Climate Change in the Sydney Metropolitan Catchments

Prepared for the New South Wales Government by the CSIRO

Border Rivers-Gwydir
Central West
Hawkesbury-Nepean
Hunter-Central Rivers
Lachlan
Lower Murray-Darling
Murray
Murrumbidgee
Namoi
Northern Rivers
Southern Rivers
Sydney Metro
Western
A number of climate change studies relevant to the Sydney Metropolitan Catchments are listed here:


- **Past Climate Variability and Projected Changes in Average Climate.** Consultancy report for the New South Wales Greenhouse Office by CSIRO and the Australian Bureau of Meteorology.

- **Human Health and Climate Change in Ossiania: A Risk Assessment.** Commonwealth Department of Health and Ageing, Canberra, Australia.


- **Dairy Cattle.** CSIRO Atmospheric Research report for the NSW Department of Industry, Trade and Tourism.


- **Linking atmospheric circulation to daily rainfall patterns across the Mumurumbidgee River Basin.** Proc. 5th International River Symposium, 3-6 September 2002, Brisbane, Australia.

- **GIS modelling of sea-level rise induced shoreline changes inside coastal re-entrants - Two examples from southeastern Australia.** Natural Hazards 31, 253-276.


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1.0 The Problem of Climate Change

The Earth’s plants and animals depend on the climate to which they are exposed – they benefit when conditions are favourable, and they suffer when conditions become extreme. Humans are no exception.

The crops and water resources that we use to sustain our communities are linked to the climate, and the economic as well as human losses that we experience from hail, cyclones, floods, droughts and bushfires are a reminder of our ever-present vulnerability to the climate system.

It is increasingly clear that our climate is changing. Whereas in the past humans have learned to cope with climatic variability and change that was natural in origin, we are now living in a climate of our own making. The rate at which our climate is being transformed is unprecedented throughout much of human history.

Evidence of a Changing Global Climate

- Temperatures in the northern hemisphere at the end of the 20th century are believed to have been warmer than they have been at any time in the previous 1,000 to 2,000 years.
- The average global temperature in 2005 was the warmest on record, and eight of the ten warmest years have occurred since 1997.
- The Earth’s average surface temperature has risen 0.7°C since 1900.
- Heatwaves and extreme rainfall have become more common in many regions.
- The sea level has risen 1.8 mm per year since 1950 and that rate is accelerating.
- There have been fewer frosts and the ice sheets of Antarctica and Greenland are shrinking.
- The timing of physiological processes in plants and animals is changing throughout the world, and populations are shifting their distributions.

Evidence of Australian Climate Change

- Average temperatures in Australia rose 0.9°C from 1910 to 2004. There have been more heatwaves and fewer frosts.
- Since 1950, annual rainfall has declined on the eastern seaboard and in the south of the continent, but increased in the northwest.
- Since 1973, droughts have become more intense, and extreme rainfall events have increased in the northeast and southwest.

According to the United Nations’ Intergovernmental Panel on Climate Change “most of the warming observed over the last 50 years is attributable to human activities.” These activities – mainly the burning of fossil fuels such as coal, oil, and natural gas – have released vast quantities of greenhouse gases into the atmosphere.
1.1 What is Causing Climate Change?

Much of the energy that drives the Earth’s natural processes comes directly from the Sun. Around half of the Sun’s energy that reaches the Earth breaks through the atmosphere, warming the surface of the planet. The land and oceans then radiate that heat, some of which is trapped by greenhouse gases in the atmosphere. The principal greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide.

This trapping of heat energy is known as the ‘greenhouse effect’ – keeping temperatures higher than they otherwise would be, just like a glass greenhouse keeps plants warm (Figure 1). Without this process, the global average surface temperature would be closer to minus 18°C, instead of the current 15°C.

The problem we now face is that human actions - particularly burning of fossil fuels, agriculture and land clearing - are increasing concentrations of greenhouse gases in the atmosphere. Since 1750, the amount of carbon dioxide in the atmosphere has risen 35%, and the current concentration is higher than any time in at least the past 650,000 years. The level of nitrous oxide has also risen 17% and methane 151%. This has enhanced the greenhouse effect by trapping more heat, leading to global warming.

Scientists assert that there will be continued warming and increases in sea levels with significant impacts on natural and human systems. Globally, these impacts include coastal flooding, more heatwaves storms and droughts, less frost, snow and polar ice, more people at risk of food and water shortage, reduced habitat for many plant and animal species and more people exposed to infectious diseases such as malaria.

Most greenhouse gases have a long lifetime in the atmosphere. This means that even with reductions in greenhouse gas emissions, there would be a delay of several decades before those reductions have a significant effect on greenhouse gas levels in the atmosphere. Recent studies indicate that no matter how quickly we act, we are already committed to additional global warming during the 21st century of around 0.5°C and the subsequent impacts that are likely to follow.

In response to this challenge, we need to do two things: start planning adaptation strategies to minimise those consequences, and reduce greenhouse gas emissions to slow the rate of global climate change.
2.0 Climate Change in New South Wales

In 2004, the CSIRO and the Bureau of Meteorology released a report on behalf of the NSW Government which looked at past and likely future changes to NSW’s climate.

The report found that between 1950–2003, NSW became 0.9°C warmer, with more hot days/nights and fewer cold days/nights. Annual total rainfall declined by an average of 14 mm per decade, with the largest declines in rainfall near the coast due to an increase in El Niño years since the mid-1970s. Extreme daily rainfall intensity and frequency have also decreased throughout much of the State.

The report predicted that by the year 2030:
- NSW is likely to become warmer than it was in around 1990
- There will be more hot days over 35°C and fewer frost days below 0°C
- Annual rainfall is likely to decline
- Rainfall runoff and stream flows will be reduced
- Droughts are likely to become more severe
- The risk of bushfires is likely to increase
- Extreme rainfall may become more intense in central and southeast NSW

More detailed findings of the report are listed in Table 1 (below).

3.0 The Sydney Metro Catchments

The Sydney Metropolitan Catchments cover 1,840 square kilometres associated with the highest population density in Australia. As of 2005 there were an estimated 4,254,894 people living in the Sydney statistical division, and relatively rapid population growth makes the catchments one of the fastest growing areas in Australia. The Sydney Metropolitan Catchments include Sydney’s Northern Beaches, Sydney Harbour, and the Narrabeen Lakes Catchment to Turimetta Head, and extends south to the catchments of Botany Bay and Port Hacking, through the Royal National Park to Stanwell Park in the south. The region also extends offshore three nautical miles. Sydney Metro’s urban area covers 1,687 square kilometres and incorporates more than 70 harbour and ocean beaches, including the famous Bondi Beach.

The important natural resources of the region underpin significant economic activity. The major industries in the region include finance, extractive and manufacturing industries, property development, tourism and recreation. The region contains Australia’s most famous waterway, Sydney Harbour, Australia’s oldest national park as well as nationally and internationally significant wetlands. The region has a variety of landscapes including bushland, foreshores, harbour areas and waterways, market gardens, densely developed urban areas, industrial estates, drowned river valleys, and...
The Climate of the Sydney Metro Catchments

Summers in the Sydney Metropolitan Catchments are relatively warm, with average maximum January temperatures of approximately 26°C (Table 2). However, the catchments do experience approximately 3 days above 35ºC each year. Winters are cool to mild, with average maximum July temperatures of 17°C. Temperatures rarely fall below 0°C. The catchments receive approximately 1,100 mm of rainfall each year. Peak precipitation occurs between January and March, and the variability in rainfall from one year to the next is high. Hail storms are common, the worst being the April 1999 event which cost $2.3 billion (IDRO, 2006). Bushfires are also common, often occurring near residential properties.

A warming of 1.0°C and a 5% decrease in rainfall (a moderate scenario for 2030) would make the climate of Sydney similar to the current climate of Paterson to the north west of Newcastle.

Figure 2. Climate Projections for New South Wales (The coloured bars show the range of projected changes corresponding with the colours in the maps)

Since 1950, the region has experienced warming of around 0.8°C. This is likely to be partly due to human activities. The catchments have also experienced a significant drop in annual rainfall at a rate of approximately 55 mm per decade. The contribution of human activities to this rainfall decline is hard to distinguish from natural variability.

The future climate of the Sydney Metropolitan Catchments is likely to be warmer and drier (Figure 2). Such trends would also increase evaporation, heat waves, extreme winds and fire risk. Nevertheless, despite this trend toward drier conditions, the possibility of increases in extreme rainfall events remains. Further details about these changes are described in the following table (Table 2), which compares average conditions for the present climate with ranges of potential change in 2030 and 2070. These projections account for a broad range of assumptions about future global greenhouse gas emissions, as well as differences in how various climate models represent the climate system.
Sydney Water

Changes in rainfall and higher evaporation rates are likely to lead to less water for streams and rivers in the Sydney Metropolitan Catchments, which will have downstream consequences for storages and place strains on the catchments’s water resources. For example, due to recent trends toward reduced rainfall, as of August 2006, catchment storages at Woronora were at only 29% of capacity.

In addition, much of Sydney Metro’s water resources are sourced from the neighbouring catchments, which will also be affected by climate change. The projections for rainfall and evaporation suggest that there will be more hot days, bushfires, droughts and intense storms. This can all place human life, property and natural ecosystems at increased risk.

### Table 2. Current and Projected Climate Change in the Sydney Catchment

<table>
<thead>
<tr>
<th></th>
<th>Present (1990)</th>
<th>Projected Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2030</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>17 – 26°C</td>
<td>+0.2 – +1.6°C</td>
</tr>
<tr>
<td>No. Days below 0°C</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. Days above 35°C</td>
<td>3</td>
<td>4 – 6</td>
</tr>
<tr>
<td>No. Days above 40°C</td>
<td>0</td>
<td>0 – 1</td>
</tr>
<tr>
<td><strong>Rainfall</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Average</td>
<td>1,094 mm</td>
<td>-13 – +7%</td>
</tr>
<tr>
<td>Extreme Rainfall³</td>
<td>-3 – +12%</td>
<td>-7 – +10%</td>
</tr>
<tr>
<td>Evaporation</td>
<td>+1 – +8%</td>
<td>+2 – +24%</td>
</tr>
<tr>
<td>No. Droughts per decade⁴</td>
<td>3</td>
<td>2 – 5</td>
</tr>
<tr>
<td>Extreme Winds</td>
<td>-5 – +8%</td>
<td>-16 – +24%</td>
</tr>
<tr>
<td>No. Fire Days⁵</td>
<td>9</td>
<td>9 – 11</td>
</tr>
</tbody>
</table>

1 Present day conditions for temperature and rainfall represent long-term averages from the Bureau of Meteorology. For extreme temperatures, the present average is based on 1964-2003. For fire danger, the present average is based on 1974-2003. For drought, the present average is for a period centred on 1990.

2 Range represents average July and January maximum temperature.

3 Defined as 1 in 40 year 1-day rainfall total. Values represent the range in seasonal projections from a limited set of climate models for central eastern NSW. However, given strong spatial gradients in extreme rainfall projections (see Hennessy et al., 2004b), these regional results may not be applicable for Sydney.

4 The values for drought represent average monthly drought frequencies, based upon the Bureau of Meteorology’s criteria for serious rainfall deficiency (see also Burke et al., 2006).

5 Number of days annually with a “very high” or “extreme” fire danger index. Changes are for 2020 and 2050, respectively, as in Hennessy et al. (2005).

### 3.2 Impacts of Climate Change in the Sydney Metro Catchments

Although changes in average temperature, rainfall and evaporation will have long-term consequences for the catchments, the impacts of climate change are more likely to be felt through extreme weather events. Projections suggest there will be more hot days, bushfires, droughts and intense storms. These can all place human life, property and natural ecosystems at increased risk. Additional details regarding climate change impacts to various activities and assets in the catchments are discussed below.

### Water

Changes in rainfall and higher evaporation rates are likely to lead to less water for streams and rivers in the Sydney Metropolitan Catchments, which will have downstream consequences for storages and place strains on the catchments’s water resources. For example, due to recent trends toward reduced rainfall, as of August 2006, catchment storages at Woronora were at only 29% of capacity. In addition, much of Sydney Metro’s water resources are sourced from the neighbouring catchments.

Temperatures and elevated nutrients create a more favourable quality within the catchments. For example, low flows, higher temperatures may also reduce water upstream from Sydney (Schreider et al., 2000).

The geographic distribution of a species is often defined by its ‘climate envelope,’ reflecting species-specific tolerances to extremes of temperature and moisture. Climate change is likely to drive changes in the distribution of some plant and animal species, driving some species out of the catchments or enabling invaders to move in. Meanwhile, even those species capable of coping with climate change alone may succumb to the cumulative effects of multiple stressors. Despite such impacts, little is actually known regarding how climate change may affect the catchment’s rich biodiversity or ecosystems, such as its endangered coastal saltmarsh.

**Biodiversity**

Changes to the climate will have significant effects on the catchment’s plants and animals. Currently, 149 species, nine populations and 21 ecological communities (i.e., collections of species or habitat) in the Sydney Metropolitan Catchments are classified as threatened or endangered (DEC, 2006). Although current threats to the catchment’s biodiversity are largely a product of historical land clearing, alterations of river flows and water extraction, climate change is likely to heighten the need for conservation efforts.

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**Other risks to biodiversity in the Sydney Metropolitan Catchments include:**

- Reductions in stream flows are likely to have a negative impact on aquatic biodiversity and wetland ecosystems.
Plants and animals may become ‘stranded’ in isolated remnants of vegetation due to changing climate and continued development within the catchments. More frequent droughts and fires are likely to increase stress on plants and animals. Sea-level rise is likely to inundate coastal wetlands and alter the discharge of freshwater into estuaries, with potential adverse effects on coastal wetland habitat.

Forests

The forests, woodlands and natural vegetation of the Sydney Metropolitan Catchments are a significant asset that is managed for biodiversity conservation, maintenance of water quality, recreation and other purposes.

Preliminary research suggests that temperate tree species and forests in Australia may increase in productivity with higher temperatures and increased concentrations of atmospheric carbon dioxide. However, these benefits may be offset by decreased rainfall, increased bushfires and changes in pests. Also the benefit of higher carbon dioxide concentrations may be limited in the longer term by the availability of nutrients (Howden et al., 1999c).

Furthermore, climate change is likely to lead to changes in the distributions of tree species, possible increased invasion by pests, and changes to the habitat that these areas provide for local plants and animals. This will raise new challenges in managing trees and forest areas for biodiversity conservation and public amenity.

Communities

Warmer winters are likely to reduce cold-related illnesses, but warmer summers are likely to increase the risk of heat-related health problems, especially in the elderly (McMichael, 2003). For example, climate change and population growth and ageing may increase annual heat-related deaths in those aged over 65 in Sydney from 176 at present, to 364–417 by the year 2020, and 717–1,312 by 2050 (McMichael et al., 2003). Warmer temperatures may also contribute to the spread of infectious diseases, although the spread of tropical diseases such as dengue fever into the Sydney Metropolitan Catchments remains unlikely.

The built environment is also vulnerable to climate change. As well as impacting on homes, it will affect infrastructure, commercial buildings and other physical assets. Changes in average climate will affect building design and performance, including structural standards and cooling and heating demand (PIA, 2004). Higher summer temperatures, for example, may induce a revaluation of building design and standards to ensure thermal comfort at minimal cost, while potential increases in extreme winds may necessitate more robust construction. In addition, a study by Austroads (2004) concluded that climate change would contribute to increases in road maintenance costs in NSW of up to 25% by 2100, largely due to assumptions about the effects of climate change and population growth on traffic volumes.

Given increases in the intensity of the heaviest rainfall events, flash flooding and strains on water infrastructure such as sewerage and drainage systems would rise, particularly in population centres. For example, a study by Minnery and Smith (1996) found that climate change may double flood-related damages in urban areas of NSW, although more recent modelling suggests that extreme rainfall events along the NSW coastline may decline, but increase further inland (Hennessy et al., 2004b). Regardless of changes in such extremes, higher temperatures and lower average rainfall are likely to lead to increased pressure on urban water and energy supplies, unless moderated by demand management measures. For example, McDonald (2006) estimated that per capita water demand in Sydney would have to decline by 54% by 2030 in order to remain within sustainable yields. Higher temperatures would increase summer peak energy demand for air-conditioning (Howden and Crimp, 2001), increasing the risk of black-outs.

Modelling of weather patterns along the NSW coast indicates the potential for increases in the frequency of weather events that contribute to extreme winds and, subsequently, storm surges (Hennessy et al., 2004b). Such increases in storm surge, in conjunction with future sea-level rise, would increase the risk of coastal inundation, erosion, and damage to infrastructure and property. Cowell et al. (2006) estimated median erosion at Manly Beach from sea-level rise of 33.2 metres (+90 metres) by 2100. Given a sea-level rise of 20 cm by 2050, coastal erosion of up to 22 metres is projected for Collaroy/Narabeen beach, rising to 110 metres given a 1 in 50 year storm surge, with associated economic losses of $230 million.

The risk of property loss due to bushfire is also likely to increase. For example, on average Sydney is likely to experience 0–2 more days with a fire danger index of “very high” or “extreme” by 2020 and 1–6 more days by 2050 (Hennessy et al., 2005; see Table 2). Given the large number of properties in bushland and the exposure of critical infrastructure, this would pose challenges for emergency management. As a consequence of these and other changes in extremes, such as winds and floods, insurance risk assessments and premiums are likely to be affected.
4.0 Adapting to Climate Change

Adaptation is a risk management strategy involving actions to reduce the negative impacts of climate change and take advantage of new opportunities that may arise. The types of adaptation measures adopted will vary from region-to-region. Because some of the decisions we make today will have lasting implications for future climate vulnerability, we must start planning our adaptive responses now. By doing so, we may help to lessen some of the environmental, economic and social costs of climate change.

Some examples of potential adaptation measures relevant to the Sydney Metropolitan Catchments include:

- Improving water-use efficiency, recycling and public education about water usage.
- Enhancing water supplies through groundwater extractions and desalination, subject to environmental impact assessments.
- Implementing early-warming and public communication systems for heat waves.
- Designing energy efficient buildings.
- Retrofitting old, and designing new, infrastructure to cope with climate change.
- Reviewing flood and fire management arrangements.
- Reviewing coastal zone management practices.
- Maintaining green spaces and ecological refugia in urban areas.

Making sure the catchment has the necessary capacity to implement such adaptation measures means continually expanding research, education and communication.

4.1 Adaptation in Action

Throughout much of Australia, users of the land have developed considerable experience in managing the high degree of variability that is characteristic of Australia’s climate. However, many individuals and enterprises are recognising that they are contending not just with climate variability, but also climate change – and the past is no longer a reliable indicator of future conditions. In response, a broad range of adaptation actions are being implemented across Australia.

In 1999, the Masters of the Climate project collected information from more than 80 landholders on how they were using climate tools to better manage their land resources and farm businesses – 23 were selected as case studies. In 2004, those 23 landowners were visited again to see how they fared during the 2002/03 drought and to identify trends in the use of climate tools over the intervening five years.

Some of the observed trends included:

- Solid understanding of local climate history as the basis for greater understanding of climate variability and change.
- Growing use of weather and climate websites for both long and short-term forecasts.
- The application of sophisticated tools (such as software for tracking sub-soil moisture and wheat yields) for making full use of all available moisture.
- Shifts in the nature of crops and stock run on the properties, with a movement away from riskier varieties and activities.
- Opportunistic decision-making – being ready to act on short notice to take advantage of weather conditions.
- In a few cases, deciding to leave the enterprise altogether.

All of the Masters of the Climate case studies from 1999 and 2004 are available over the internet at www.managingclimate.gov.au/information_resources.asp.
Sydney

5.0 What is the New South Wales Government Doing?

The NSW Government is taking a leadership role in the management of climate change. In late 2005 the NSW Greenhouse Plan was released, which outlines the NSW Government’s response to climate change.

The NSW Greenhouse Plan outlines polices and actions in three main areas:
- Awareness Raising
- Adapting to Climate Change


6.0 What’s happening in the Sydney Metro Catchments?

The following activities are currently underway within the Sydney Metropolitan Catchments with the goal of improving knowledge about climate variability and change in the catchments, and adaptation options to reduce the catchments’s vulnerability:

- The Upper Parramatta River Catchment Trust is coordinating a $1 million, 3-year study by CSIRO called Climate Change Rainfall Extremes in Sydney and Region. It is developing fine spatial and temporal scale projections of rainfall intensities under current climate and in 2030 and 2070 for coastal NSW, from Taree to Nowra. The local partners and financial contributors are the Upper Parramatta River Catchment Trust, Australian Greenhouse Office, Sydney Metropolitan Catchment Management Authority, Southern Rivers Catchment Management Authority, Hunter Central Rivers Catchment Management Authority, and Sydney Water. Other agencies on the study Steering Committee are the NSW Greenhouse Office, Metropolitan Water Directorate, Sydney Catchment Management Authority and NSW Dept of Natural Resources.

- The NSW Government’s Climate Change Impacts and Adaptation Research Program (CCIARP) is supporting a collaborative research effort to assess the impacts of climate change on water supply and demand in the Sydney Metropolitan Catchments. Of particular relevance to the Sydney Metropolitan Catchments is an examination of the impacts of climate change on demand measures implemented to improve water use efficiency. This includes investigation of the link between water consumption patterns and an increased number of hot days.
  - The NSW Government’s CCIARP is supporting research within the NSW Department of Environment and Conservation to quantify changes in fire regimes from projected climate change in the Sydney Metropolitan Catchments, and risks to biodiversity, ecosystem functions, people and their property.
  - The NSW Government’s CCIARP is also supporting research by the Sydney Coastal Council Group (SCCG) to calculate the value of selected beaches in the Sydney metropolitan region, which will also help governments make more informed decisions on how to protect ‘at risk’ coastal property, infrastructure, beach environments and amenity as a result of inevitable and immediate coastal erosion risk.
  - SCCG is collaborating with CSIRO to study the implications of climate change on the fifteen member councils and evaluate challenges and opportunities for pursuing adaptive decision-making on climate change at the scale of local government.
  - The University of New South Wales, in collaboration with the Sydney Metropolitan Catchment Authority, is undertaking a study to downscale the global and regional climate models to the scale of Sydney’s water supply catchment. The modelled catchment scale rainfall projections will subsequently be translated into runoff projections and will provide an indication of future changes in catchment yields under different greenhouse gas emission levels.
A number of climate change studies relevant to the Sydney Metropolitan Catchments are listed here:

The NSW Greenhouse Office website:  
www.greenhouse.nsw.gov.au

This site provides the latest news on catchment management projects and programs, relevant policies, and access to brochures and publications related to management of the catchment.

The Australian Greenhouse Office’s National Climate Change Adaptation Program:  