADAPTATION PRACTICES AND RESEARCH

Managing the social impacts of any risk or hazard is extremely challenging and an area for further consideration. There is still much to be understood as little has been achieved in responding to the potential social impacts that could result from the impacts of climate change on the water industry because:

> there is still a great deal of work to be undertaken to understand physical and hydrological impacts; and

> interpreting and quantifying how the community will be affected in future is difficult.

The community however does have a basic understanding of the impacts of climate change such as less water availability and drought because they have already had exposure to this. However the more intangible impacts such as emotional stress and change to lifestyle as an outcome are hard to predict at this point in time.

As an example however, Health care provider Ozcare said the number of people suffering mental health problems has increased significantly since the Queensland floods of 2010/11. Ozcare's Disaster Recovery Program has received Federal and State funding for the next two years to provide both emotional and practical support to flood victims.

3.4 ECONOMIC AND FINANCIAL CONSIDERATIONS

3.4.1 COST OF WATER

The increasing financial cost of water in many parts of Australia is reflective of the increasing need to diversify water sources and move away from 'low cost' water sources. Whilst different approaches to water pricing are adopted the need to meet increased environmental requirements and obligations across Australia, it is likely that a majority of the water utilities will see the cost of water continue to rise as infrastructure such as desalination plants, pumping stations, improved tertiary treatment plants for sewage and changes to water grids are constructed.

The community, industry, government and water utilities are all facing small or major financial decisions in their own right already, making decisions about the role of rainwater tanks, greywater recycling, water rights, dams and desalination plants. (Ron Ben-David 2010). These decisions and associated costs will only continue to become more complex as Australia considers transition into water markets, potential privatisation and increasing water security issues. Understanding what customers may be willing to pay for will be an important part of water planning and management in the future.

3.4.2 INSURANCE

Insurance is a method of responding to risk through means of providing financial recovery to weather related (or other) incidents. The insurance industry is taking climate change very seriously. In the Reserve Bank of Australia (RBA) March 2011 Financial Stability Review it was noted that:

"..there has been a pick-up in the frequency of large claim events in recent years. Nine of Australia's fifteen largest claim events since 1967, measured in constant price terms, have occurred since 2006. Consistent with this, total annual catastrophe claims, in constant prices, have averaged around $2 billion since 2006, compared with an average of $0.6 billion since 1970." (RBA, p.39)

Projections for increased storm intensity and heatwaves could result in more damage which could mean increased insurance premiums. Water utilities are required to take out insurance for their own assets and public liability. Therefore increased insurance premiums as well as potentially greater numbers of insurance claims may add to the financial implications for climate change on the water industry.

3.4.3 LOSS OF REVENUE

Many water utilities are required to produce revenue and pay dividends or contributions to government for various purposes such as water planning and management or environmental purposes. There has been some concern expressed amongst water utilities as to the effects of water conservation on revenue. Whilst conserving water in a hotter, drier climate is ideally favourable, further understanding may be required of the implications of potentially decreasing demand for water on revenue in the short term, and hence the dividends or contributions paid to government.

ECONOMIC AND FINANCIAL CONSIDERATIONS – CURRENT ADAPTATION PRACTICES AND RESEARCH

As customer's expectations increase, there is greater demand for accountability and transparency from water utilities and governments on their spending and investment in infrastructure. Water utilities face increasing pressure to justify projects and face rigorous expenditure and project planning to do so. Adaptation to climate change is expected to increase expenditure for water utilities, to which regulators will ensure spending is appropriate and justified.

Most jurisdictions have a tiered pricing arrangement – 'inclining block tariffs' – the primary aim of which is to encourage the conservation of water. In particular, the tiered pricing structure seeks to deter discretionary water use by imposing higher prices once the volume consumed over a certain period exceeds a particular threshold. Each state has independent regulators to provide for this transparency in water pricing under the National Water Initiative.

3.5 TRIPLE BOTTOM LINE (SUSTAINABILITY) AND DECISION-MAKING

3.5.1 INVESTMENT DECISIONS

The triple bottom line assessment for water utilities refers to the need to assess and consider economic, environmental and social impacts in decision making. Whilst sometimes also referred to as the quadruple bottom line (i.e. including cultural or spiritual impacts), these assessments may overlook the need to consider future climate change. Investment decisions we make today will determine our ability to adapt and respond in the future. Uncertainties that exist in climate science and the 'precision' of projections and impacts can lead to inaction which may later find water utilities wanting in their response to climate change. The uncertainties of scale, scope, timing and onset all affect decision making and deciding what to invest in and when (Ron Ben-David 2010).

Whichever way the decision goes, there will be a financial cost to the community. Investing in expensive solutions as an early or preparatory response to climate change impacts will increase the price of water in the immediate term. If climate change impacts do not eventuate, fall short of predictions, or better technology is developed then the over investment will cost the community. However on the flip side, inaction will also cost the community in the future if climate change continues its path and water issues intensify. This presents the question: Will waiting cost communities more or less? This presents an issue in using discount rates in assessing the viability of infrastructure investments and other actions (Ron Ben David 2010). The answer to this is once again filled with many uncertainties and qualifiers; therefore it will be up to the water industry and water utilities to assess and consider the triple bottom line.

TRIPLE BOTTOM LINE (SUSTAINABILITY) AND DECISION-MAKING

CURRENT ADAPTATION PRACTICES AND RESEARCH

AdaptWater

Collaboration between WSAA, Sydney Water, Climate Risk and other utilities such as Melbourne Water, SA Water and Water Corporation has resulted in the development of a climate change adaptation planning tool specifically for water utilities called AdaptWater. AdaptWater will capture and quantify the complexity of modern water utilities' economic, social and environmental performance requirements and integrate the effects of evolving direct and indirect climate change hazards to provide plausible adaptation cost-effectiveness projections and flexible adaptation pathways to make decisions on adaptation plans. (Sydney Water et al 2011)

Socio-Environment Tool

The Water Corporation has developed a sustainability assessment tool called the Social and Environment Tool (SET). The SET is an Excel-based Advanced Cost-Benefit Analysis tool linking a database of values commonly used in water industry business case analyses. The tool is enhanced with the capacity to analyse the effects of uncertainty using Monte Carlo Analysis.

3.6 RESEARCH AND ADAPTATION OPPORTUNITIES – BUILT AND SOCIAL ENVIRONMENT

3.6.1 MODEL BUSINESS CASES

> As economic and investment issues potentially have a large impact on the built and social environment in terms of infrastructure investment and the cost to the community, it is recognised that there is a great deal of work to be done in this realm. Developing a model business case for investment in a water project (infrastructure or otherwise) considering climate change adaptation will provide an example for water utilities and regulators around Australia. Develop a balance between centralised and decentralised systems for water supply, sewerage treatment and stormwater management where sustainable.

> Investigate the use of tools for valuing water and determining a dollar value for environment and social costs, e.g. the Bush Tender approach. Bush Tender is an auction-based approach to protecting and improving the management of native vegetation on private land. Under this system, landholders competitively tender for contracts to better protect and improve their native vegetation. This may also assist in monetising the cost of adaptation for the urban water industry to provide Government and stakeholders with a monetised value proposition.

> Coupled with the development of model business cases is the need to engage with the economic, public health and environmental regulators specifically on climate adaptation to become more climate ready.

> Investigate the potential for customer choice in products.

3.6.2 STAKEHOLDER MUD MAPS AND ENGAGEMENT

> Develop a 'mud map' of stakeholders with an interest in climate change adaptation identifying those with interests in policy, climate science and adaptation. This will assist water authorities in identifying the potential range of stakeholders to be engaged with in climate change adaptation studies and programs.

> Collaborate with other stakeholders including international groups and alliances such as Water Utility Climate Alliance (WUCA), Water Research Foundation (WaterRF), Water Environment Research Foundation (WERF) in the United States of America and the PREPARED program in Europe. There are opportunities for information sharing and joint research with these organisations including examination of case studies of decision making tools such as scenario planning and real options analysis.

> Continue to invest in and collaborate with research agencies such as CSIRO, BOM and Centre for Excellence in Climate System Science (UNSW) to influence modelling and outputs required for adaptation work to help reduce uncertainties that may affect investment decisions.

3.6.3 COMMUNITY EDUCATION

> Measure the community's current water literacy levels in order to define what a water and climate change literate community could look like.

> Develop programs and mechanisms to inform and educate the community about climate change and its impacts on water supply to help them understand the potential issues, and aid building resilience.

3.6.4 KNOWLEDGE SHARING

- Build and share knowledge on water utilities and industry responses, (including insurance issues), to record-breaking floods, catastrophic bushfires and extreme heatwaves. This will help water utilities to learn from previous experience and help communities to be more prepared in the future.
- Invest and better utilise social media tools for information sharing and communication amongst the water utilities, other agencies and the community.

3.6.5 WATER SENSITIVE CITIES

The vision endorsed by the Centre for Water Sensitive Cities is to transform cities and their communities in ways that will help them to live in harmony with natural water environments. The centre is building Australia's capacity to advance sustainable urban water practices through research excellence, engagement with planning, development & water management professions and supporting the development of government policies. The Centre has just received $30 million in federal funding. Water utilities and WSAA will be engaged, and plan to contribute to this project.

CASE STUDY: BUILT AND SOCIAL ENVIRONMENT

There are increasing numbers of examples of adaptation in the built and social environment. In 2010, WSAA and Melbourne Water co-hosted a workshop to discuss 'Cities of the Future'. 'Cities of the Future' is part of an International Water Association program focusing on developing the concept of water security for the world's cities through design and planning.

Water managers from across Australia came together at Ozwater 2010 to explore the Australian water sector's role in facilitating this concept. The themes and principles guiding the vision are presented in a Discussion Paper for the World Water Congress held in Montreal in September 2010 that can be found at https://www.wsaa.asn.au/NewsAndMedia/MediaCentre/ .

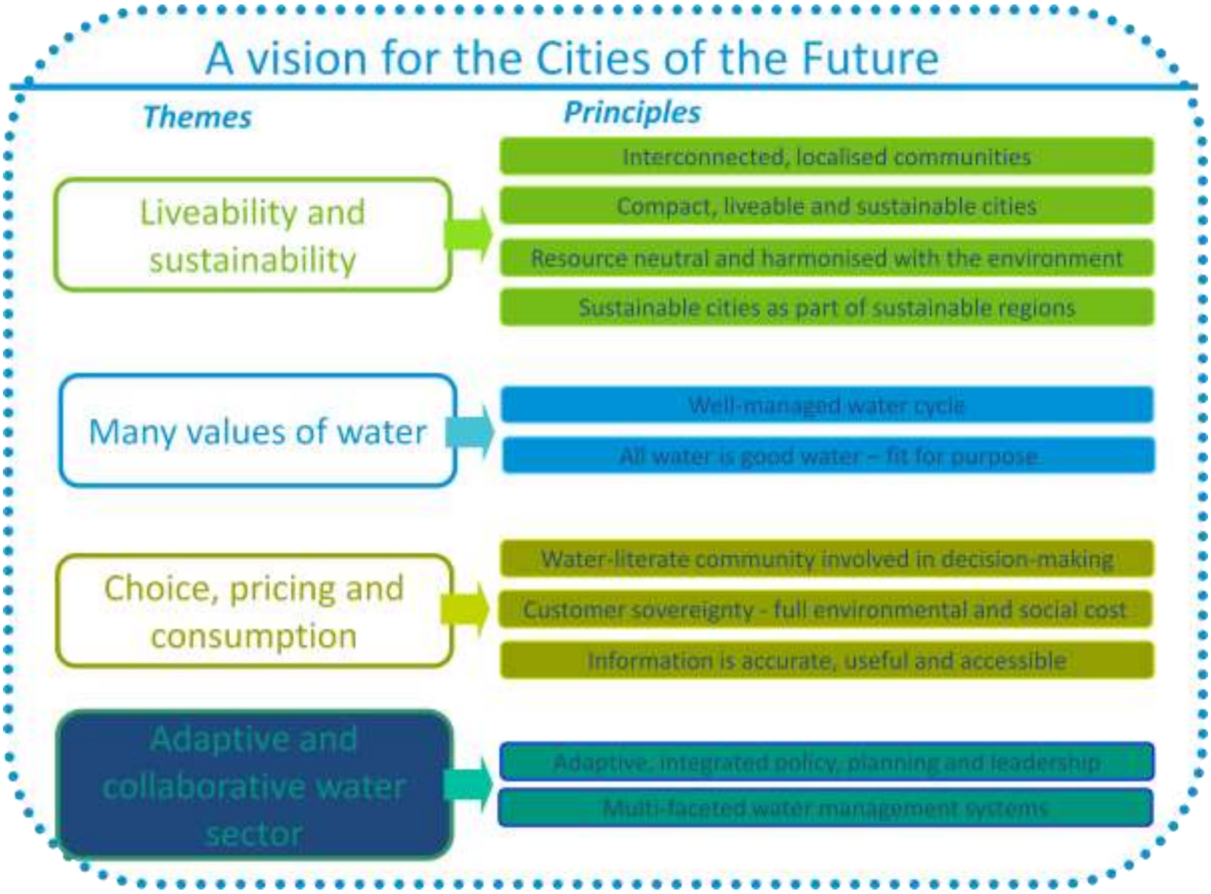
A city of the future is a sustainable, liveable, and prosperous city in which water utilities work with all sectors in a collaborative manner to ensure integrated water management in future urban planning.

This approach to planning will influence the built form and function of a city. Such planning would incorporate climate change and its impacts to ensure resilience and adaptability (WSAA 2010).For the water sector, this means integrating existing centralised systems with new sources of decentralised water management systems, and continuing to push the traditional boundaries of water and sewage management into the areas of water use efficiency and urban design. (Binney et al 2010

By collaborating, consulting and using its unique position as custodian of water resources, the water sector is taking a lead role in planning resilient and liveable Cities of the Future.

The 2011 Cities of the Future Workshop – held in Adelaide at Ozwater11 – focused on a series of case studies to demonstrate this leadership role, and how public and private water organisations were facilitating new approaches to designing urban environments.

Each case study presented examples of collaboration and integration of industry involved, sustainable design and infrastructure considerations, healthy/liveable city considerations and the project's adoption of Cities of the Future principles.



A Vision of a water sensitive city. Source: Melbourne Water 2010

4.0 Theme 2 Biophysical Environment

The second theme of the workshop was the biophysical environment which encompasses impacts related to public health, water quality, source water, catchments and river health and receiving waters.

KEY POINTS

> Maintaining high levels of drinking water quality to protect public health is a very high priority for utilities. Climate change and its impacts could affect drinking water quality, and has already been seen in the dams and catchments affected by the 2010 Victorian bushfires and the 2011 Queensland floods. An estimate of the dollar value of the ecosystem services provided by the Victorian dams and catchments has been determined at ?

> Predictive modelling and real time decision support systems for reservoirs are helping the urban water industry to manage the impacts of climate change on drinking water quality. Further research work will be required on the concentrations and behaviour of certain pathogens, toxicants and pollutants under climate change to maintain drinking water quality.

> The availability of surface water and groundwater in the environment will be affected by climate change as mentioned in the previous chapter. Maintaining the productivity of surface water and groundwater catchments while protecting their ecosystem values remains a challenge for utilities and has seen responses like groundwater replenishment (injecting highly treated wastewater into drinking water aquifers), greater use of deeper, confined groundwater aquifers (and less use of superficial aquifers) and catchment thinning to increase runoff into dams.

> Increases in sewer overflows, and shock loads of organic matter, into rivers and creeks can occur as a result of severe storms which are predicted to increase. Fish deaths and a ban on swimming are often the outcomes of this. Better monitoring systems are being investigated and implemented to manage this.

> Seawater intrusion into coastal wetlands, estuarine sections of waterways and coastal groundwater aquifers is likely to increase as sea levels rise. The Commonwealth Government are currently determining which areas around Australia are particularly vulnerable and hence, will require special management

4.1 CLIMATE CHANGE RISKS AND CHALLENGES

IMPLICATIONS FOR THE BIOPHYSICAL ENVIRONMENT

- Decreased water availability compromising ecosystem health
- Lower groundwater tables affecting groundwater-dependent ecosystems
- Increased bush fires affecting water quality
- Increased algal blooms and pathogens affecting drinking water quality
- Receiving waters quality
- Decline in environmental flows and river health
- Decline in wetland and estuarine health and salinity
- Flora and fauna, biodiversity and ecosystem impacts and threats in catchment areas
- Increased turbidity issues
- Changes in catchment vegetation species cover
- Increased pollution events
- Increased erosion in waterways

As detailed above, climate change will have implications for the urban water industry in maintaining the biophysical environment. These key implications, the current adaptation practices (including research) and the potential opportunities are discussed in further detail below. They cover the three broad areas of:

- health impacts:
- source waters and catchments;
- and receiving waters

4.2 HEALTH IMPACTS

4.2.1 DRINKING WATER QUALITY

Increases in average annual temperatures and extreme heatwaves have the potential to increase the ambient water temperature and change the temperature profile within large bodies of water (e.g. reservoirs). These increased temperatures may lead to a rise in the prevalence of algae and pathogens in water supply resulting in the need for more advanced treatment. With reduced rainfall contributing to lower stream flows, river health in systems like the River Murray is under great threat. The Murray Darling Basin Authority has reported that during low flow periods, blue green algae outbreaks are more intense and frequent. (MDBA 2008)

Higher levels of algae and bacteria in water may also impact on water supply pipeline performance. The formation of biofilm on the inside of water mains and supply pipelines is not unusual, however higher temperatures could mean either accelerated formation or a greater area of the network may be affected.

The quality of water in times of low water storage in reservoirs presents a potential health risk. The lower a reservoir is drawn down to access water in times of a prolonged dry period, the poorer the quality of water. Limits as to the maximum draw down level possible for reservoirs may need to be set in an attempt to minimise this.

Catastrophic storms have also been known to cause short term water quality and turbidity issues in catchments and waterways particularly in exposed bank areas of drawn down storages. Greater volumes and velocities of flows in waterways generally mean an increase in turbidity and suspended solids in the waterway and receiving water body (e.g. reservoir). Therefore further increases in storm intensity may increase the number of short term water quality incidents in reservoirs and hence, changes to treatment processes. This can be further exacerbated during heavy rain following bushfires in catchments. The impacts of bushfire on water quality are caused mainly by loss of riparian vegetation and influx of sediment, ash and burnt organic material from the catchment. Water quality issues following bushfires can last for a number of years until understory re-establishes and natural filtering processes are restored.

4.3 SOURCE WATERS AND CATCHMENTS

4.3.1 SURFACE WATER SOURCE AVAILABILITY

Most areas of Australia have a dependence on surface water for supplies. The open water supplies in regions with higher evaporation rates that will increase with climate change temperature projections will be more vulnerable than those areas with lower evaporation rates or alternative sources of water.

A decrease in average annual rainfall can lead to declining stream flows over time in areas across Australia (e.g. South-west of Australia) (Figure 3).   Whilst there is a direct relationship between declining rainfall and stream flows, the relationship is not a linear one. Changing rainfall averages and seasonal patterns see changes in catchment conditions such as reduced soil moisture levels, and changed vegetation cover, species and distribution. These factors in particular influence the volume of runoff that is generated from rainfall. In some parts of Victoria during the period 1996 to 2010, reductions in stream flows were four times greater than the decline in rainfall (CSIRO 2010). Changing runoff rates may also occur as a result of natural changes in catchment vegetation or forestry management practices in catchments, or regrowth after bushfires.

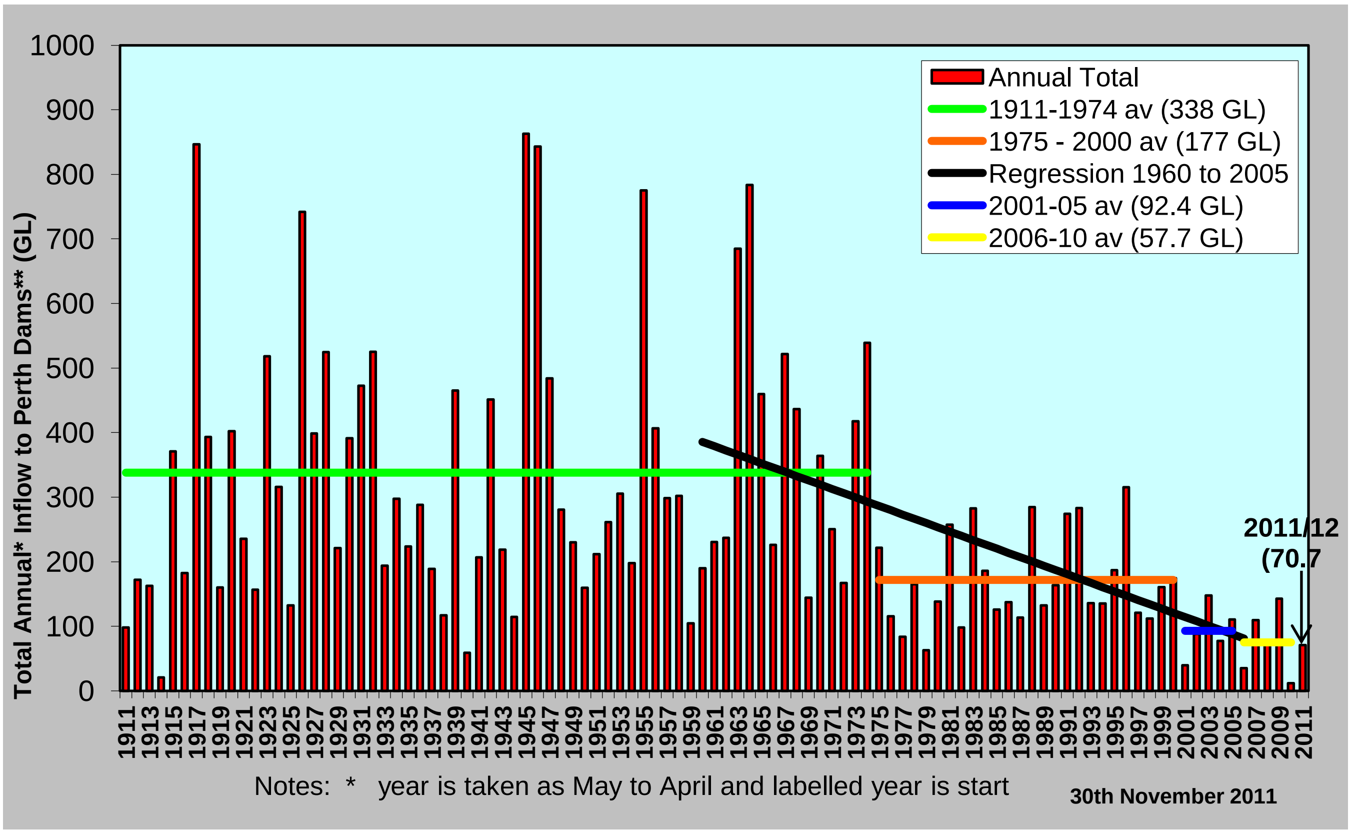


Figure 3: Reductions in streamflows into Perth dams

(Source: Water Corporation)

4.3.2 GROUNDWATER SOURCE AVAILABILITY

Around 30% of Australia's total water consumption comes from groundwater with 17% of this used for public water supply (NWC 2011). Western Australia has the largest reliance on groundwater as a resource (e.g. groundwater supplies at least 35 – 50% of Perth's drinking water, with approximately 60 - 70GL of groundwater also being used by about 167,000 households across Perth for garden irrigation). Use of this groundwater resource in Perth for drinking water and garden irrigation purposes began in the mid-1970's when pay for use water charges were first introduced and when another total sprinkler ban for scheme water users was invoked (Figure 4).

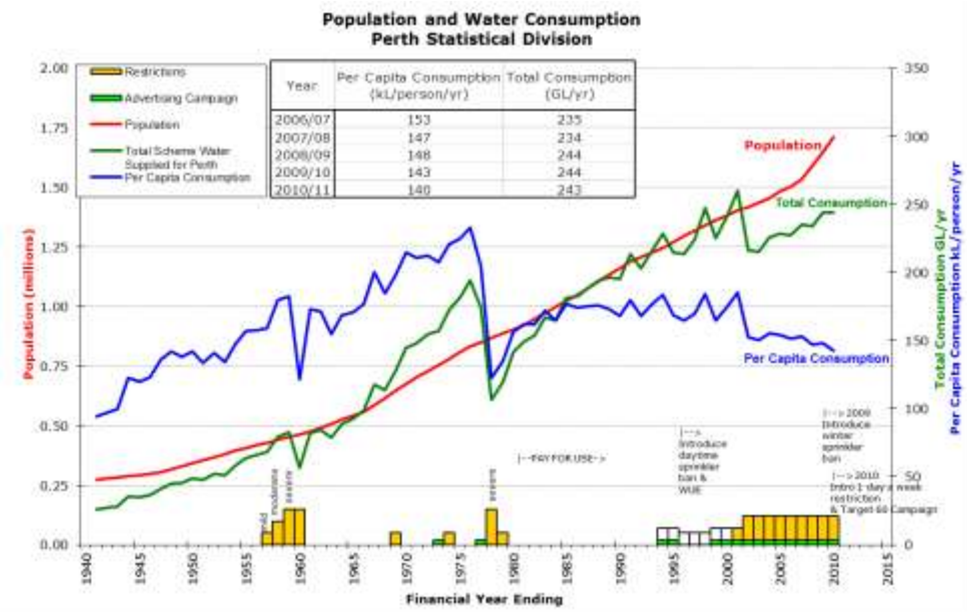


Figure 4: Population and water consumption, Perth

(Source: Water Corporation)

Groundwater is the component of the hydrological cycle that is perhaps the least understood hence, the impacts of climate change are very challenging to quantify. It is likely that recharge from surface water to superficial groundwater will potentially cause water tables to drop (Figure 5 shows this potential on the Gnangara Mound in Perth). However, due to decreasing stream flows it is highly likely there will be an increase in use of groundwater. Therefore allocation and extraction must be carefully managed in a sustainable manner. While there is much uncertainty around the rise or fall of different groundwater tables under a changing rainfall pattern and climate change some work has been done in both Perth and Adelaide in this regard. This is referred to in the Water Forever (Perth) and Water for Good (Adelaide) plans. In fact Water Corporation's ten year plan ('Water Forever: Whatever the weather') for Perth includes the abstraction of groundwater from the deeper aquifers to protect the superficial groundwater environment that is dependent on rainfall recharge.

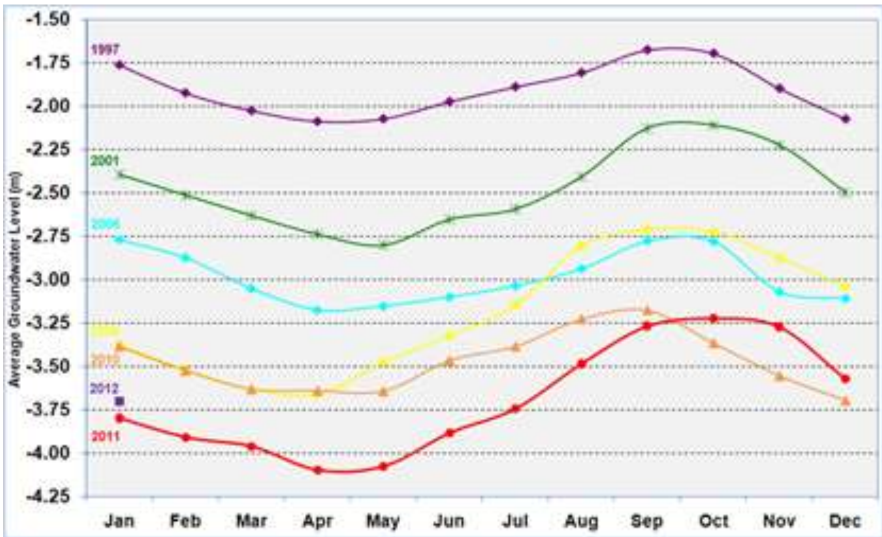


Figure 5: Water levels on Gnangara Mound

(Source: Water Corporation 2011)

4.3.3 ENVIRONMENTAL FLOWS

River health is a largely unexplored area in so far as quantifiable climate change risks and impacts. This is because different ecosystems will respond in different ways to a changed climate. River health has always been affected by climate variability and waterways rely on climate and seasonal variability to sustain their natural processes and systems. However long term changes in climate and the extremities of climate variability may cause some undesirable and unexpected changes. Quantifying and even understanding many of the risks will present challenges such as determining new flow regimes, temperature thresholds for flora and fauna and the changing biochemical characteristics of waterways.

A drop in baseline environmental flows due to decreased average annual rainfall and changed catchment conditions will almost certainly lead to increased vulnerability and pressure on riverine and estuarine health. Passage of stream flow and flow into wetlands and natural water bodies may become more ephemeral and recede to pools or dry out more often due to reduced average annual rainfall and could be compounded by increasing temperatures and increased evaporation. This presents a great risk for fish species migration, which could decline as a result. This will increase pressures on water sharing arrangements within catchments and implications for water supplies.

4.3.4 CATCHMENT COVER

Changes in rainfall as a result of climate change have the potential to affect the vegetation type and distribution of species in water supply catchments. The risk to vegetated and forested catchments is further compounded by the increased potential risk of bushfires. As the catchments become drier, their risk profile for bushfires increases. Bushfires can reduce vegetation cover and alter the vegetation species and distribution within a catchment. Changing vegetation species and distribution have the ability to affect water supply yield in the short and long term as trees grow and regenerate. The bio-physical environment case study on page 36 is such an example of this.

4.4 RECEIVING WATERS

4.4.1 SEWAGE SPILLS

Sewage spills into the drainage network and waterways pose a threat to public and river health. Spills are generally untreated sewage that may contaminate waterways. Many of Australia's waterways and receiving waters are used for recreational purposes (e.g. boating, fishing and swimming). Although the public is advised to avoid contact with creek, rivers and waters following heavy rainfall, there are no strict controls to prevent this. Therefore public health may be at greater risk if storm intensity increases leading to greater sewer spills.

4.4.2 RIVERS AND CREEKS

Another climate change impact not well understood is the potential change in pollutant loads from hard urbanised surfaces and rooves during heavy rainfall. Pollutants such as hydrocarbons, surfactants and heavy metals build up on surfaces such as roads and are transported via runoff when it rains to stormwater and waterways potentially affecting river health. Extended dry spells combined with more intense storms due to climate change may significantly increase (above average) the pollutant load in stormwater. Shock loads of organic matter (e.g. leaf litter) from intense storms are already causing deoxygenating and fish deaths in the upper reaches of the Swan estuary in Perth. This effect may be a greater threat than metals etc.

Further compromising the health of waterways and estuaries are the potential effects of higher peak flows (resulting from more intense storms) on erosion. Greater erosion combined with the declining condition of catchments and waterways (particularly their banks), may increase pollutant loads of suspended solids, and impact on waterway stability.

4.4.3 ESTUARINE AND WETLAND CHANGES

Sea level rise and increases in storm surge intensity present a risk for coastal wetlands and estuarine sections of waterways. The delicate saline and freshwater balance that exists in estuarine and wetland environs could be permanently altered.. Estuarine health could be exacerbated by the potential reduction in environmental freshwater flows from upstream and the increased turbidity associated with flooding.

Damage to estuarine and wetland health is already occurring from late season storms, which dump fresh water and organic matter on top of the salt wedge, increasing the biological oxygen demand (BOD) and reducing oxygen exchange. These events kill fish and other species.

Current adaptation practices and research

HEALTH IMPACTS

> Online real-time sewerage monitoring systems for industrial trade wastewater discharges such as those used by Sydney Water provide industrial customers and Sydney Water with real-time monitoring results on the quality of trade waste discharge. This system will enable monitoring and analysis of changes in trade waste into sewage over time in relation to weather and climate related phenomena over time that could provide a greater understanding of climate change impacts on sewerage.

SOURCE WATER AND CATCHMENTS

> The South Eastern Australian Climate Initiative (SEACI) is a major research program investigating the causes and impacts of climate change and climate variability across south eastern Australia. SEACI is a partnership between CSIRO, the Australian Government's Department of Climate Change and Energy Efficiency, the Murray Darling Basin Authority, the Bureau of Meteorology and the Victorian Department of Sustainability and Environment. Through these projects and their associated milestones, the program aims to deliver a holistic and better integrated understanding of climate change and climate variability across south-eastern Australia to support water managers and policy makers.

- Predictive modelling is a relatively new area of research that will prove useful in climate change adaptation. Melbourne Water used plume and temperature modelling following the devastating Victorian bushfires in 2009 to assess the impact of the fires on runoff into Melbourne's catchments. This tool and others like it will prove very useful in predicting the impacts of bushfires on water supplies in catchments potentially taking into account the increasing frequency of bushfires and changing catchment conditions.
- Many water utilities and catchment authorities have complex reservoir management systems that enable water managers to model water volumes and transfers through a water supply system. Sydney Catchment Authority have developed a real time decision support system for reservoir management to aide in long term and short term management strategies in response to impacts on water quality following catastrophic storms, floods, bushfires or heatwaves.
- The Commonwealth Government are performing a nationwide vulnerability assessment of seawater intrusion and its impact on coastal groundwater resources. The study is currently underway and is being undertaken by Geosciences Australia. The study is being done in collaboration with the National Centre for Groundwater Research and Training as well as state and territory water agencies and authorities.

4.5 RESEARCH AND ADAPTATION OPPORTUNITIES

4.5.2 WATER QUALITY

- Investigate how climate change will affect pathogen survival and persistence in the environment via vectors and sources in relation to the causes of endemic disease. Molecular studies, epidemiology and Quantitative microbial risk assessment (QMRA) can be combined to try to provide better estimates of water-related disease.
- Study the impacts of climate change on land use and land management practices and investigate evidence of water quality impacts.
- Develop tools to predict, monitor and assess trends in concentrations of pollutants, toxicants and pathogens in water sources.
- Investigate the behaviour of cyanobacteria under climatic conditions and develop models and empirical tools to predict future changes.
- Develop a database collection on water quality information soil characteristics and changes over time from different sectors and organisations across the world.

4.5.3 WATER QUALITY, QUANTITY AND ECOSYSTEMS

- Investigate environmental thresholds and how climate change may affect these thresholds and what it may mean for species, habitat or water quality.
- Develop a conceptual model of climate change and how it affects water quality and water quantity. The model can integrate and link the many disciplines and hydrological areas involved.

CASE STUDY: BIO-PHYSICAL ENVIRONMENT

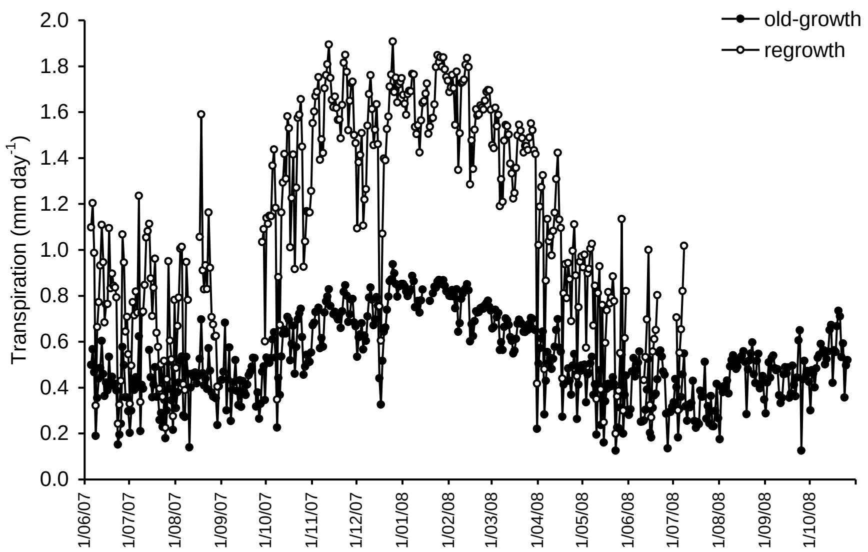
There are few examples of adaptation to climate change in the bio-physical environment. This is primarily because of the complexities of the bio-physical environment and the difficulty in quantifying potential or observed impacts attributable to climate change. Adaptation measures for the bio-physical environment will heavily rely on building resilience in catchments and ecosystems.

An ambitious example of building resilience into natural ecosystems is the forest thinning trial in the Wungong catchment to the south east of Perth. The Water Corporation's Wungong Catchment Trial is a $20-million project that began in 2005 and will span 12 years. Please see http://www.watercorporation.com.au/W/wungong_index.cfm for more information.

The objective of the trial is to assess whether carefully planned forest thinning can be used to 'bio-engineer' the catchment back to an approximation of old growth form to increase stream flows and hence water yields to the Wungong Reservoir, restore formerly perennial streams and aquatic habitats while restoring or maintaining natural biodiversity. The Water Corporation can no longer depend on its Darling Range reservoirs for water supply because of their declining reliability in response to the severe drying trend in south-western Australia.

Perth's forested catchments consist mainly of regrowth jarrah and marri eucalyptus trees. The Wungong Catchment is degraded, having been altered by past forestry practices, the introduction of Phytophthora dieback disease (a water mould) and bauxite mining. Jarrah (Eucalyptus marginata) is unusual, as it sprouts multiple stems from the stump when harvested. This is called 'coppicing', and has two serious consequences – one is the failure to replace the harvested tree with another valuable straight, single stem and the other is that the total leaf area of coppiced jarrah forest is about double that of 'old growth' forest. The increased leaf area means that the forest uses much more water than in its natural state – see Figure 2.

Figure 2: Daily overstorey transpiration over time, calculated from sap velocity and sapwood area at the Dwellingup old-growth and regrowth stands. Missing data indicate periods of power supply or instrument failures (CSIRO).



Old-growth transpiration accounted for 20% of the average annual rainfall for the experimental site, in contrast to 40% for regrowth. In April 2011, after a long hot summer, the consequences of the unmanaged regrowth on the forest's water balance became obvious.

Drought deaths in approximately 5-10% of the forest were seen, with many other parts yellowing and stressed. Stressed and dying vegetation was even observed in the healthiest part of the catchment, around the reservoir. Trees are known to lag in their response to water shortages, which suggests the situation may be worse than it seems. Trees in thinned areas were healthier than those in unthinned areas, indicating more favourable groundwater and soil moisture levels in the thinned patches – see the photograph below

Thinned (left) and unthinned forest (right) in the Wungong catchment, 15 April 2011, showing large areas of stressed and dying trees in the unthinned forest.

Dr George Matusick from Murdoch University has estimated that 16,000 ha of trees in the northern jarrah forest have died. This is about 1.7% of the total forest area, with an additional 5% showing signs of severe stress. These figures are staggering given the forest experiences an estimated 'normal' annual mortality rate of about 0.05%. The trees were found to die in patches which ranged from 0.3 ha to over 50 ha in size. Following the 2011 winter only 35% of dead stems showed signs of re-sprouting.

Rainfall in the south west of Western Australia has declined by about 12-15% since the mid-1970s; this has resulted in reductions in groundwater recharge and stream flows in the order of 70%. The Wungong study seems to show that the water balance of the jarrah forest is now at the limit – further drying will result in forest tree deaths on a massive scale.

Dr Richie Silberstein of CSIRO estimates that trees are now intercepting or transpiring about 98% of rainfall in most years. So the community has a choice – either to proceed with controlled forest thinning on a large scale, or to risk the uncontrolled collapse of more of the jarrah forest.

5.0 Theme 3 Infrastructure

The theme infrastructure encompasses assets and facilities owned by water utilities and highlights considerations relating to the supply chain through which services are delivered.

Climate change is expected to impact on water related infrastructure across Australia in many ways and has been the subject of a number of studies. Types of assets affected and the impacts they face is discussed widely, however identification of individual assets at risk requires more detailed analysis by water utilities. Water utilities are also dependent on the supply chains which provide energy, infrastructure parts, and materials used in maintaining and running assets. Disruptions to supply chains can impact the ability of water utilities to provide services.

KEY POINTS

- The range of infrastructure assets managed by water agencies across Australia is extensive. It ranges from natural assets such as catchments, waterways and wetlands, through to long lived constructed civil, mechanical and electrical assets such as pipelines, treatment plants, pumping stations and data acquisition systems. The replacement cost of the network assets alone range from $40B to $175B for the water network and $34B to $150B for the sewer network.
- Water utilities are subject to disruptions in supply chains which may increase under climate change. The supply chain also refers to any component, supplier or process that is related to the water sector. The supply chain for water supply, sewage collection and treatment, drainage and flood management is extensive and variable. Water utilities rely on mains power and telecommunications for pumping and treatment operations, telemetry and monitoring. To ensure continual supply water utilities are now investing in backup generators and other 'off the grid' electricity supplies.
- Cracks in pipes (caused by soil drying out and stressed tree roots looking for water) are likely to increase under climate change leading to leaks and bursts interrupting supply and upsetting customers. Work to identify and manage infrastructure that is particularly vulnerable to this is being undertaken by utilities and the Australian Government. Simultanously work to identify corroded pipes, (that are particularly susceptible to climate change) is also occurring in partnership with the industry and CSIRO.
- Peak flows inundating assets causing either sewer or dam overflows is particularly challenging to manage. The national significance of this issue is seen in the modelling and analysis currently being undertaken in this area. The AdaptWater tool being developed by the industry will also help identify risk and vulnerability of assets. The industry is also already learning from, and will continue to learn from the events that affected public water services during the 2011 Queensland floods.
- Climate change impacts will need to be considered in the design standards for renewing existing infrastructure and building new infrastructure.
- Utilities will also need to consider the 'retreat' option ie look for any opportunity to move crucial equipment, pumps and other important assets out of low lying areas. Linking in with this is considering the best time to renew or move assets based on climate change predictions.

5.1 CLIMATE CHANGE RISKS AND CHALLENGES

IMPLICATIONS FOR INFRASTRUCTURE

> Peak demand changes & infrastructure sizing
> Ground movements / root intrusion
> Salt water intrusion, changing sewage concentrations and increased corrosion rates
> Power outages resulting from extreme floods, heatwaves and bushfires
> Spillway capacity design
> WSUD asset life
> Flooding and inundation of low lying & buried assets
> System capacity exceeded during heavy rainfall and high tide
> Groundwater table changes impact integrity of asset foundations and clay lined basins

The range of infrastructure assets managed by water agencies across Australia is extensive. It ranges from natural assets such as catchments, waterways and wetlands, through to long lived constructed civil, mechanical and electrical assets such as pipelines, treatment plants, pumping stations and data acquisition systems. The replacement cost of the network assets alone range from $40B to $175B for the water network and $34B to $150B for the sewer network as illustrated in the table below. The variability of average replacement costs is dependent on the complexity of the replacement and the number of customers that the utility serves.

	Mains (km)	Low Complexity Replacement Cost ($b)	High Complexity Replacement Cost ($b)
Water	146,000	40	175
Sewer	123,000	34	148

Table 4: Australian water and sewer network replacement costs

The main impacts on water related infrastructure of climate change are:

> the risk of not meeting levels of service for which the asset has been designed;
> a reduction in asset life, that also has the potential to lead to need for more frequent asset maintenance and replacement, and
> in severe circumstances asset failure.

The risk to these assets may also be influenced by changes in single or multiple climatic variables, a combination or cumulative conditions or due to extreme events, or a combination of all.

Total asset failures can have serious consequences as was seen in the 2011 Queensland floods. Asset failure may occur more frequently under the extreme weather events of climate change therefore it is prudent to consider asset failure in climate change programs. In examining asset failure the US EPA (2008) recommends considering questions such as:

> How can and how do the assets fail?

> What are the likelihood and consequences of asset failure?

> What are the financial, social and environmental consequences of asset failure and repair?

> What are the systems in place to prevent or mitigate failure?

As a result of these impacts to levels of service and potential asset failure, and the uncertainty in the extent of the impacts on many assets, capital expenditure costs and operational expenditure costs to maintain assets can be expected to face a probable rise in future which in turn affects the price of water, sewerage and drainage services.

There is a range of areas under which levels of service may be affected by climate change. The following outlines some of the risk areas, particularly affecting levels of service and asset life that have been identified in climate change studies.

Water utilities are subject to disruptions in supply chains which may increase under climate change. The supply chain also refers to any component, supplier or process that is related to the water sector. The supply chain for water supply, sewage collection and treatment, drainage and flood management is extensive and variable. Water utilities rely on mains power and telecommunications for pumping and treatment operations, telemetry and monitoring. Electricity supplies and telecommunication could also suffer from disruptions as a result of climate change and increased extreme events such as lightning, wind, rain and heat. This will have potential impacts of continuity of services in the water sector, and potentially have significant impacts on ability to meet levels of service.

As detailed above, climate change will have implications for the urban water industry in maintaining infrastructure. These key implications, the current adaptation practices (including research) and the potential opportunities are discussed in further detail below. They cover the two broad areas of:

> levels of service: and

> asset life.

5.2 LEVELS OF SERVICE

5.2.1 CHANGES TO SOIL CONDITIONS

Decreased average annual rainfall and increased evaporation may result in changes in the structure and moisture content of soil, leading to ground movement and cracking. This could increase pipeline bursts or leakage (particularly in areas that have expansive clay soils). Under climate change, drying clay soils present a risk to infrastructure; particularly non flexible concrete drainage pipes and deteriorating metal pipes. More extreme or frequent wet-dry cycles may also cause old brick-lined sewers or drains to collapse and block, increasing the need for maintenance and the frequency of service disruption.

Water utilities infrastructure such as retaining basin or dam walls and levee banks may also be at risk from changing soil moisture conditions. Earth embankment types of infrastructure are generally constructed with some form of clay core, as it is a reliable material that under normal wetting and drying conditions provides a barrier or surface with very little or no hydraulic conductivity. These barriers help contain floodwaters and protect other assets in times of extreme flooding. In the event of movement of these structures there is potential for pathways to be created for water flow which can impact on asset integrity.

Root intrusion into sewers and other water infrastructure is also likely to increase as trees and vegetation seek out the nearest sustaining water source in drying soils. Root systems can crack and destroy underground infrastructure leading to ongoing issues (e.g. leaks and bursts) and in extreme cases asset failure.

5.2.2 INCREASED RISK OF POWER FAILURE

The projection for more intense storms, bushfires, heatwaves and flooding increases the likelihood of power failure.. Heavy rainfall can result in changes to the flood risk for low lying assets and high winds can short out or bring down power lines. Catastrophic bushfires can also bring down power lines and interrupt supplies, with heatwaves likely to cause an overloading of the power grid as people turn up their air conditioners to keep cool. The interruption to power supplies can affect the ability of water utilities to undertake their functions such as pumping, transfer and treatment for water supply, sewerage and drainage pump stations.

5.2.3 WATER QUALITY IMPACTS FOLLOWING BUSHFIRES AND HIGH WINDS

Bushfires also have the potential to cause multiple impacts in the short and long term. Water utilities have many assets located in high bushfire risk areas such as forested catchments (e.g. pumps, waterways and biologically valuable riparian zones). Loss of assets such as pipes, pumps and reservoirs would affect the operational capacity and ability of a water utility to deliver water supply. Water supply reliability can be affected both in the short term and the longer term following a fire. Reservoirs may need to be taken offline following a significant bushfire in the catchment, due to accumulation of sediment or debris which impacts water quality. Catchment yield may be reduced for decades following a fire as the trees regrow, which may result in water shortages or restrictions which impact customers.

Extreme winds can also cause damage to assets and block access routes due to windblown trees, branches and debris. Strong winds and heavy rainfall in the catchments can also transport organic and tree debris to reservoirs where it accumulates and presents a risk to spillway integrity and outlet function.

5.2.4 DECREASES IN WASTEWATER FLOWS AND OTHER WASTEWATER IMPACTS

A decrease in dry weather water flows in sewers from a reduction in average rainfall, and increased water conservation by customers, could result in more concentrated sewage. Whilst the amount of water being used and disposed may be reduced, the volume of waste that is often transported by the sewage flows can potentially remain the same. For example an improvement in the efficiency of water using appliances such as toilets and washing machines may reduce volumes but loads will be more concentrated. Further compounding this is the potential for rising temperatures to increase the temperature of waste water causing greater evaporation and increased concentrations. A more concentrated sewage will generally result in a more salty recycled water product which may be unfit for delivery to customers unless energy-intensive membrane technologies such as reverse osmosis are used to remove salt. The warmer temperatures expected under climate change may have benefits for biological wastewater treatment plants, in which biological activity and resulting pollutant removal rates generally increase with temperature. However algal blooms including blooms of toxic algae like blue-green algae are more likely under warmer conditions. Blooms could occur in sewage treatment plants, water supply reservoirs and potentially other water bodies, which could result in service disruptions.

The impacts of sea level rise and more frequently intense storm surge will be felt differently around the coast of Australia. Low lying coastal assets for water utilities such as sewerage treatment plants, drainage outfalls and underground pipelines (water, sewerage and drainage) could be affected.

5.2.5 PEAK FLOWS AND THE INUNDATION OF ASSETS

Inundation of sewage treatment plants could affect treatment processes or cause releases of inadequately treated sewage into the sea due to the changes in the hydraulic grade of treated sewage outfalls. Sewerage and drainage assets with higher standing water levels at the outfall may also suffer from reduced hydraulic efficiency and backing up within the system, which has the potential to cause back flow in drains or spills from sewers into the environment. In some areas saline-affected sewerage and groundwater could compound the challenges of producing recycled or drinking water of adequate quality and may lead to disruption of services to customers.

Some sea walls and levees owned by public water utilities that provide protection of water or sewage assets or inundation protection of community assets may also be affected by sea level rise. These assets have been designed to provide a certain level of protection that may be exceeded as sea levels continue to increase.

Drainage assets may also face increased risk through the need to cope with greater flow volumes and velocities. Drainage and flood protection infrastructure; drains, outlets, rock chutes, pump stations, flood gates, levees; retaining basins; are designed to convey specific flow volumes in accordance with industry and regulated standards, and provide flood protection for the community also to an agreed standard. Increased volumes, velocity, hydraulic forces and pressure on these assets above the design standards could undermine their integrity causing failure or collapse. Failure of drainage assets in times of flood can have devastating effects causing environmental damage, property damage, injuries to people or worse – fatalities. The financial cost from a liability and insurance perspective as well as social and emotional impacts of such an incident could be immeasurable.

Any potential changes in rainfall intensity due to climate change may have implications for the calculation of the probable maximum flood (PMF). Changes to the PMF at this stage however are still poorly understood and therefore difficult to quantify. But the consequences of any such change to a PMF could affect the risk profiles of dam spillways around Australia which may need upgrading to ensure appropriate protection and safety standards are maintained.

Similarly, stormwater and drainage pipelines, and floodways are designed to convey a particular peak flow (anywhere up to 1 in 100 year event is standard based on local requirements). Should the intensity of heavy rainfall and subsequent peak flows be greater than the current capacity of pipelines and floodways; flood levels, flood reach and flood frequencies may increase and more properties may be affected. Bridges and crossings are also designed to provide a particular level of flood protection, therefore if flood levels increase roads may become inundated and will restrict access to utilities assets.

Changing climatic conditions also has the potential to result in the need for review of a range of design parameters, standards and levels of service used throughout the water industry. Changes in the frequency, duration and severity of climatic events (e.g. rainfall, temperature, wind) may bring into question the appropriateness of designs for existing assets and design standards for expected climate change conditions, including the underlying baseline climate conditions. This may have implications for capital expenditure should there be changes in these standards to take account of climate change.

5.3 ASSET LIFE

Fatigue and degradation of materials due to extreme events or long term change can lead to a decrease in asset life and earlier renewals or replacement schedules. Surrounded by uncertainty and variability in almost all areas of water resource planning; water supply, sewerage treatment planning, drainage and flood management; it is challenging for water utilities to plan for and size their infrastructure. Assets are constructed with an expected life span; therefore it is now becoming important to understand how the requirements or expectations for infrastructure will change in the future if the climate continues to shift. Water utilities face the risk of over sizing or under sizing infrastructure due to the explicit uncertainties in climate science and the uncertainties of translating the climate science into hydrological models. Fixed assumptions we have relied on in the past are changing along with the climate.

5.3.1 RAINFALL VARIABILITY – IMPACT ON STORMWATER ASSETS

Stormwater quality treatment devices such as bio-retention systems, tree planters, infiltration systems and rain gardens may also face shorter asset life or even failure due to decreased average annual rainfall. Although many of these systems can be designed so that they do not require regular flows, prolonged dry or drought conditions can affect the health of filtration vegetation and the ability to regrow biofilms that treat nutrients in stormwater. On the other hand, extreme rainfall events may dislodge or uproot vegetation, or damage drainage or stormwater infrastructure, potentially resulting in more frequent asset replacement or repair.

5.3.2 SEA LEVEL RISES – IMPACT ON DRAINAGE AND GROUNDWATER

Rising seas have implications for drainage outfalls. Outfalls are generally set above or at the normal tide water line. A higher than normal water line due to sea level rise and storm surges could result in large areas being inundated for long periods of time.. Outfalls in tidal or saline environments are generally constructed from salt tolerant concrete, which may differ from the drain construction material further upstream. It is these sections of drains that may suffer from corrosion and a reduction in asset life due to the incremental increase in saline levels upstream.

A rising sea level could also lead to a rising coastal groundwater table. Permanent water table rise in coastal regions could see a significant increase in infiltration of saline water into the sewage system, which could present an issue in normal or dry weather flows. Increase saline water in the system either through the network or at the treatment plants increases the salt levels in the sewage and could further affect the life of these assets and others along the coast such as underground water mains due to corrosion. Increased salt levels in sewage also affect the effectiveness of the treatment processes as salt inhibits the activated sludge process and other treatment methods that are used at many treatment processes across Australia. Warmer temperatures and more concentrated sewage may support increased production of toxic gases such as hydrogen sulphide that are corrosive and affect the life of particularly metal and concrete assets found in sewers, sewage pumping stations and sewage treatment plants. Freshwater groundwater tables near the coast could be impacted by salt water intrusion, which may also increase the risk of saline groundwater infiltration into sewers in some lower lying areas. It may also increase saline intrusion into coastal groundwater bores (particularly those in Perth, many of which are used to water gardens).

Current adaptation practices and research

LOSS OF ASSETS

- Water utilities are starting to undertake and act on vulnerability assessments to identify infrastructure that may be vulnerable or sensitive to climate change. Vulnerability and risk assessments are being undertaken by water utilities for bushfire, sea level rise and flood management through the AdaptWater project.
- At a national level, the Australian Government's Critical Infrastructure Protection Modelling and Analysis Program (CIPMA) is a major initiative aimed at improving and protecting the future security of Australia's critical infrastructure. The program will be covering infrastructure across all areas and identifying paths to enhance resilience.
- The National Climate Change Adaptation Research Facility was established in 2008 to take the lead on collaborative research across different fields and sectors in relation to research into climate change adaptation. Settlements and Infrastructure is one of the priority themes identified and a National Adaptation Research Plan (NARP) has been specifically developed as well as a Settlements and Infrastructure Implementation plan.
- A collaborative study between City West Water, South East Water, Yarra Valley Water and Melbourne Water, (the Melbourne Metropolitan Sewerage Strategy) sets out the future issues and management strategies for Melbourne's sewage. It covers uncertainties such as climate change, population, urban growth and living standards, and uses of sewage, such as recycling or disposal.

ASSET MANAGEMENT

- A number of states are developing or have developed strategies to detect, manage and replace concrete and metal pipelines that are corroding or at risk of corrosion, and have active leakage detective programs. The increasing issue of pipe corrosion is at the centre of research being undertaken by CSIRO and Australian water utilities to better understand the factors and conditions that influence copper pipe corrosion.
- Eleven Australian water industry organisations are working with university and industry partners from Australia and overseas to develop national standards for cost-effective methods to manage and minimise concrete corrosion and odour emissions from sewers. The work is part of an Australian Research Council Linkage Grant. This is a five-year, $19 million, national program involving water utilities from NSW, Queensland, Victoria and Western Australia.

- In response to the frequency of power outages due to extreme events and to minimise interruption to continued supply, water utilities are investing in back-up generators and looking at other sources of power that are not dependent on the electricity grid. Sources such as wind power, bio-gas and solar electricity are being considered and developed and not only provide the benefit of non-power grid dependent sources, but contribute to the reduction of reliance on carbon intensive energy sources.

5.4 RESEARCH AND ADAPTATION OPPORTUNITIES

5.4.1 SEWER FLOWS AND OVERFLOWS

- Complete detailed studies to understand the impacts of sewer overflows under future climate change scenarios and use this information in decision-making processes.
- Develop innovative approaches to stop (mitigate risk of) cross-connections in third pipe systems and of stormwater connections to sewer that contribute to high sewer flows in wet weather events.
- Consider climate change scenarios in the design standards on sewer flows.

5.4.2 IDENTIFYING, MONITORING AND MOVING VULNERABLE ASSETS

- Examine how infrastructure in other regions and countries performs under climatic conditions similar to those predicted in particular regions of Australia.
- Develop a suite of conceptual models, incorporating a ‘model business case’ including CIPMA (Critical Infrastructure Program for Modelling and Analysis) overlays to identify vulnerable assets, infrastructure and communities. AdaptWater will assist with this.
- Undertake an opportunistic move of crucial communication equipment, pumps and other important assets out of low lying areas so they are not susceptible to flooding or other extreme events.

5.4.3 SUPPLY CHAINS AND PROJECT PHASES

- Build understanding of the exposure of water utilities to disruptions in supply chains under climate change and identify opportunities to work closer with other sectors in our supply chain for better planning and cost sharing to prepare for events
- Incorporate climate change into all phases (acceptance, approval, planning, design, construction operation and maintenance) of an infrastructure project.
- Optimisation of existing asset life such as the timing of renewals considering the climate change projections and data and investment options.

CASE STUDY: INFRASTRUCTURE

Managing the risks to infrastructure associated with climate change requires a pragmatic approach. Unlike the bio-physical environment, infrastructure adaptation relies on the ability to obtain quantifiable information and data. This is because infrastructure planning and design depends on the ability to define sizes, volumes, frequencies and other data in modelling.

Due to the high number of uncertainties, it is necessary to include a high number of assumptions and caveats on the use of climate change models and outputs. It is important to note however that the uncertainties are not generally accepted as an excuse for inaction. If project planning and delivery is transparent and investment decisions can be justified, adaptation to a changing climate is achievable.

The reliance on surface water supplies as the primary source of drinking water in many areas of Australia means that under climate change scenarios, a majority of these supplies would be under stress. As such, a number of state government agencies and water utilities are taking action to diversify sources and build redundancy into water supply networks by increasing interconnectedness between water supply systems. One such investment is that of the Queensland State Government.

The Queensland Government's $6.9 billion South East Queensland (SEQ) Water Grid was implemented when South East Queensland was suffering from the worst drought in modern history. In response, the Queensland government developed the South East Queensland Water Strategy which provided the path for the region's water future. The strategy outlined the extensive infrastructure projects that would help to secure South East Queensland's water future and call it the SEQ Water Grid. The Water Grid comprises of an infrastructure network of treatment facilities and two-way pipes that move water from new and existing sources across the region.

The SEQ Water Grid includes:

> 12 connected dams

> 10 connected drinking water treatment plants

> 3 advanced water treatment plants producing purified recycled water

> 1 desalination plant

> 28 water reservoirs

> 22 bulk water pump stations

> 535 kilometres of potable bulk water mains

The SEQ Water Grid connects water supplies, storages and treatment plants across South East Queensland, from Noosa to Coolangatta and out to the Lockyer Valley.

It provides South East Queensland with both climate dependent (dams and rainfall) and climate independent (desalination and purified recycled water) sources of water. The SEQ Water Grid is a Queensland Government initiative designed to provide a guaranteed level of security for the region's water supply, regardless of the demands of population growth and climate change.

6.0 Adaptation Actions

The criticality of all research and adaptation opportunities identified across the three themes was assessed at the workshop with the result being a list of priority actions (see Table ?) for the urban water industry. These and other less important actions are discussed in more detail under the following headings:

> climate science, hydrology and uncertainty;

> decision support; and

> collaboration.

Adaptation requires robust decision support processes and models. This aspect of adaptation is the increasing focus of utilities. The Water Utility Climate Alliance (WUCA) in the United States of America undertook a study of 5 planning decision support methods: decision tree, scenario planning, robust decision making, real options and portfolio planning. The study concluded that no one option is best.

Adaptation is becoming more about embedding climate change considerations into the everyday business of a water utility, at all levels. It is a top down and bottom up approach,. In order for this to occur, water utilities need to build capacity in the field of climate change and what it means for employees and their jobs. Only then can the water utilities truly collaborate within and outside of the water sector.

6.1 PRIORITY ACTIONS

Issue	Key Priority Action	Outcome
Identifying key stakeholders	Identify stakeholders (including international organisations) with strong interest and involvement in climate change adaptation to clarify and prioritise opportunities for collaboration in both policy and science.	A mud map of key stakeholders that can form the basis for the National conversation, and help in developing and delivering on the roadmap.
National conversation	WSAA to lead a national conversation with its members on the topic of climate change in the context of the 2009 Victorian bushfires, the 2011 Queensland floods, the 2010 record dry winter in Perth and the pending carbon tax.	A roadmap that provides clear research and policy direction to Government, research institutions and customers on what is necessary to ensure essential water services are protected from climate change.
Engagement with regulators	Engage with economic, public health and environmental regulators to encourage them to become 'climate ready.'	Regulators have a deep understanding and appreciation for climate change issues, the impacts for future decision-making frameworks and the likely trade-offs required in investments in infrastructure.
Collaboration with National scientific institutions	Collaborate to leverage access and potentially influence climate change modelling and adaptation work undertaken by CSIRO, BOM and the Centre of Excellence for Climate System Science	Climate Change modelling and adaptation science at the National level has relevance to the real issues facing water utilities, and significantly assists the industry in managing for climate change.

Collaboration with International scientific institutions	Collaborate with the US based Water Utility Climate Alliance (WUCA) and utilise existing WSAA relationships with the Water Research Foundation (WaterRF) and the Water Environment Research Foundation (WERF) in priority areas, developing, trialling and documenting case studies of decision-making tools	Climate Change research at the International level covers decision-making tools which can be applied in the Australian context.
Conceptual models	Develop a suite of conceptual models, incorporating a 'model business case' and including CIPMA overlays, to identify vulnerable assets, infrastructure and communities. Develop a 'model business case' for investment (in infrastructure or a program) that incorporates a climate change adaptation perspective – for use in sector capacity building and for engagement with industry regulators.	People and assets in vulnerable areas are protected from climate change impacts or moved away if protection is not possible. The urban water industry and regulators understand the scale of what is required to adapt to climate change from an economic, financial, health and wellbeing perspective. And appreciate the flow on effects that catastrophic events can have in the community, natural environment and economy.
Knowledge sharing	Build and share knowledge on water utilities' responses to record-breaking events.	All water utilities have a good understanding on how to plan for, manage and continue to meet customer needs in the face of events which may affect them like catastrophic storms, floods, heatwaves, drought or bushfires.
Climate Change Adaptation Network	Develop a Climate Change Network in which members will be communicated with on an ongoing basis and updated on relevant research and projects via WebPages on the WSAA website. These WebPages will also include a Climate Change Clearinghouse where members can download information and upload reports to share with other members.	All members have a 'one stop shop' for climate change issues (particularly adaptation issues) to encourage sharing of information and ideas, and to ensure doubling up of work is avoided where possible.

6.2 ADDRESSING CLIMATE SCIENCE, HYDROLOGY AND UNCERTAINTY

6.2.1 AREAS OF CLIMATE SCIENCE RESEARCH

Whilst there has been significant modelling of the potential extent and impacts of climate change in Australia, there are (and will remain) limitations to these forecasts. Work is underway to provide more localised projections and additional precision. An important initiative in this field is the University of NSW Climate Change Research Centre, a multi-disciplinary climate research group with a strong focus on climate modelling . Climate change research is also being undertaken through other local and regional authorities.

New approaches and areas of research must continue in order to provide the decision makers with practical information such as data to a scale that it can be applied in local hydrologic models.

Suggested primary focus areas for research agencies such as CSIRO include:

> Review current global climate models and small scale renewable energy scheme (SRES) scenarios and local models for relevance and validity and compare with UNSW work at the Climate Change Research Centre in order to provide more likely scenarios and more accurate model outputs.

> Undertake sensitivity analysis for uncertainty of different models and develop a tool to provide this information in such as way that utilities can determine how important the sensitivity of models may be.

> Undertake further studies comparing historic climate variability with uncertainty and the ranges within climate change projections to gain a better idea of how climate variability may be changing over time (both observed and within the models).

> Continue work in the field of changes to heavy rainfall under climate change for all areas of Australia to produce usable data for modelling. Also expand on lesser investigated areas of climate change (e.g. changes in the frequency of lightning strikes)

> Identify a better way for WSAA and utilities to connect into activities being implemented by BOM, CSIRO and other researchers to minimise the duplication of projects and maximise contributions to other projectsDevelop a formal review process with researchers and water utilities to identify gaps in climate science and water utility requirements to be addressed.

6.2.2 AREAS OF HYDROLOGICAL IMPACT RESEARCH

A key challenge in the research of climate science for use by water utilities, is providing the information in such a way that it can then be utilised in hydrologic and hydraulic models for areas such as environmental flow modelling and forecast, water supply modelling, flood modelling, evaporation and evapotranspiration rates, and even water supply demand modelling.

Further ensuring that the hydrologic and hydraulic models appropriately take into account the effects of climate change and modelling outputs is another issue. Water utilities across Australia use different models for different purposes with relatively little consistency save for the key principles of modelling. This leads to further confusion in the types of information required and the formats it should be provided in for water utilities. As such, the water industry must work together with the support of WSAA to:

> Support the development of water industry relevant models to address gaps in modelling areas and develop information sets in a consistent manner that can be applied to multiple agencies and utilities.

> Support the development of fundamental knowledge for water utilities such as soil maps, rainfall, environmental flows and flooding data.

> Undertake a comprehensive review of available models that reflect climate change impacts above and beyond water supply i.e. incorporating impacts on the social/cultural environment, land use, soil, temperature, evaporation rates, evapotranspiration and flood modelling.

> Share information that quantifies the hydrological changes and impacts of climate change in different water sheds across Australia to enable more informed adaptation measures and minimise over- or under- investment.

- Support studies that clarify further onset timing and critical thresholds for different impacts of climate change on the water cycle such as environmental flows, water supply levels or flood frequency to identify timing or commencement of adaptation responses.

AREAS OF INFRASTRUCTURE RESEARCH

Impacts of climate change on water related infrastructure can arise over the short or long term. An area for further investigation is the potential impacts of bushfire on buried infrastructure, communications, and electricity using the bush fire risk Fire Danger Index (FDI).

6.3 DECISION SUPPORT

6.3.1 GOVERNMENT AND REGULATORS

Action on climate change needs to be driven by employees in the water industry, the community, and governments introducing appropriate policy and legislation to deal with emission reductions and adaptation.

Many people see climate change as an economy wide challenge, where costs are not isolated. Five policy prescriptions that could guide decision making when dealing with water management in light of climate change include:

- invest in scientific research to reduce uncertainty and help better understand the local consequences of climate change;
- prepare and plan; share information and increasing climate literacy of business and the community;
- embrace diversity and innovation, acknowledging that there is no one solution for all water utilities (however policy, frameworks and institutions that support this diversity are needed);
- deepen markets to help absorb climate change impacts and events and enable flexible allocation of scarce resources and attracting investment; and
- clarify the role of government and enable flexibility in response to changing demands

(Ron Ben-David 2010)

Water utilities need to continue to work with government on key climate change issues. However, WSAA must play a coordinating role and represent the sector's interests in key negotiations with Federal agencies. Other areas that will affect decision making and support requiring further consideration by WSAA and its members include:

- working with regulators - public health, environmental & economic – to ensure they are climate ready and working from the same risk assessment and investment profile and provide transparent decision making processes in areas that have a considerable investment due to climate change;
- undertake benchmarking of climate change preparedness across different agencies and sectors to see where water utilities can learn and benefit from other experiences;
- working with regulators to investigate a broader pricing formula, understanding that high capital expenditure may reduce operational expenditure in the future; and
- consider discount rates when assessing investing in climate change adaptation measures for infrastructure and examine least cost analysis and lifecycle assessments

6.3.2 UTILITY BUSINESS PRACTICES

In addition to obtaining the most valid or up to date climate science and modelling outputs for use by water utilities, businesses must also be set up or structured to enable adaptation in a 'business as usual' approach to climate change. Water utilities need to embed climate change adaptation consideration into everyday business decisions and planning in a similar manner to that which greenhouse gas emissions and energy consumption is becoming considered. Processes and procedures that WSAA or water utilities could give consideration to include:

- ensure that each water utility understands and has identified where climate change fits within their business drivers, strategic goals or policies;
- the development of a standard climate change risk assessment template for water utilities to use in planning and projects including the development of consistent supporting information to enable assessment of risks;
- developing a benchmarking process for WSAA members to work through in planning adaptation actions: including where to start, what to do and what not to do;
- developing a planning paradigm and tools that can deal with the uncertainty of climate change and the uncertainties created when applying to hydrologic or hydraulic modelling;
- improving the use of spatial tools such as GIS to understand and map risk areas of impacts of climate change Expanding and developing resources for education and training with appropriate framing for the required skill-set. Ensure employees have the capacity and technical abilities as well as leadership skills to lead the way on issues that have no precedence or standard approach; and
- water utilities identifying low cost 'no regrets' options for climate change adaptation action and implementation for high and low risk impacts.

6.4 COLLABORATION

6.4.1 STAKEHOLDER COLLABORATION

As water utilities, there are a diverse and large number of stakeholders. Adaptation to climate change and response to impacts cannot be undertaken by a single agency. There are many stakeholders for water utilities: state and federal government, regulatory agencies, other sectors and utilities, non government organisations, community, research agencies and consultants, business and customers.

Interactions with stakeholders vary from in depth engagement on specific projects, to knowledge sharing with other government departments and utilities, to high level consultation with community in relation to general action on climate change. Some of the more specific collaboration activities to be explored by water utilities include:

- Developing climate change stakeholder collaboration tools/approaches for water utilities to use in engaging with the community and other stakeholders.
- Learn from the frameworks of other communities and organizations and their response to climate change adaptation particularly community participation and engagement, planning processes for adaptation and responses.
- Look at large collaborative project opportunities and find other opportunities to collaborate with other utilities, share knowledge: WSAA to assess Committee and Network structure to best utilise existing expertise and build more expertise and share information across the membership.
- Reviewing state and Federal government role in collaboration and develop a framework of opportunities for collaborations; simplify the complex relationships and networks in the climate change area in Australia and internationally.
- investigating opportunities for staff exchange, secondment and sector swaps (overseas, between utilities) to share and develop skills
- More engagement/collaboration through WSAA or by individual utilities with the CSIRO Climate Change Adaptation Flagship, National Climate Change Adaptation Research Facility (NCCARF), Nat CoE in Climate Change, GOYDER institute, state research facilities and leverage off existing work undertaken and data collected..
- Collaborate with international and US agencies, with regard to case studies (e.g. WUCA, WATERRF), tools ('mitigation cost curve'), and scenario planning and decision support methods.

6.4.2 BUILDING RESILIENCE

A key to building resilience to climate change is diversity and integration. Given the challenge in identifying the onset of short term climate change effects, action for WSAA and water utilities are:

- Work with Federal agencies and water utility risk managers to enhance approaches to the management and response to extreme events
- Work with CIPMA for a national approach to manage risks and build resilience into critical infrastructure

6.4.3 INTEGRATED WATER MANAGEMENT

The Cities of the future initiative (explored earlier in the Built and Social Environment Case Study) is an excellent example of integrated water management. This integrated approach assists in the building of resilience to climate change impacts. Better use of integrated water management (by water utilities and stakeholders) to adapt to climate change may involve investigating the development of Adaptation Cost Curves.

7.0 Conclusion

The variable climate of Australia is changing and the water industry has been one of the first sectors to feel the effects of it.

Utilities have done their best to adapt, despite facing a fair amount of uncertainty in both the climate projections for the future as well as the impact on water resources. The development of strategies, planning approaches, new augmentations and a bigger focus on interconnectivity and collaboration have all been adopted as tools of change.

The time has come however, for the water industry to continue to adapt and position themselves for future climate change impacts. The Water Services Association of Australia along with its members is leading the way for the global water industry. By applying existing adaptation measures and developing new adaptation responses, Australia is demonstrating why they are world leaders in water management and climate change adaptation.

A number of key priority areas have been identified and agreed by WSAA and the water utilities as well as a number of other actions that have been classified according to themes.

There will undoubtedly be challenges in responding to climate change and implementing these actions, which is why it is recommended that the actions be reviewed regularly and modified and communicated as necessary.

Learning from our own experiences as well as our international counterparts needs to continue as does collaborating and working closely with all of the other utility sectors across Australia. Climate change adaptation will not be the success of one organisation or utility, but by the ongoing collaborative efforts of everyone.

References

1. BOM (2010) State of the Climate, CSIRO and Bureau of Meteorology, 2010

2. CSIRO (2011a) Climate Science Update: A Report to the 2011 Garnaut Review, The Centre for Australian Weather and Climate Research, Keenan, T.D. and Cleugh, H.A.

3. CSIRO (2010) Climate variability and change in south-eastern Australia: A synthesis of findings from Phase 1 of the South Eastern Australian Climate Initiative (SEACI), CSIRO.

4. Fraser A., Press Statement. 05 June 2011., http://www.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=75079

5. Clare Mullen, Seasonal climate summary southern hemisphere (summer 2008-09): National Climate Centre, Bureau of Meteorology, Australia (Manuscript received November 2009)

6. BOM (2011), SPECIAL CLIMATE STATEMENT 24 First Issued 7th January 2011 Updated 24th February 2011, National Climate Centre, BOM

7. Victorian Bushfire Royal Commission, Final Report, July 2010

8. Pittock A. B., The Enhanced Greenhouse Effect; Threats to Australia's Water Resources, Journal of the Australian Water Association, June 2007,

9. Chiew, F., Young, W., Cai, W., and Teng, J. (2010). Current drought and future hydroclimate projections in southeast Australia and implications for water resources management [online]. Stochastic Environmental Research and Risk Assessment, DOI: 10.1007/s00477-010-0424-x.

   http://dx.doi.org/10.1007/s00477-010-0424-x.

10. Church, J.A., Hunter, J.R., McInnes, K.L., and White, N.J. 2006 Sea Level Rise around the Australian Coastline and the changing frequency of extreme events, Australian Meteorological Magazine 253-260

11. Gallant, A.J.E. and Karoly, D.J. 2010. A combined climate extremes index for the Australian Region. J. Climate, 23, 6153–6165. doi: 10.1175/2010JCLI3791.1

12. CSIRO (2011b) Climate change : science and solutions for Australia, edited by Helen Cleugh, Mark Stafford Smith, Michael Battaglia, and Paul Graham, CSIRO 2011

13. CSIRO and BOM (2007) Climate Change in Australia, CSIRO and Bureau of Meteorology for the Commonwealth Government 2007

14. CSIRO (2009) The science of tackling climate change, CSIRO, September 2009

15. IPCC (2007) Climate Change 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

16. Maddocks (2011): The role of regulation in facilitating of constraining adaptation to climate change for Australian infrastructure,Maddocks for the Department of Climate Change and Energy Efficiency 2011

17. Abbs, D., and Rafter, A., Impact of climate variability and climate change on rainfall extremes in Western Sydney and surrounding areas: Component 4 – dynamical downscaling. Report to the Sydney Metropolitan Catchment Authority and Partners. CSIRO Marine and Atmospheric Research, 2009

18. Abbs, D., The impact of climate change on the climatology of tropical cyclones in the Australian region. CAWCR Technical Report, 2009

19. CMAR (2011) CSIRO Centre for Marine and Atmospheric Research, 2011, http://www.cmar.csiro.au/sealevel/sl_proj_21st.html

20. DCC (2009), Climate Change Risks to Australia's Coasts: A First Pass National Assessment, Department of Climate Change, 2009

21. Ron Ben-David, presentation to WSAA workshop, October 2010

22. Sandman, P., Outrage Management, Peter Sandman Risk Communication Website 2011, , http://www.psandman.com/index-OM.htm

23. WSAA (2010), Outcomes from the 'Cities of the Future' workshop held at Ozwater'10 in Brisbane 9-10 March 2010, WSAA and Melbourne Water

24. Binney, P., Donald, A., Elmer, V., Ewert, J., Phillis, O., Skinner, R., and Young, R., IWA Cities of the Future Program: Spatial Planning and Institutional Reform Discussion Paper for the World Water Congress, September 2010. https://www.wsaa.asn.au/NewsAndMedia/MediaCentre/News%20releases/20100917%20IWA%20Spatial%20Planning%20and%20Institutional%20Reform%20Group%20Montreal%20Discussion%20Paper.pdf

25. (MDBA) 2008, FACT Sheet: Blue-green algae in the River Murray, Murray Darling Basin Authority, 2008, http://www.mdba.gov.au/water/blue-green-algae

26. (NWC 2011) National Water Commission website 2011, http://www.nwc.gov.au/www/html/172-introduction---groundwater.asp

27. NCCARF (2009) Implementation Plan for Climate Change Adaptation Research: Settlements and Infrastructure, December 2009

28. Sydney Water et al, (2011)ADAPTWATER– A Climate Change Adaptation Assessment Tool for the Australian Water Industry, Sydney Water, WSAA and Climate Risk for the Department of Climate Change and Energy Efficiency's, May 2011

29. US EPA Office of Water 'Asset Management: A Best Practices Guide' EPA 816-F-08-014 (April 2008) www.epa.gov/safewater

30. SEQWG (2010) South East Queensland Water Grid Fact Sheet 2010, Water Grid- The Story, http://www.watergrid.com.au/u/lib/Water_Grid_FS_The_Grid_Story2010.PDF

Appendices

APPENDIX 1

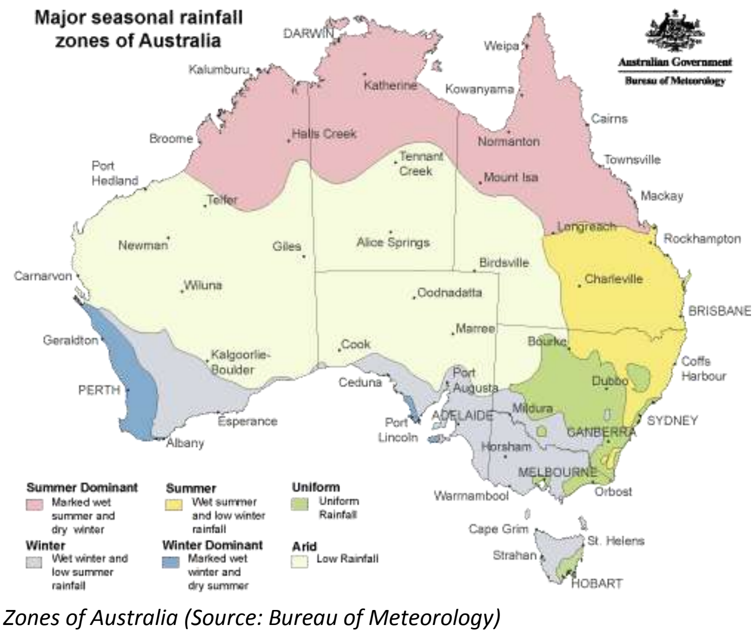
CLIMATE SCIENCE

Our Current Climate

Natural greenhouse gases have an important role to play in balancing the earth's temperature by absorbing and re-radiate the Sun's warmth, and maintaining the Earth's surface temperature at a level necessary to support life. Increased concentrations of greenhouse gases such as carbon dioxide, due to anthropogenic activities, have led to an increased trapping of the Sun's heat and in turn a warming of the earth's atmosphere and surface known as global warming. This global warming is causing the climate worldwide to change. Climate science suggests expecting different changes in different parts of the world; changing averages temperatures and rainfall, more extreme weather and sea level rise. All of which could prove disastrous for communities on every continent.

The Australian climate influences the location of agriculture and primary production across the country as well as the way in which water supply is sourced and distributed for consumption, the manner in which stormwater and waterways are managed and sewage is treated. Overlaying seemingly small changes in climate over natural climate variability of both the short term events (e.g. daily) and long term (e.g. decadal), can have devastating and lasting effects on Australia's water resources and human settlement.

The Australian climate is both diverse and variable. These climates define the way communities live and the attitudes to water in the different regions. Decadal variability of the different climatic regions is affected by a number of different features such as the El-Nino Southern Oscillation and the Indian Ocean Dipole. Further synoptic weather patterns like low pressure systems, tropical cyclones and cold fronts influence rainfall and temperatures across Australia on a shorter more immediate timescale. (Pittock A. 2007)



Map A: Rainfall Zones of Australia (Source: Bureau of Meteorology)

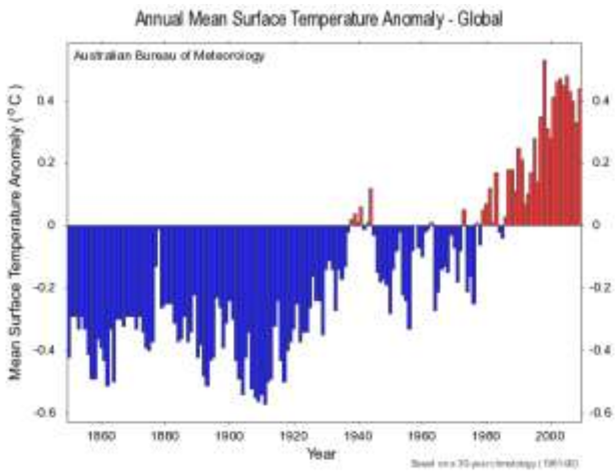
Map A illustrates the different seasonal rainfall climate zones that influence the seasonality and variability of rainfall. For example the north of Australia receives a majority of its rainfall in summer and the south of Australia receives most of its rainfall in winter.

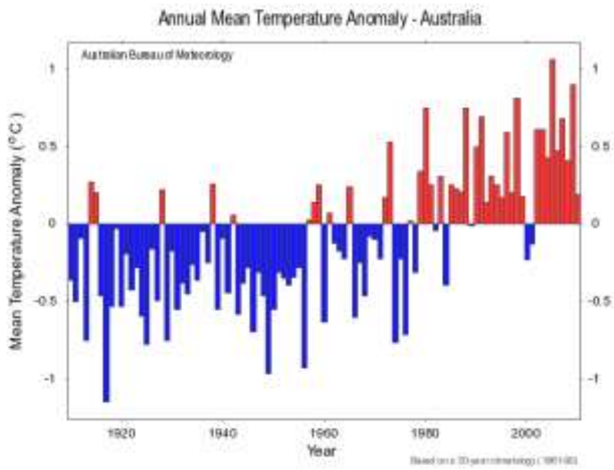
CLIMATE OBSERVATIONS

Many journalists and eminent scientists have been looking to Australia as a sign of things to come in terms of climate change, even referring to Australia as “the coalmine canary of climate change” (The Australian, 02 September 2008). Here in Australia, we’ve been observing a climate shift for over a decade and need to better understand where we are headed and the changes and impacts we could be facing if we are to be adequately prepared and adaptable.

TEMPERATURE

Global annual mean surface temperatures have been above average compared to the 30 year average of 1961-1990 and current Australian climate trends comparing the annual mean temperatures to the 30 year average (1961-1990) also indicate fairly consistent anomalies post 1990 that appear to be increasing on average every year.

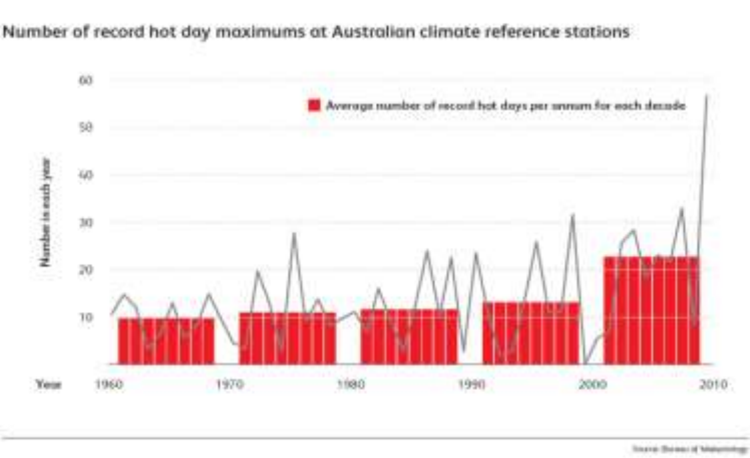




Graph A: Global Temperatures Anomalies

Graph B: Australian Temperature Anomalies

Observations analysed by the Australian Bureau of Meteorology conclude that surface temperatures in Australia rose by just under 1ºC over the 100 years from 1910 to 2009 (CSIRO 2011b). The decade 2000-2009 was Australia’s warmest decade on record (State of Climate 2010). Furthermore; the trend for the average number of extreme hot days per annum per decade is also increasing despite annual variability in the number of hot days. Graph C illustrates the gradual decadal increase in number of hot days and the sharp increase over the last decade.

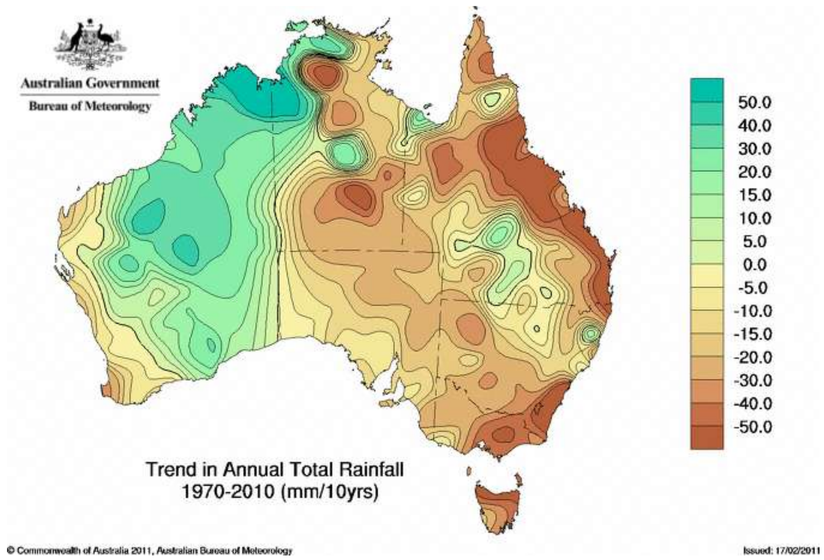


Graph C: Number of record hot days (Source: Bureau of Meteorology)

In January 2009, Victoria experienced a record heatwave with temperatures above 43oC for three successive days (BOM 2010). Not long after the heatwave, on 7th February 2009, searing record high temperatures across the state of 46.4oC combined with wind of up to 100km/hr to produce unforeseen fire danger conditions which ended in the most disastrous bushfires Australia has ever seen. Fire Danger Index Ratings between 140 and 200 were recorded across the state. Western Australia has suffered through a number of severe bushfires in the last decade as have New South Wales, Australian Capital Territory and South Australia.

RAINFALL

The trend in annual rainfall for the period 1960-2010 demonstrates quite a significant decline in annual total rainfall along the east coast and southern Australia as well as central and south west Australia. This has led to ongoing drought in these areas for over a decade putting pressure on the agriculture industry as well as the urban water industry to supply potable water for consumption. The decrease in rainfall across the various regions of Australia appears to be generally seasonal. For example south west Western Australia has experienced its greats decline in rainfall in winter, with averages down by around 15%, whereas the Murray Darling Basin region experienced rainfall reductions in autumn and winter. (CSIRO 2011b)



Map B: Australian Annual Rainfall Trend (Source: Bureau of Meteorology 2010)

However whilst some parts of Australia have been in drought, other areas have been receiving great the average rainfall, particularly north west Australia. This highlights the extremely variable climate of Australia and the climate shift to which the water industry and other sectors have had to adapt quickly.

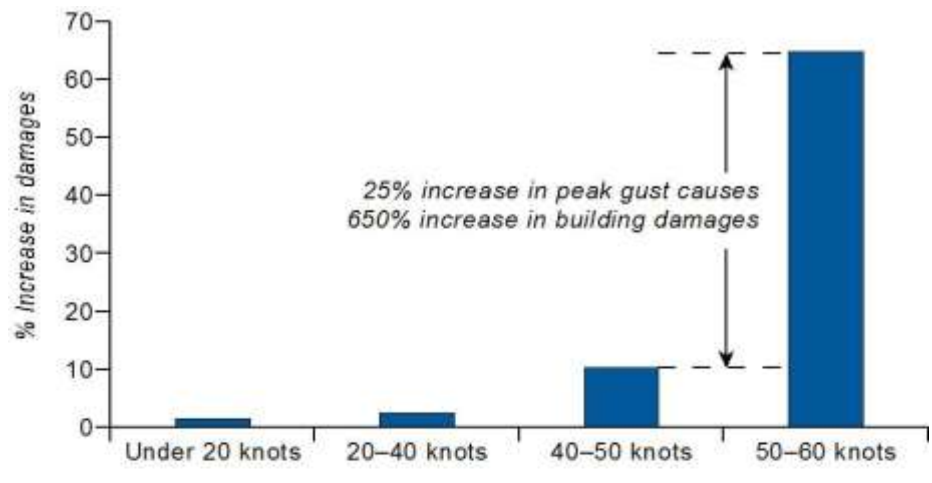
EXTREME EVENTS

Australians are not strangers to the extreme events that climate variability can bring. Extreme wind events and rainfall events can have devastating impacts on human settlement. Strong winds have the potential to cause extensive damage to buildings and infrastructure and intense extreme rainfall events can cause widespread flooding.

There has been a global trending increase in extreme precipitation events in the second half of the twentieth century and into the twenty first century. On a smaller scale, changes in extreme precipitation events across Australia are regionally and seasonally variable. Gallant and Karoly (2010) concluded that for Australia as a whole (but not at all locations) there has been an increase in the extent of wet extremes and a decrease in the extent of dry extremes annually and during all seasons from 1911 to 2008 at a rate of between one per cent and two per cent per decade. They also noted that these trends mostly stem from changes in tropical regions during summer and spring. (CSIRO 2011a)

The year 2010 was also a La Nina year. Record rainfall was recorded in spring 2010 in Queensland, New South Wales and the Northern Territory. Victoria also experienced its wettest summer on record. The Murray Darling Basin region that had been suffering for over a decade from severe drought and the state of Queensland saw 2010 bring their wettest year on record. All of this rain including the extreme events in spring and summer brought the Australian mean rainfall total for 2010 to 701 mm, which was well above the long-term average of 465 mm. (CSIRO 2011a)

Extreme wind events coupled with storm surges and rainfall events have the potential to cause extensive damage to human settlement. Extreme wind events alone have the potential to cause building damage with a small increase in wind gusts leading to a great increase in damages.



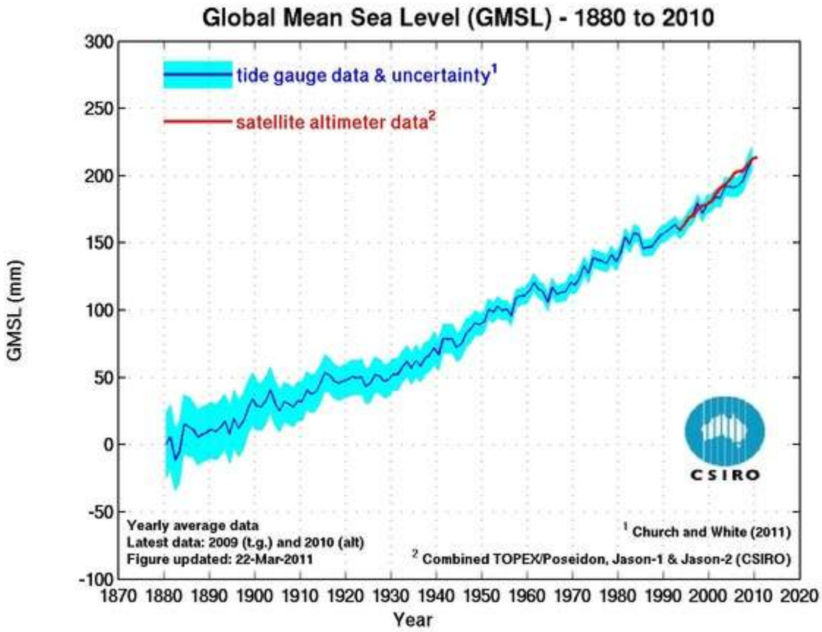
Graph D: Increase in building damage as a result of increase wind speed NSW NRMA buildings insurance only (Source: Insurance Australia Group 2003)

Graph D illustrates the increase in damages to buildings as a result of increasing wind speed

SEA LEVEL RISE

Whilst sea levels rising and falling is common throughout historical periods, levels had been relatively stable for the last 3000 years with only small rates of change in sea level until the late 19th century

As global and local temperatures rise, the oceans warm. This results in thermal expansion that causes sea levels to rise. Despite the much talked about concern over the melting of the ice sheets and glaciers, most of the observed sea level rise since the 19th century has been attributed to thermal expansion. However, results from recent studies indicate an increase contribution from melting ice over the last decade (CSIRO 2011a).

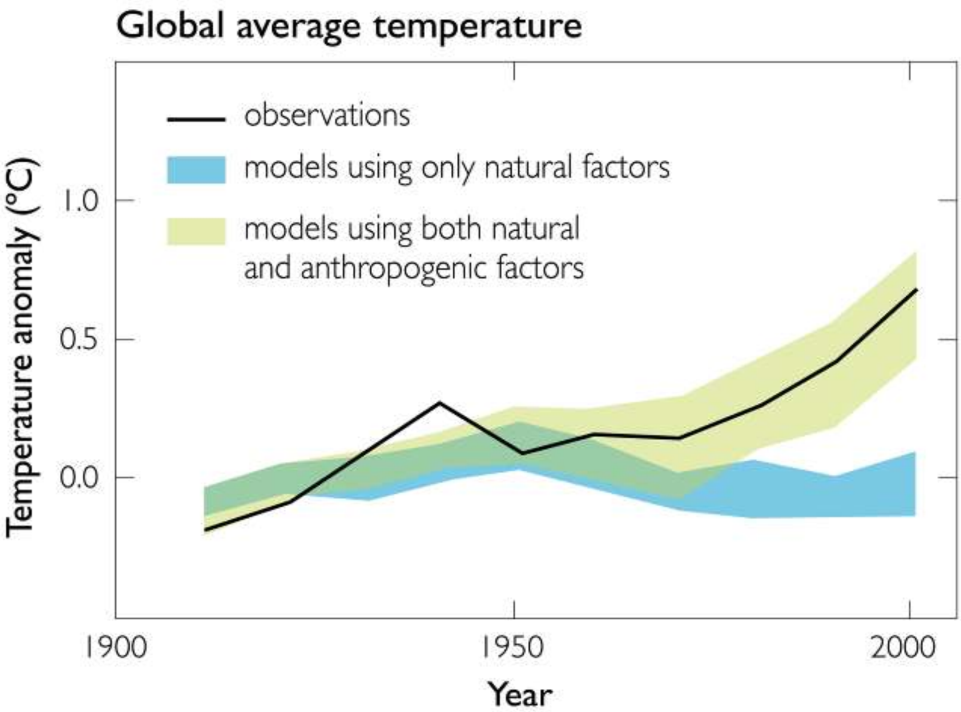


Graph E: Global Mean Sea Level (Source: CSIRO 2011b)

According to the State of the Climate Report by CSIRO and the Bureau of Meteorology, from 1870 to 2007, the global average sea level rose by close to 200mm as illustrated by Graph 5. Observations indicate that global sea levels rose at an average of 1.7mm per year during the 20th century and about 3.0mm per year from 1993-2009. Since 1993, Australian sea levels have risen 7-10mm per year in the north and west, and 1.5-3mm per year in the south and east. Sea level rise combined with increase in intensity of extreme storm surge events has led to greater inundation of land in coastal areas (Church et al 2006).

CLIMATE CHANGE PROJECTIONS

The IPCC have produced four major reports on climate change. The Fifth Assessment report is expected to be released in 2013/4. Each report takes into account advances in climate science and modelling and is compiled and reviewed by well respected climate scientists and experts from across the world. The models and climate science continue to improve with time allowing for greater advances in predicting climate change and its impacts. Graph F illustrates the general trend of temperature observations over time compared with model results for changes in temperature looking at both natural factors and combined with anthropogenic factors. The observations clearly align with the models incorporating natural and anthropogenic factors.



Graph F: Observed increases in average temperature versus model results (Source: CSIRO 2009)

The IPCC Fourth Assessment Report and its SRES emission scenarios have formed the basis of the regional models and emission scenarios used to develop climate change projections for Australia (CSIRO 2007). The projections for the nation are:

> An annual warming of approximately 1oC by 2030 based on 1990 climate baseline

> An annual warming of 0.8-1.8oC for a low emission scenario and 1.5-2.8oC for a high emission scenario by 2050

> An annual warming of 1.0-2.5oC for a low emission scenario and 2.2-5.0oC for a high emission scenario by 2070

> An increase in maximum and minimum temperatures and the number of hot days and nights

> Increased extreme wind events

> Increases in annual precipitation in the north and decreases of 2-5% across the rest of Australia by 2030

Regional projections for Australia are as follows (CSIRO 2007):

North Western Australia	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(^{o}C)	26.7	27.8 (27.5-28.3)	28.5 (28.0-29.3)	30.2 (29.1-31.7)
No. days over 35^{o}C	54	86 (71-107)	119(89-173)	220 (147-281)
Annual Rainfall (mm)	664	649 (588-705)	639 (543-742)	616 (448-795)

South Western Australia	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(^{o}C)	18.5	19.3 (19.1-19.7)	19.9 (19.5-20.5)	21.2 (20.4-22.3)
No. days over 35^{o}C	28	35 (33-39)	41 (36-46)	54 (44-67)
Annual Rainfall (mm)	747	702 (650-754	665 (590-754)	605 (471-762)

Top End	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(^{o}C)	27.8	28.8 (28.5-29.2)	29.5 (29.0-30.1)	31.0 (30.1-32.2)
No. days over 35^{o}C	11	44 (28-69)	89 (49-153)	227 (141-308)
Annual Rainfall (mm)	1847	1847 (1718-1960)	1829 (1644-2032)	1829 (1459-2217)

Central Australia	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(^{o}C)	21.0	22.2 (21.8-22.6)	22.9 (22.3-23.7)	24.7 (23.6-26.2)
No. days over 35^{o}C	90	109 (102-118)	122 (112-138)	155 (132-182)
Annual Rainfall (mm)	326	306 (270-342)	297 (241-352)	270 (182-378)

Southern South Australia	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(^{o}C)	16.5	17.4 (17.1-17.8)	18.0 (17.5-18.6)	19.3 (18.4-20.5)
No. days over 35^{o}C	17	23 (21-26)	26 (24-31)	36 (29-47)
Annual Rainfall (mm)	463	444 (412-472)	430 (379-481)	403 (315-500)

Tasmania	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(°C)	13.0	13.6 (13.4-13.9)	14.1 (13.7-14.5)	15.1 (14.5-15.9)
No. days over 35°C	1.4	1.7 (1.6-1.8)	1.8 (1.7-2.0)	2.4 (2.0-3.4)
Annual Rainfall (mm)	576)	571 (542-594	559 (519-600)	542 (467-623)

Northern Coastal Queensland	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(°C)	24.9	25.8 (25.5-26.1)	26.4 (26.0-26.9)	27.8 (26.9-28.8)
No. days over 35°C	3.8	6.6 (5.4-9.1)	12 (8-22)	44 (19-96)
Annual Rainfall (mm)	2112	2112 (1943-2281)	2091 (1816-2387)	2091 (1584-2640)

South East Queensland	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(°C)	20.5	21.5 (21.2-21.9)	22.1 (21.6-22.8)	23.6 (22.6-24.9)
No. days over 35°C	1.0	2.0 (1.5-2.5)	3.0 (2.1-4.6)	7.6 (4-21)
Annual Rainfall (mm)	1192	1109 (978-1230)	1133 (978-1300)	1085 (799-1395)

New South Wales	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(°C)	18.3	21.3 (20.5-22.6)	19.9 (19.4-20.5)	19.2 (18.9-19.6)
No. days over 35°C	3.5	4.4 (4.1-5.1)	5.3 (4.5-6.6)	8.2 (6-12)
Annual Rainfall (mm)	1277	1238 (1162-1315)	1225 (1098-1340)	1174 (957-1404)

Victoria	Present Average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Annual temperature(°C)	15.7	16.6 (16.3-16.9)	17.1 (16.7-17.7)	18.5 (17.6-19.5)
No. days over 35°C	9.1	11.4 (11-13)	14 (12-17)	20 (15-26)
Annual Rainfall (mm)	654	628 (596-661)	615 (563-668)	582 (491-674)

These projections paint generally hot and dry future for most of Australia.

HOT

The average annual warming of Australia by 1oC by 2030 is further broken down as a 0.7oC-0.9oC average warming in coastal areas and a 1-1.2oC warming across inland areas. By 2050, projections estimate an annual warming range for Australia between 1.2oC for the B1 scenario (where the world moves to a more sustainable future) to 2.2oC for the A1F1 scenario (where the world continues its reliance on fossil fuels). By 2070 projections estimate an annual warming range for Australia between 1.8oC for the B1 scenario to 3.4oC for the A1F1 scenario. (CSIRO and BOM 2007)

In conjunction with increased average annual temperature is the increase in frequency of hot days and maximum daily extreme temperatures. The number of days over 35oC is expected to increase across all regions; similarly the number of warm nights is also expected to increase. Projections indicate that in summer, the maximum temperatures may increase by up to 5% above the mean over Western Australia, most coastal areas and Tasmania and increase by up to 10% less than the mean over New South Wales, southern Queensland and southern Northern Territory (CSIRO and BOM 2007).

Extreme fire weather conditions that contributed to the conditions that led to the devastating bushfires in Victoria in 2009 are also predicted to increase with the number of extreme fire rating days projected to increase by 5-65% by 2020 and by 10-300% by 2050 (CSIRO 2011). Changes are not only projected for mean and maximum temperatures, but also minimum temperatures with fewer frost days and fewer extreme low temperatures predicted (CSIRO 2011a).

DRY

Rainfall projections for the different regions are variable with small increases in average annual rainfall predicted for the north and larger decreases in average annual rainfall in the south (CSIRO and BOM 2007). Southern Australia could receive up to 10% less rainfall by 2030 and up to 20% by 2050. And areas of northern Australia may receive changes of -10% to +5% by 2030 and -20% to +10% by 2050 (CSIRO 2009). Due to the projected decline in average annual rainfall over the south of Australia and associated dry moisture conditions, the frequency of extreme dry conditions is expected to also increase in Victoria, Tasmania and south-west Western Australia. Exceptionally dry years are expected to occur more often (CSlRO 2011a) which would contribute to drought conditions, length and frequency.

The seasonal changes in rainfall are also important in understanding how reduced rainfall translates into impacts on water resources which is discussed briefly later on in Theme 2 – Bio-physical Environment. Best estimates predict a decline in the winter and spring seasons (CSIRO and BOM 2007), which is interesting in comparison to the actually experience of the period 1996-2009 in south eastern Australia that mainly saw a decrease in rainfall in autumn rather than spring and winter. (CSIRO 2010)

WET

It has also been determined that extreme intense rainfall events will become more intense due to the wetter warmer atmosphere (CSIRO 2011a). A study by Rafter and Abbs (2009) showed that there was a tendency for increased in intensity of extreme rainfall events for all regions across Australia with results also indicating that the short duration intense events, the type that often lead to urban flash flooding are more likely to change rapidly that the longer duration rainfall events that lead to widespread riverine type flooding (CSIRO 2011a). In some areas such as southern Australia, the intensity of extreme events will increase in summer and autumn and the northern Australia, in winter and spring (CSIRO 2009).

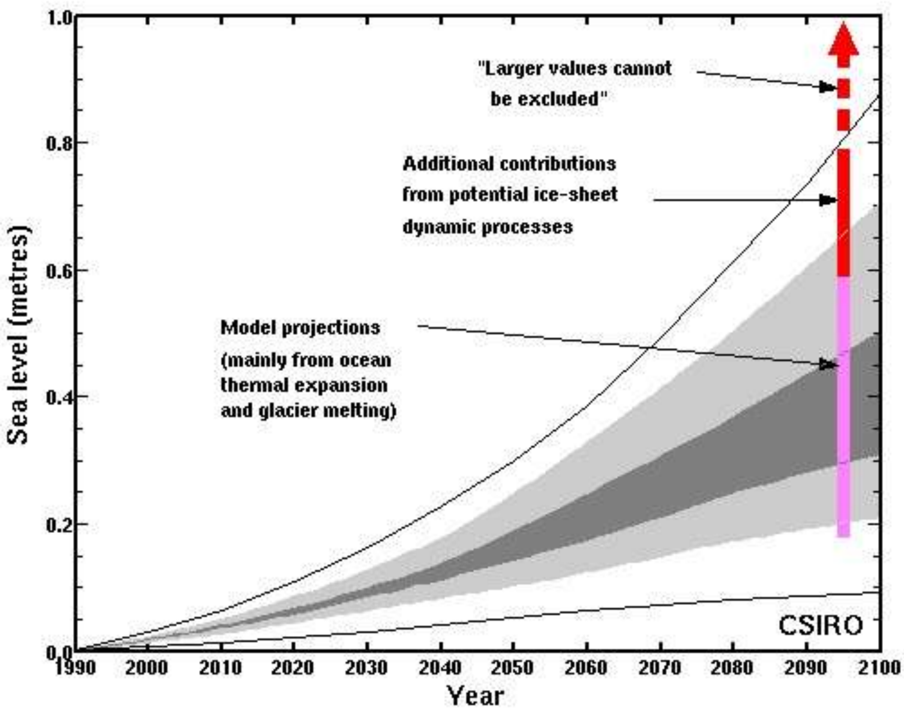
According to work undertaken by Abbs (2009), model simulations showed an average decrease in the number of tropical cyclone (TC) days. These results are consistent with other studies published internationally, however a report release by CSIRO (2009) indicated that TC days are projected to increase in the north east, but decrease in the north west.

The intensity of the strongest cyclones is also predicted to become more intense (CSIRO 2009). Abbs (2009) reports model results showing a southward movement in the creation and decay of cyclones, with more southward movement in cyclone on the east coast of Australia than the west (CSIRO 2011a).

Though a small amount of work on wind has been undertaken projections have indicated that wind speed and strength will generally larger, particularly in coastal area. Once again changes are seasonality and geographically variable. The greater estimated increases in wind speed are for eastern Queensland and north-eastern New South Wales in Spring and south eastern Tasmania in Winter by up to 7.5%. (CSIRO and BOM 2007)

SEA LEVEL RISE

Sea levels are projected to continue to rise over the next century and beyond due to both thermal expansion and melting of glaciers and ice sheets. Plausible estimate for sea level rise based on the modelling of thermal expansion and sea ice indicate that seas are expected to rise by up to 0.8m by 2100 (CSIRO 2011a). The understanding of how much ice sheets will contribute to sea level in the future is limited and therefore difficult to predict but could contribute to further rise this century. Graph G provides the indicative projections for sea level rise in the 21st century (CMAR 2011).



Graph G: Projected sea level rise for the 21st century (Source: CSIRO Centre for Marine and Atmospheric Research)

Sea level rise is expected to vary regionally. For example south eastern Australia would potentially have a greater rise than the global average and north western Australia could have a sea level rise less than global average.

These levels are for sea level rise alone and do consider the additional extent and destructiveness of storm surge. Storm surge are extreme high sea levels brought about by storms and weather phenomena such as high winds, tropical cyclone and/or low pressure systems. With projections for an increase in the frequency and intensity of storm surge events, a storm tide could add a further 82cm on to mean sea level and a 1 in 100 year extreme storm surge event could occur as often as once every 30 years in 2030 and once every 5 years in 2070 (DCC, 2009).