OFFICE OF
climate change

Climate Change: Adaptation for Queensland

Issues Paper







Toward Q2
Tomorrow's Queensland

Queensland Government

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Message from the Premier and the Minister

From drought to flood, Queensland is no stranger to harsh weather and dramatic shifts in climate.

After enduring a summer of unprecedented natural disasters, we understand the devastation that extreme weather can inflict on our communities and our economy.

Scientists warn that in the future Queensland faces far greater risks from changes in temperature, rainfall, sea level, and extreme weather events. To minimise the impacts of future climate change, we need to prepare.

The Queensland Government has already taken significant action on adaptation through its *ClimateSmart Adaptation 2007-2012* and *ClimateQ: toward a greener Queensland* strategies. However, we cannot afford to become complacent.

Climate-related risks are not static, and therefore our preparations require continual reassessment.

The recent floods and cyclones in Queensland, while devastating, also provided an opportunity to assess our preparedness for the likelihood of more frequent and extreme events. They also provided an opportunity to reassess where, and to what standard, key community and economic infrastructure should be built to better prepare for future climate change.

The Queensland Government has produced this Issues Paper to seek your input on how we will need to adapt to climate change and its impacts on our community, natural and built environment and rural sector.

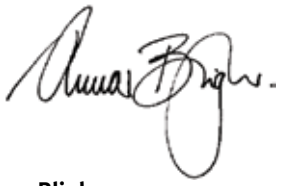
This consultation will help shape the final strategy expected to be released in 2012.

This strategy will complement the Government's response to the findings from the Queensland Floods Commission of Inquiry and any work undertaken by the Queensland Reconstruction Authority.

It will also respond to the range of climate-related risks, beyond floods and cyclone, and cover all key economic sectors.

This Issues Paper gives you the opportunity to provide feedback on the issues that will affect you, your business and community as we all prepare for climate change.

We look forward to hearing from you.



Anna Bligh,
Premier of Queensland and Minister for Reconstruction

The Honourable Vicky Darling MP
Minister for Environment

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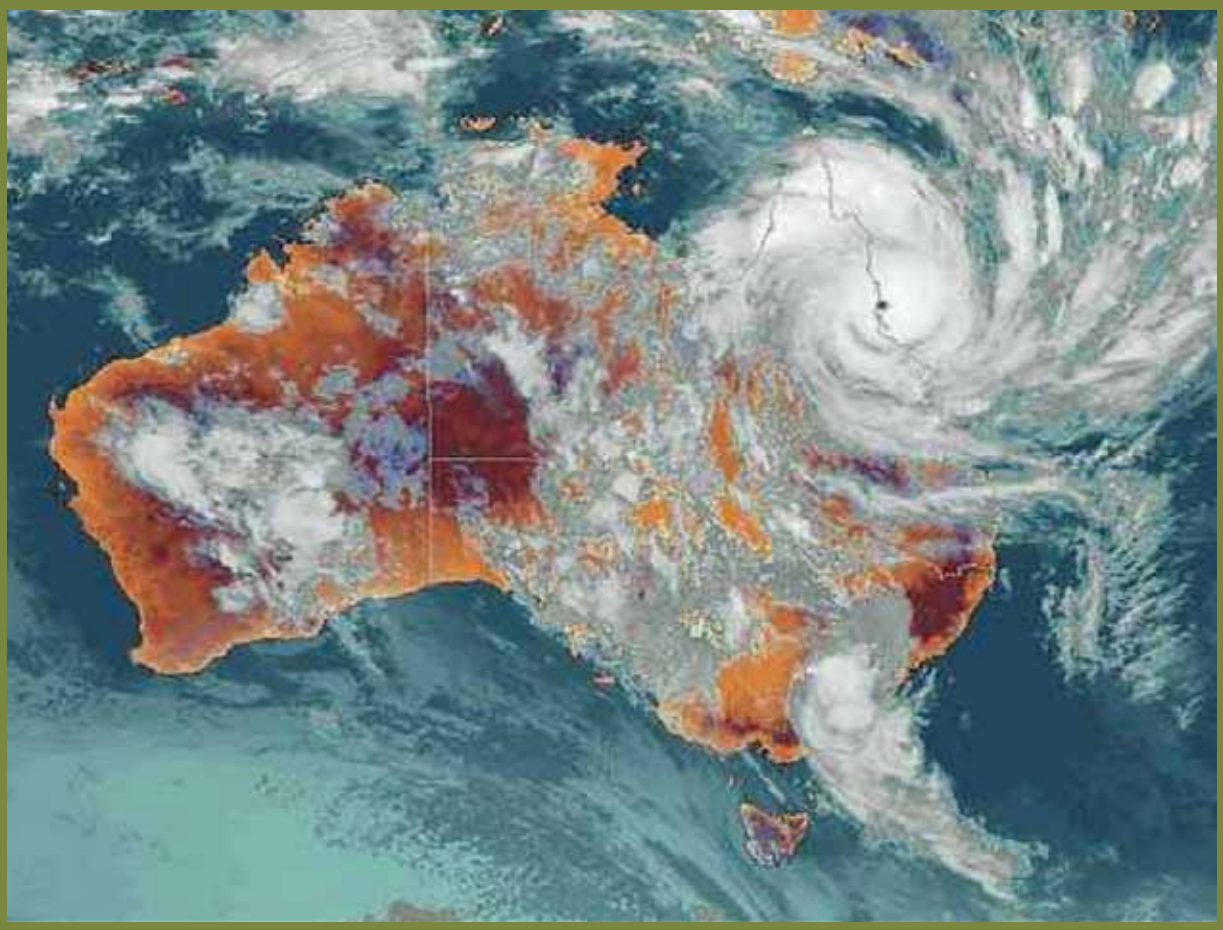


1 Adapting to a changing climate

1.1 Overview

Historically, Queensland has had a variable climate, and recent weather has reminded us of that fact. After experiencing the longest drought in recorded history, Queensland is now emerging from one of the wettest years on record. Heavy rains over the 2010-11 summer period resulted in almost the entire state being activated under joint state and Commonwealth government natural disaster relief and recovery arrangements. Two of the strongest cyclones to have crossed the Queensland coast – Yasi and Larry – have also hit in the past five years.

Climate change is likely to amplify aspects of natural climate variability

The question of whether the extreme weather events recently experienced by Queensland were influenced by climate change unnecessarily diverts attention away from the urgent need to prepare for the changes which are expected in the future.

Science overwhelmingly indicates that climate change is likely to amplify aspects of natural climate variability and result in weather events currently considered extreme becoming normal. In addition, there is a growing body of scientific evidence suggesting that climate change is already starting to have this effect.

Failure to adapt to climate change has the potential to severely impact on the lives Queenslanders

The impacts of other changes such as temperature and sea level rise are expected to be more incremental, but no less threatening. This combination of gradual and punctuated changes amplifies the risks that we face.

The science of climate change in Queensland – the essential question of what we are adapting to – is covered in further detail in the *Science* chapter.

While climate change will impact regions of Queensland differently, the science clearly indicates that adjustments will be required to ensure the wellbeing and safety that Queenslanders currently enjoy can be maintained into the future.

Conversely, failure to adapt to climate change has the potential to severely impact on the lives Queenslanders. For example, the estimated $5.8 billion damage to homes and businesses caused by recent flooding across Queensland highlights the vulnerability of the built environment to extreme weather events. Iconic natural systems like the Great Barrier Reef, and the $5 billion tourism economy it supports, are also under threat.

1.2 What is climate change adaptation?

Broadly, 'adaptation' actions aim to reduce the adverse consequences of climate change on both human and natural systems.

Adaptation actions can take a variety of forms. They may involve transforming existing systems to reduce their exposure to climate related risks. For example, moving existing development away from hazard-prone areas, or building biodiversity corridors to facilitate movement of species.

Other actions may involve building the resilience of existing human and natural systems to withstand or recover from climate change impacts. For example, building flood levees to protect existing development, or defending ecosystems from threats such as pests and weeds which weaken resilience.

1.3 Adaptation to complement mitigation

With overwhelming evidence demonstrating the link between greenhouse gas emissions and climate change, policy development in many jurisdictions has focussed on reducing emissions to avoid catastrophic climate change. These efforts are commonly referred to as mitigation and will need to be continued and strengthened.

At the United Nations Framework Convention on Climate Change conference in Cancun in December 2010 the world agreed to take action to limit global warming to 2°C above pre-industrial levels.

Even with only 2°C global warming there are serious risks to Queensland from the impacts of climate change, and it is important to start planning now to manage these risk. Where decisions have very long term implications – for example with land use planning and major infrastructure – it may be prudent to consider the implications of a sub-optimal global mitigation response.

This realisation provides even stronger arguments than before for continuing to pursue aggressive reductions in greenhouse gas emissions. The Commonwealth Government's climate change advisor, Professor Ross Garnaut argued that the costs of mitigation are far lower than the costs

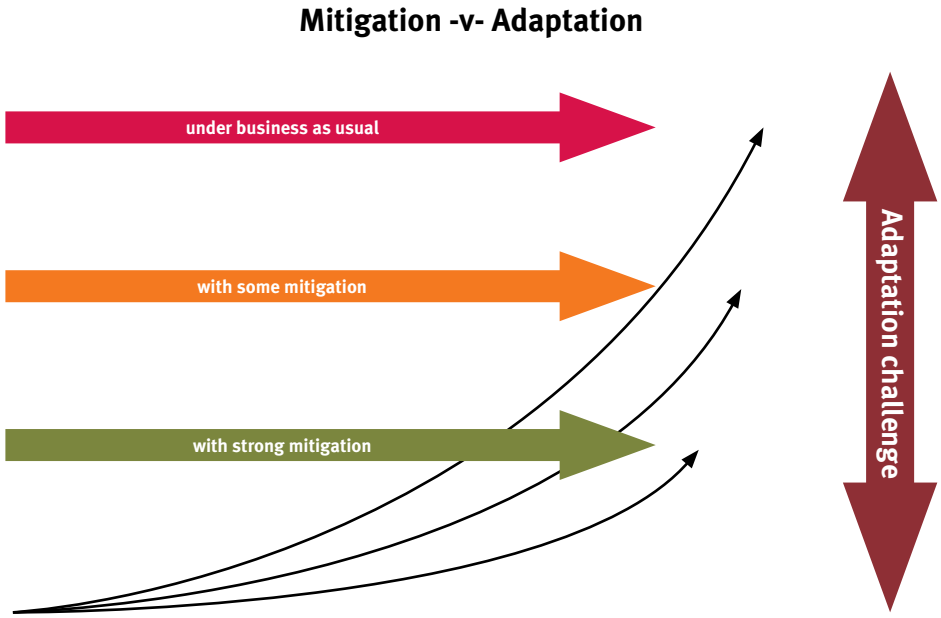


Figure 1: The relationship between climate change adaptation and mitigation

of unmitigated climate change, and preventative measures to minimise impacts before they occur tend to be cheaper than dealing with them once they unfold.

Queensland accepts the importance of mitigation and has reduced emissions more than five per cent below 1990 levels. Although from a high base, this represents the highest absolute reductions of any state. Queensland continues with its transition to a low carbon economy via implementation of its climate change strategy, *ClimateQ: toward a greener Queensland* (ClimateQ).

Increasingly, however, there is an imperative to consider how we can adapt to the impacts of climate change which cannot be avoided.

Despite the importance of global efforts to stabilise and reduce emissions, the reality is that many climate change impacts are now locked-in. As global emissions continue to rise to levels scientists consider dangerous, the more important effective adaptation policy will become.

Figure 1 shows the conceptual relationship between adaptation and mitigation. Although this representation does not reflect the complex scientific relationship, it is useful in showing why adaptation is a necessary complement to mitigation from a risk management perspective.

Many climate change impacts are now locked-in

1.4 What are the benefits to Queensland?

The benefit of climate change adaptation should be viewed in terms of the potential impact which has been avoided. In this sense, Queensland also has the most to gain of any state from strong adaptation.

The Garnaut Climate Change Review (Review) warned that Queensland is the Australian state most at risk from the impacts of unmitigated climate change. Without mitigation and adaptation, climate change is expected to reduce Queensland's Gross State Product (GSP) by more than 10 per cent by 2100.

Results from the Review's modelling show impacts such as a 92 per cent decline in irrigated agriculture from the Murray Darling, extensive damage to coastal infrastructure, costs to water supply infrastructure, severe impacts on tourism, and more than 4000 additional heat related human deaths in Queensland each year.

These costs do not include the immeasurable cost of losing iconic ecosystems such as the World Heritage listed Great Barrier Reef and Wet Tropics rainforest, or the impact that loss would have on future generations.

These impacts would create a severe cost burden on individual Queenslanders. The projected impact on national Gross Domestic Product (GDP) from unmitigated climate change is equivalent to every single Australian being around $17,000 worse off (in today's dollars) than they would have been at 2100 – and this is a conservative estimate[1].

The Queensland Government's major investments in climate change adaptation have the state recognised nationally and internationally as leaders in this field – providing a solid platform for the next phase of Queensland's adaptation response.

1.5 Costs versus benefits of adaptation

While significant work has been done on the relative costs and benefits of climate change mitigation, economic cost benefit analysis for adaptation is an emerging field. Like mitigation, effective adaptation can be achieved in a variety of ways – some responses are economically efficient, others less so.

The overall impact of unmitigated climate change on the Queensland economy is projected to be severe. However, where the costs of certain adaptation responses are considered too high, some impacts may be economically tolerable.

It is important that Queensland's adaptation policies are economically responsible.

While the general value of climate change adaptation is accepted, further work needs to be undertaken to investigate the relative costs and benefits of alternative adaptation options. In Queensland, growing numbers of economists have started focussing on this important issue.

2 Queensland's adaptation policy framework

2.1 Science and policy integration

Climate change will be pervasive and impact on all sectors of the economy in different ways. These sectoral differences are exacerbated by Queensland's size and naturally variable climate. For example, although rising sea levels are a general threat to the Queensland coast, the impacts on the Gold Coast will not necessarily be the same as those in Mackay.

While the general threat of climate change is well established globally and nationally, effective adaptation requires an understanding of regional-specific climate risks.

Queensland's adaptation policy framework therefore prioritises the integration of science and policy, and recognises the different role of research agencies and different levels of government in understanding and responding to climate risks.

Effective adaptation requires an understanding of regional-specific climate risks

Figure 2 shows how the Queensland Government uses science outputs from national research agencies – including the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Bureau of Meteorology (BoM), and the National Climate Change Adaptation Research Facility (NCCARF) – as the basis for developing climate science specific to Queensland regions. This, in turn, provides the basis for the state to work with local governments to develop and implement targeted adaptation responses.

In responding to this Issues Paper, stakeholders are encouraged to differentiate between adaptation research priorities and policy priorities.

Adaptation issues are not easily divided and will often cut across sectors

2.2 Queensland's sectoral approach to adaptation

Along with science, this Issues Paper covers key sectors of Human Settlements, Infrastructure, Ecosystems, Water Management, Primary Industries, Emergency Management and Human Health.

However, adaptation issues are not easily divided and will often cut across sectors. For example, adaptation for the water sector raises issues for both human settlements with urban stormwater drainage and runoff, and major infrastructure such as dams and desalination plants.

Although there are a number of different sectoral approaches which could have been adopted for this Issues Paper, the sectors above have been selected as a best fit for the key adaptation issues facing Queensland.

This Issues Paper also recognises that adaptation responses in one sector can have positive or negative consequences in another. For example, effective land use planning for human settlements can reduce stress on emergency management systems in a natural disaster. Adaptation responses which maintain ecosystem health and function can have positive outcomes for primary producers which depend on certain ecosystem services, such as water quality.

This Issues Paper explores some of the complex relationships between adaptation issues and responses across sectors.

2.3 Role for state governments

Like other state and territory governments, the Queensland Government delivers a broad range of services, administers a significant body of legislation and manages a substantial portfolio of assets and infrastructure.

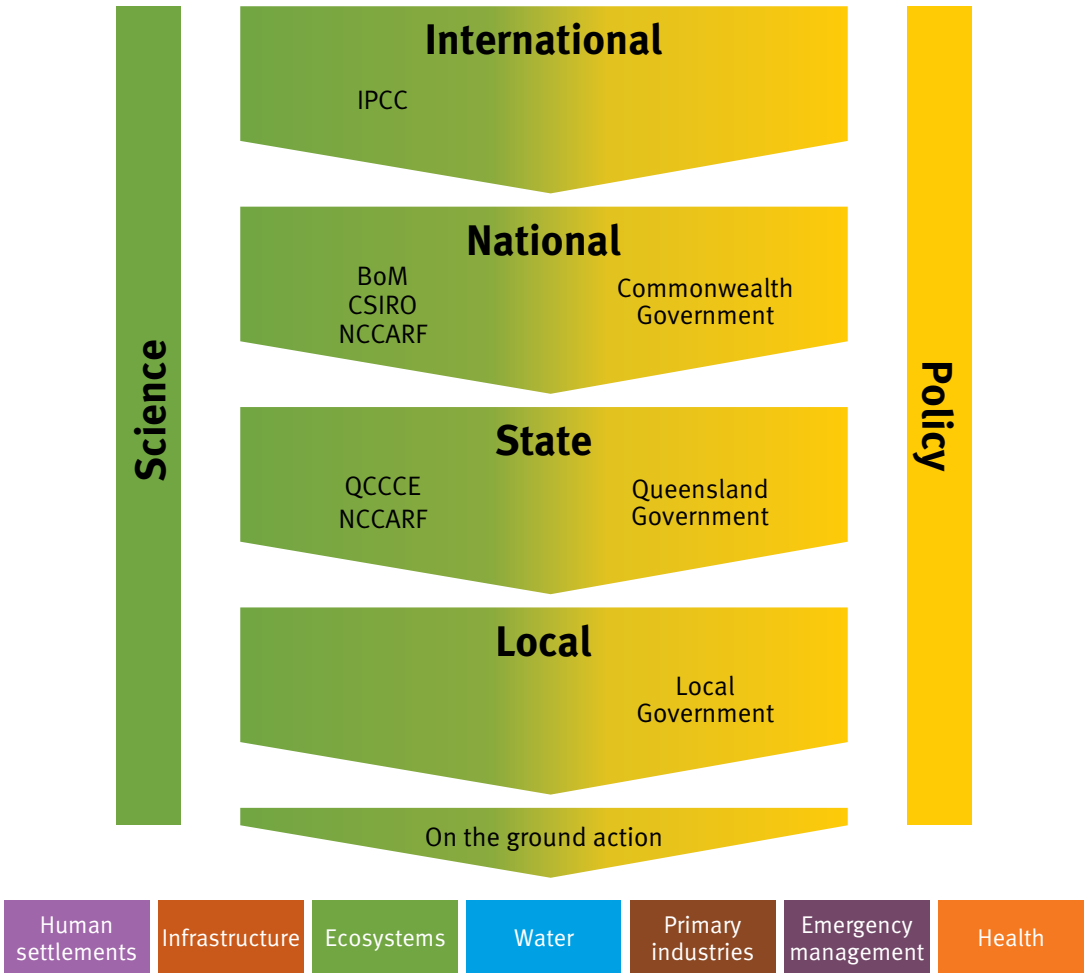


Figure 2: Key organisations involved in climate change adaptation in Queensland

States have a clearly established role in minimising climate change impacts on key areas of service delivery and publicly-owned infrastructure: such as emergency services, water, electricity transmission and transport. It is also the responsibility of the state to work with stakeholders to protect key ecosystems and other environmental interests from climate risks.

The role of the state in relation to private interests at risk from future climate change is multi-faceted. The provision of regionally-relevant information by the state is vital for the effective management of privately-held climate risk. There is a clear role for state governments in creating the right conditions and incentives for households and businesses to manage their own climate risks. State governments also have a key role in ensuring planning, regulatory and market frameworks appropriately deal with climate risks.

What is less clear is the extent to which states should use planning and regulation to minimise private risks, for example by requiring adaptation measures as a condition of development or even prohibiting development in certain high-risk areas.

2.4 Role of other governments

The three levels of governments (federal, state, local) have different responsibilities and therefore have differentiated, yet complementary roles, in helping Queenslanders adapt to the impacts of climate change.

Given that climate risks will vary from region to region, the Queensland Government's adaptation objectives are necessarily achieved in close partnership with local governments. Local governments are on the frontline in dealing with the impacts of climate change. They have a critical role to play in ensuring that particular local circumstances are adequately considered in the overall adaptation response, and in involving the local community directly in efforts to facilitate effective change. They are strongly positioned to communicate directly with communities, to inform the Queensland Government about on-the-ground needs of local and regional communities, and to respond appropriately and in a timely manner to local changes.

However, some issues cannot be addressed by state and local governments alone. Like the Queensland Government, the Commonwealth invests heavily in delivering scientific and other information to support adaptation and manages extensive assets vulnerable to climate change. The Commonwealth is also responsible for some key areas of regulation which can influence climate change outcomes, for example in relation to insurance markets.

Adaptation will be cheaper and more effective if all levels of government provide consistent and appropriate information and incentives. The Queensland Government is engaged with the Commonwealth and other state and territory governments to establish national adaptation priorities through the Council of Australian Governments (COAG).

Adaptation will be cheaper and more effective if all levels of government provide consistent and appropriate information and incentives

2.5 What has Queensland done?

The Queensland Government has already implemented a range of initiatives which provide the vital scientific and policy basis for helping our economy, communities and ecosystems to adapt.

Queensland Climate Change Centre of Excellence

In 2007, the Queensland Government established the Queensland Climate Change Centre of Excellence (QCCCE) as a specialist whole-of-government centre based within the Office of Climate Change. The Queensland Government is the only state or territory with its own dedicated climate science capacity.

QCCCE undertakes leading-edge, innovative research into climate change issues of particular relevance to Queensland. QCCCE is undertaking a range of projects and is working collaboratively with national and international research agencies, industry and all levels of government. QCCCE has links to world-leading international research organisations, such as the UK Met Office Hadley Centre and the University of Reading's Walker Institute.

QCCCE has developed regional-scale climate change projections for 13 regions in Queensland. These projections are important for assessing the risks of climate change at a local level and for the development of targeted adaptation responses.

ClimateSmart Adaptation 2007-12

In 2007, the Queensland Government released ClimateSmart Adaptation as its five-year plan to build Queensland's resilience to climate change. It was the first climate change adaptation strategy of its kind to be released in Australia.

The strategy contained 62 actions which focused on increasing our understanding about the impacts of climate change, many of which are outlined in further detail throughout this Issues Paper.

Initiatives include the incorporation of climate change risks and issues into statutory regional plans, including the *South East Queensland Regional Plan 2009-31* and the *Far North Queensland Regional Plan 2009-31*, the inclusion of sea level rise figures in coastal planning, and delivering programs to assist agricultural industries to better understand and manage the risks from climate change impacts.

The implementation of CSA drew heavily on the climate science capacity established at QCCCE. Now largely implemented, the CSA has informed a significant body of new adaptation work occurring across government.

National Climate Change Adaptation Research Facility

In late 2007, NCCARF was established to lead and coordinate climate change adaptation research across Australia. Reflecting Queensland's position at the forefront of climate change adaptation, Griffith University (Gold Coast campus) was chosen to host the facility.

NCCARF's key role is to synthesise knowledge, coordinate research activities, broker research partnerships and provide information for decision makers.

Funding for research is provided by the Commonwealth Government and a consortium of partner organisations. The Queensland Government is one of eight partner organisations in the NCCARF consortium.

As the only state government with partner status, Queensland is uniquely placed to influence the national adaptation research agenda and ensure that research outputs meet the government's policy needs.

The Queensland Government's OCC is represented on the NCCARF management committee and has a strategic role in governance and priority-setting for the facility.

3 Science

Key Points

- The IPCC AR4 found unequivocal evidence that climate change is happening.
- 2010 marked the hottest decade on record for Australia, with each decade since the 1940s warmer than the last. Globally, 2010 was the hottest on record.
- By 2050, Queensland is expected to experience increasing temperatures, changes in rainfall, rising sea levels and increasing intensity of cyclones.
- Queensland's approach to adaptation prioritises the integration of science with policy to ensure targeted, regionally-specific responses.
- Through QCCCE, the Queensland Government has made significant investments in climate science research to understand what changes in the global climate system will mean for Queensland.
- Climate science and information on the impacts of extreme events such as tropical cyclones, and sea level rise is continually improving, so adaptation policies need to be flexible.
- As our understanding of the climate risks to Queensland improves, key issues to be addressed include managing scientific uncertainty in adaptation and achieving better consistency in developing projections and advice, and communicating the science.

3.1 Overview

Climate science is critical for effective adaptation. As discussed in Section 1, a sound understanding of regional-specific climate risks is required to develop policy responses that are appropriately targeted. This is particularly important in a state as large and regionally diverse as Queensland.

As the only state government in Australia with a dedicated climate science capacity, Queensland is uniquely positioned to address the adaptation challenges posed by climate change.

An increase of 2°C would have significant implications for Australia

The Queensland Government accepts the overwhelming scientific evidence that climate change caused from human actions is real, and that it presents a genuine risk to our social, economic and environmental welfare and security. Scientific evidence indicates that human induced climate change is already influencing Queensland's naturally variable climate[2].

The leading international body for the assessment of climate change science is the Intergovernmental Panel on Climate Change (IPCC), which was established by the United Nations Environment Programme and the World Meteorological Organization to provide the world with a clear scientific view on the current state of knowledge on climate change.

The IPCC has one of the most comprehensive and robust peer review processes on climate change science. The latest synthesis report totalled more

than 2500 pages and was reviewed by more than 2000 of the world's best scientists from a diverse range of fields including climate science, oceanography, ecology, medicine, economics and the social sciences.

It is not possible for policy-makers to process and interpret all available scientific evidence on climate change. To provide policy-makers around the world with a clear scientific view on the current position of knowledge in climate change, the IPCC releases assessment reports approximately every 6 years.

Released in 2007, the IPCC's most recent report is the *IPCC Fourth Assessment Report* (AR4). The next report, the *Fifth Assessment Report* (AR5) is expected to be released in 2013-14. It is expected that AR5 will provide further detail on impacts, adaptation and vulnerability than previous assessment reports.

The 2°C target will be very difficult to achieve without rapid and significant decreases in carbon dioxide emissions

AR4 concluded that warming of the climate system is unequivocal, and that there is a more than 90 per cent probability that the warming is due to greenhouse gas emissions generated from human activities, predominantly the burning of fossil fuels and clearing of natural vegetation.

Based on IPCC warnings there was international acceptance at Copenhagen in 2009 to support the United Nations objective of restricting global mean temperature increases to 2°C above pre-industrial levels which is broadly equivalent to stabilising emissions at 450 parts per million (ppm).

An increase of 2°C above pre-industrial levels would have significant implications for the distribution of rainfall in Australia, the frequency and intensity of flood and drought, and the intensity and frequency of conditions for catastrophic bushfires[3].

Recent reviews by the Climate Commission's *The Critical Decade* and *The Garnaut Review Update – 2011* suggests the 2°C target will be very difficult to achieve without rapid and significant decreases in carbon dioxide emissions.

On this basis, policy-makers need to consider the potential impact of an increase in global mean temperature well above 2°C.

3.2 Climate observations and projections

A change in the global mean temperature of 2°C will impact countries around the world in different ways. Effective adaptation requires an understanding of what global climate trends mean for countries and their regions. Queensland, with its variable climate and regional differences, is no exception.

Observed changes in global climate

Current levels of atmospheric carbon dioxide (CO_2) are around 390 ppm[4]. This is a much higher concentration, than the natural range over the last 800,000 years (172–300 ppm)[5].

Concentrations of the two other main greenhouse gases—methane and nitrous oxide—have also increased, and remain well above concentrations of the last 20 000 years.

There is observational evidence from the land, oceans and the atmosphere which strongly indicate a warming climate system:

- Global average land based temperatures have increased by around 0.75°C over the last century[6]. In 2010, Australia recorded its hottest decade on record[7]; reinforcing the trend that every decade since the 1940s has been warmer than the last[8]. Globally, 2010 was the hottest on record.
- Global average sea surface temperatures have warmed by 0.7°C in the past 120 years[9].
- Global sea levels are currently rising at around 3.2 mm a year, nearly twice the average rate (1.7 mm per year) experienced during the 20th century[10].
- Net loss of mass from the Greenland Ice Sheet has increased from an estimated 50 Gigatonnes per year in the period 1995-2000 to approximately 200 Gigatonnes per year in the period 2004-2008. The current loss (~200 Gigatonnes per year) represents enough water to supply more than one billion city-dwellers.[11]

Ocean acidification directly follows the accelerating trend in world carbon dioxide emissions. Measurements indicate that the average seawater acidity has increased by 30 per cent since pre-industrial times and is expected to increase further by 2100[12].

Implications for Queensland

In 2009, the Queensland Government – through QCCCE and CSIRO – developed regional climate change projections for Queensland based on the IPCC AR4. These projections provide the best available information on projected temperature, rainfall and evaporation for 13 Queensland regions along with expected impacts[13].

The regional projections show that Queensland's environment, communities and economy face significant risks from increasing temperature, evaporation, and changes in rainfall patterns. Also, future changes in tropical cyclones, sea level rise and ocean acidification pose climate change risks more specifically for coastal Queensland.

Temperature

The average surface temperature in Queensland has risen by almost 0.9°C since the early 1900s. The figure below shows the warming trend for Queensland (Figure 3).

Over the next 40 years, Queensland regions can expect to experience increased temperatures of between 1.0 and 2.2°C, indicating a significant acceleration in the rate of warming.

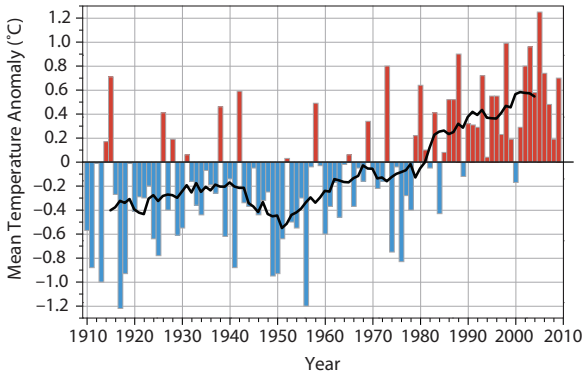


Figure 3: Warming trend for Queensland

Temperature rise in Queensland is projected to lead to increased frequency of heatwaves. The number of hot days (those with a maximum temperature greater than 35°C) is also expected to increase, particularly in inland areas. For example, by 2050, Longreach can expect the number of days of over 35°C to increase by around 40 per cent, that is, from 112 to around 156 days per year.

Rainfall

Queensland's rainfall varies greatly from year to year. Seasonal variations have impacts – for example the summer Monsoon affects weather patterns, such as high rainfall events and cyclonic activity. Year-to-year fluctuations in the climate system, particularly in the El Niño Southern Oscillation (ENSO) mode of natural variability, have a strong impact on Queensland's rainfall and cyclones.

There is also a multi-year cycle known as the Interdecadal Pacific Oscillation (IPO) which contributes to extended dry or wet periods in Queensland.

The number of 'exceptionally hot' years is projected to increase from an average of one in every 22 years to an average of one every 1.7 years by 2050

These fluctuations do not represent climate change but understanding these natural variations will improve our knowledge of climate change impacts. This is one reason why rainfall is one of the most difficult phenomena to predict under climate change.

Projecting future changes in rainfall is difficult. Current projections indicate that rainfall is expected to decrease across most of Queensland, except for Cape York, the Gulf Region and Far North Queensland. Depending on the region, modelling indicates that this decrease could range between 1-7 per cent, by 2050.

Climate change will also influence the seasonal and daily patterns of rainfall intensity, increasing flood risk. Projections indicate an increase in 2-hour, 24-hour and 72-hour extreme rainfall events for large areas of south east Queensland.

Analysis has shown that rainfall associated with tropical cyclones (within 300 kilometres) is also likely to increase by approximately 20 per cent on average by 2100[14].

Evaporation

Increasing temperature can increase water loss from surface water and soils.

By 2050, Queensland is expected to face an increase in annual mean evaporation of 5-7 per cent. A reduction in mean annual rainfall, combined with increased evaporation can affect water availability for people and agricultural productivity.

Drought

Projections of changes in the number of exceptionally hot years provide an indication of future drought conditions. The number of 'exceptionally hot' years (those years with a mean annual temperature in the highest five per cent of years on record) is projected to increase in frequency from an average of approximately one in every 22 years to an average of one every 1.7 years by 2050[15].

Tropical cyclones

It is very difficult to distinguish between natural variability and human-induced climate change as the cause of changes in cyclone behaviour[16].

Studies undertaken to date indicate that the global frequency of tropical cyclones is projected to either stay about the same, or even decrease[17].

Rainfall associated with tropical cyclones is likely to increase with warmer temperatures; with a projected increase of around 20 per cent within 100 km of the eye of the cyclone[18].

As the climate warms, a modest increase in intensity of the most intense systems, and a southward shift of 100km in where they start and finish is projected[19].

More research is still required on tropical cyclone activity[20]. This uncertainty is due to a lack of good observational data and the limited ability of global climate models to represent cyclone behaviour.

So while Queensland may see fewer cyclones in the future, cyclones may strengthen and affect new areas.

Sea level rise

The IPCC has projected a global sea-level rise of up to 0.79m by 2100[21]. For planning purposes, Queensland is currently using 0.8m[22]. However, differences in tidal and underwater topography will cause local and regional variations in sea level rise.

Considerable debate is underway about the causes and potential extent of sea-level rise. The uncertainty is not about whether it is occurring, but about the rate of the ice loss from the dynamics of the Greenland and Antarctic icesheets.

This means that there could be a larger rise in sea-level than current projections indicate with the latest models predicting 0.9m to 1.6 m above the 1990 level by 2100[23]. High uncertainty surrounds estimates of future global sea levels. The upper limit of sea-level rise in the 21st century is a matter for continuing research.

Ocean acidification

The acidification of oceans, caused by carbon dioxide dissolving in seawater, has the potential to significantly affect marine organisms, such as corals and shellfish, including those that sustain important fisheries.

Ocean acidification can be determined with a high level of certainty. Measurements indicate that average seawater acidity has already increased. It is predicted that by 2050 ocean acidity could increase by 150 per cent[24].

3.3 Evolving science

Our understanding of the climate system is continually improving. There is now widespread scientific agreement that the world is heading for at least 2°C warming[25]. Other recent research indicates that some climate change impacts may be more severe than identified in the IPCC AR4[26]. The extent to which the world is successful in reducing emissions, will influence the scale of the impacts which we need to adapt to. As these impacts become clearer these will be reflected in ongoing updates to the science. Cumulative emissions need to be restricted to 1000 billion tonnes for the period 2000-2050, to have a good chance of limiting global warming to 2°C.[27]

IPCC AR5, due out in 2013-14, will update our knowledge of climate change science and impacts.

3.4 Rationale for further work

The evolving nature of climate science poses challenges in the implementation of adaptation policy. Some of these issues such as communication, planning, and dealing with scientific uncertainty are outlined below.

Managing adaptation and scientific uncertainty

While the scientific evidence is unequivocal that climate change is happening, there remains uncertainty about likely regional and local impacts. Projecting detailed, localised changes – including future changes in rainfall – are very difficult. As is projecting 'tipping points' (or rapid climate transitions) with any real confidence.

Models that better represent climate feedbacks will help improve knowledge around the magnitude and rate of global warming, and the associated risks for regional and local areas. To assist with this, QCCCE

– with the support of CSIRO – are conducting global climate modelling to simulate the past, present and future climate. Information from the modelling will be submitted for inclusion into the IPCC AR5 to more accurately reflect Queensland's climate.

It is essential to learn how to live with uncertainty

The Queensland Government is one of around 20 global institutions currently undertaking global climate system modelling to input into the AR5.

QCCCE's expected contribution to the IPCC AR5 will also underpin the development of more accurate and up-to-date downscaled regional projections for Queensland. Once complete, the updated projections will be used to inform policy and planning decisions.

In this context, it is essential to learn how to live with uncertainty in decision making surrounding climate change. This means that governments and industry sectors therefore need to put in place flexible planning arrangements that can accommodate updated projections.

Although the Queensland Government's climate science program provides a basis for better targeted adaptation, policies must still account for scientific uncertainty.

Achieving a comparable and consistent approach to climate change projections

To the extent possible, consistency in climate change information is needed for planning purposes. Projected changes in variables from different climate change research organisations on temperature or rainfall should be comparable. For example a consistent baseline period is necessary to enable comparisons between global, national, state, or regional variables. This issue needs to be addressed at a national level.

Improved communication of climate science

Communication is a central and complex part of the process of disseminating information. Government, industry and the community want clear information on which to base decisions.

An unusual feature of the climate change 'debate' in Australia is that while the evidence that our actions are affecting the climate is increasing, parts of the community are unclear of the differences between natural climate variability and climate change, and their drivers.

A recent CSIRO survey found that about 75 per cent of Australians believe the climate is changing, but a significant minority were still not sure about the causes. Less than six per cent said the climate was not changing at all[28].

The complexity of climate science language may be a contributing factor. Climate change information is often difficult to communicate to the general public who want information that is easy to interpret and relevant to their specific situation.

In order to help explain the science of climate change and explain the purpose and operation of a carbon price, the Commonwealth Government has established the independent Climate Commission. The Commission is conducting information and public forums around Australia.

For further information see Appendix 1.

About 75 per cent of Australians believe the climate is changing

Seeking your views

Have you considered how climate science can deliver more for you, and what new climate-science initiatives could be considered for Queensland?

1. Do you feel well informed about the risks that climate change poses to your community?
2. Are there any specific areas of climate change science research that the Queensland Government should be undertaking or enhancing?
3. What areas of climate science need better communication?
4. How can we make the modelling of Queensland's future climate more relevant for you?

Key Sectors

4 Human Settlements

Key points

- Climate change, development and population growth, will accentuate existing natural hazard risks to human settlements from land and sea based flooding and extreme weather events such as cyclones and droughts.
- The Queensland Government has already taken key actions to address the risks through land use plans and policies, including the Queensland Coastal Plan and statutory regional plans as well as through state and national building standards and resources.
- Further action is required to better plan for flood risks, develop adaptation strategies for high risk coastal areas and vulnerable coastal communities, address barriers to adaptation action and plan climate resilient developments.

Overview

Queensland's human settlements refer to larger cities and towns, as well as smaller communities across the state. The growing economy and liveability of Queensland's regions continues to attract new people to many areas of the state. In accommodating this growth and maintaining the attractiveness of our regions it is important to plan now for climate resilient settlements and buildings.

The summer of 2010-11 clearly demonstrated the vulnerability of Queensland's settlements to extreme flooding and cyclonic events. The scale of damage to buildings and businesses resulting from these events has not been seen in Queensland's recorded history, with more than 136,000 homes and businesses affected[29].

The summer of 2010-11 clearly demonstrated the vulnerability of Queensland's settlements with more than 136,000 homes affected

These extreme events cannot be directly attributed to climate change. However, the science indicates that with climate change, Queensland will experience more frequent floods and heatwaves and more severe cyclones which will impact on human settlements[30].

Cost effective approaches to planning, building and settlement design are therefore required to enhance resilience to climate change.

Settlements already located in areas vulnerable to natural hazards will need measures to address the increased risks from climate change. New settlements and buildings should be designed to avoid or mitigate the risks from the start.

Adaptation measures adopted will need to be location specific and informed by the community on what constitutes an acceptable level of risk.

4.1 Climate risks

The specific impacts of climate change on Queensland's human settlements will largely depend on their location. For example, coastal communities may not be as greatly affected by increases in temperature as their inland counterparts, but are exposed to natural hazards associated with sea level rise and more intense cyclones. This regional variation in climate impacts is an important consideration in preparing human settlements for a changing climate.

Inland flooding

Flooding has historically been number one in the hierarchy of risks for Queensland. In 2010-11 most of the state was disaster declared due to flood impacts. The majority of human settlements are located on flood plains and are therefore susceptible to flooding, as demonstrated by the

repeated flooding of the towns of Condamine and Roma. Extreme rainfall events are projected to intensify with climate change and could lead to more severe flood events in the future[31].

The current 1 in 100 year storm event is expected to occur every 14 years with a sea level rise of 0.8m

Sea level rise and storm surge

Higher sea levels are likely to increase the extent of coastal flood events and shoreline erosion in parts of low lying coastal settlements such as Townsville and Mackay[32]. A recent study of South East Queensland (SEQ) has found that current storm surge events will occur more frequently as a result of sea level rise. For example, the current 1 in 100 year storm event in SEQ is expected to occur every 14 years with a sea level rise of 0.8m[33].

Cyclones

Cyclones can impact anywhere along the Queensland coast but are more common in northern Queensland[34]. They cause damage to homes and infrastructure from strong winds and can result in a storm surge when they make landfall as occurred at Cardwell, Tully Heads and Hull Heads with Tropical Cyclone Yasi in 2011. Climate change is projected to lead to an increased intensity of tropical cyclones in Queensland and cyclones occurring further south[35] .

Heat impacts

Urban environments are vulnerable to heat island effects on very hot days, and all settlements are vulnerable to reduced water availability in times of drought. The number of hot days (over 35°C) is projected to increase throughout Queensland, with the greatest increases in temperature occurring inland. Both our rural and urban settlements will need to continue to adapt to extreme heat events and longer dry periods. Peri-urban areas and some rural areas may also be at increased risk from bushfires.

4.2 Action so far

To assist in building climate resilient settlements the Queensland Government has undertaken a significant body of adaptation work including:

The Queensland Coastal Plan and coastal hazard area maps

The Queensland Coastal Plan (the Plan) deals with the increased threats from climate change on coastal hazards (for example coastal erosion and storm tide inundation) by incorporating a climate change factor of 0.8m sea level rise by 2100, and a 10 per cent increase in cyclone intensity.

In an Australian first, the Plan also incorporates coastal hazard area maps based on high resolution digital technology that will allow councils and other stakeholders to begin planning for the impacts of future sea level rise along our coast.

Improved coastal mapping

Through a $14.6 million investment, high resolution digital elevation models are being acquired for populated areas of Queensland. This data will help local governments and other sectors to undertake locally specific climate change risk assessments (such as flooding, coastal hazards and fire risks) which assist with land use planning and disaster management.

Inland Flooding Study – better flood mapping guidance for local government

Developed in partnership with the Local Government Association of Queensland (LGAQ) this groundbreaking study advises councils on how to account for increased rainfall intensity from climate change. The study recommends a climate change factor of 5 per cent increase in rainfall intensity per degree of global warming be incorporated into flood studies when planning human settlements.

The study also includes an example model code for assessing development in flood prone areas and recommendations for consideration in the review of *State Planning Policy 1/03: Mitigating the adverse impacts of flood, bushfire and landslide*.

Effective flood mapping requires not only data on the amount of water likely to flow through the catchment (including a climate change factor for increased rainfall intensity) but also data on the topography of an area so that the movement of water into and through settled areas can be modelled.

The Commonwealth and Queensland governments are in the process of obtaining high resolution digital elevation data for 100 inland communities. The data will be available in early 2012 and can be used by local governments to better understand flood behaviour when undertaking flood studies.

Planning instruments account for climate change

The Queensland Government is also working to ensure that all relevant state planning instruments and land use plans take account of climate change impacts such as increased intensity of floods, fires, storms and heatwaves.

Using regional climate change summaries for Queensland enables the projected impacts of climate change to be incorporated into statutory regional plans, growth management plans and guidance for local government. This helps ensure that new development avoids areas projected to be impacted by climate change or is designed to cope with the impacts.

Building standards that help address the likely effects of climate change

The Queensland Government has taken a number of steps to ensure our building standards are reviewed and adapted to incorporate the likely impacts of climate change.

A range of resources have been developed to assist Queensland communities faced with the task of repairing and rebuilding after recent natural disasters. This includes encouraging the use of building materials and techniques that enable buildings to have greater disaster resilience in the future.

The Queensland Government is also involved in a technical reference group that will develop design guidance for buildings in certain flood affected areas. The updated design requirements are intended to be incorporated into the national Building Code of Australia.

Through its membership on the Australian Building Codes Board, the Queensland Government is helping to ensure our buildings are designed to withstand the likely impacts of climate change, particularly impacts from future cyclonic events.

Water by Design

Jointly funded by the Queensland Government and local governments through the Healthy Waterways partnership, Water by Design is a capacity building program that supports the uptake of Water Sensitive Urban Design in South East Queensland[36].

The program provides guidance and training on Water Sensitive Urban Design for the development industry. Inclusion of Water Sensitive Urban Design measures in new development will help to retain water in the urban landscape and therefore reduce urban heat island effects. Better management of urban stormwater (for example through stormwater harvesting) will also help communities prepare for potential reductions in water availability due to climate change.

4.3 Rationale for further work

Despite the government's early action to adapt Queensland's human settlements to climate change impacts, significant further work remains. Population growth and urban expansion and encroachment into more exposed areas increase the risks that Queenslanders face from climate change, and raise the need to further invest in climate resilient planning and building design. Such investment will help reduce impacts from future extreme events as well as the gradual onset of climate change impacts.

More than 80 per cent of Queenslanders live on the coast – it is imperative to ensure preparedness for sea level rise

The natural disasters over the summer of 2010-11 have made reconstruction of our human settlements the highest priority of the Queensland Government. The reconstruction effort provides an opportunity to ensure that affected human settlements are built back to be more resilient.

Better planning and building design for flood risks

Floods such as those experienced in 2009, 2010 and early 2011 raise a range of issues associated with expanding human settlements in flood prone areas.

Such issues include whether changes are needed to existing planning and building measures to cater for projected future flood risks — for example habitable floor heights, construction standards, and retreat options.

As part of the Queensland Floods Commission of Inquiry, all aspects of land use planning and building requirements will be considered to minimise future infrastructure and property impacts from floods. The final report from the Inquiry is expected to be released in early 2012 and there will be a need to implement relevant recommendations from the Inquiry into land use plans, building standards and state planning instruments.

Review the sufficiency of 0.8m sea level rise based on the latest climate science

With more than 80 per cent of Queenslanders choosing to live on the coast, it is imperative to ensure those communities are resilient to the impacts of future sea level rise. The recently released *Queensland Coastal Plan* has set a benchmark for sea level rise of 0.8m by 2100.

However, recent scientific studies indicate that larger estimations than those currently projected cannot be excluded when ice sheet melt is taken into account[37]. There will be a need to review this sea level rise benchmark within the context of ongoing advances in internationally agreed science and to establish a nationally consistent sea level rise benchmark for planning in Australia.

Developing adaptation responses for high risk coastal areas

The Queensland Coastal Plan requires councils to prepare a coastal hazard adaptation strategy to help manage growth and build the resilience of existing urban areas projected to be at risk from coastal hazards over the next 100 years. Options for managing the risks associated with sea level rise include protect (coastal defences), accommodate (for example short term land use rights, expendable developments or flood tolerant building design), and retreat options.

However, each approach requires complex analysis and trade offs of local social, economic and environmental factors; an analysis of the cost and benefits of each option; and the optimal timing for action[38] in the context of constrained resources of many local councils. There is a need for the Queensland Government to work collaboratively with local governments to provide guidance on developing a coastal hazard adaptation stategy.

Torres Strait Islands

The Torres Strait Islands are particularly vulnerable to sea level rise from climate change. Every year, many Torres Strait Islander communities are inundated by high tides which flood houses, infrastructure and cultural sites. Even small increases in sea level will have immense impacts on Torres Strait communities, and large increases may result in some islands being completely inundated.

The Torres Strait Regional Authority's *Torres Strait Climate Change Strategy 2010-2013* identifies the need for upgrades to sea walls on specific islands to address immediate flooding issues; however, there are limited resources available to the region to protect against future sea level rise and related climate change impacts on Torres Strait Islander communities. There is a need to work with these vulnerable communities to determine a longer term strategy for managing risks associated with sea level rise.

Addressing barriers to adaptation

Considerable development and land use planning decisions occurred long before the risks of climate change were fully appreciated. Now that there is greater awareness of these risks, there is a need to find legal, social and market mechanisms which enable more resilient development.

There is a need to examine fair and feasible options to address issues associated with historic planning decisions and internationally recognised climate change science. For example, further investigation is needed into issues associated with the liability of stakeholders if they fail to take climate change impacts into account[39].

Increases in sea level may result in some Torres Strait islands becoming completely inundated

The potential for compensation claims against local government from changes to planning schemes or planning scheme policies that reduce the value of land may result in reluctance on the part of the local governments to implement adaptation strategies.

Options to achieve the implementation of adaptation strategies, while at the same time balancing land owner rights with the protection of local governments from potentially significant compensation claims, need to be examined.

Risk allocation mechanisms

With climate change projected to increase the intensity and frequency of extreme weather events, there is a need to better understand how climate change risks to the built environment are currently allocated and managed amongst governments, individuals, and businesses. Alternative risk management mechanisms such as compulsory disclosure of risks, developer monetary guarantees, buy-outs, redevelopment funds and prioritisation of infrastructure investments away from high hazard areas may be future options for addressing risks to settlements in Queensland.

Improving private insurance

There are also uncertainties associated with the ongoing effectiveness of market mechanisms, such as insurance, to deal with increased or more extreme weather events. Insurance is a mechanism to spread risks, but the 2010-11 natural disasters raised a range of issues associated with the adequacy and affordability of insurance cover for businesses and households. These issues are being examined by the Commonwealth Government's *Natural Disaster Insurance Review* which will examine possible new arrangements for flood insurance for homes, home content, strata title and other residential properties, and small business.

The scope of the review will also consider non-insurance and under-insurance, consumer understanding, flood risk measurement and mitigation and some aspects of government funding of natural disaster relief and recovery. A Queensland response to this national review will be needed to ensure that issues specific to Queensland policy holders and homeowners are effectively addressed within the context of the projected impacts of climate change on adequate insurance cover.

Planning a climate resilient settlement

The historical basis of town planning has often seen development in areas that we now understand are, or will become, vulnerable to sea level rise, storm surge and extreme weather events generated by our changing climate. So far we have moved a long way towards understanding the climate change science at a regional level and its implications for urban planning, building and design across the residential, commercial, infrastructure and industrial sectors. We also know that it is easier and more cost effective to plan now for climate change than to retrofit development in the future.

Local government planning schemes, under which development applications are assessed, play an important role in ensuring settlements are more resilient to climate change impacts through the use of development codes which consider location, design, layout and orientation to natural breezes and sun.

Also the Urban Land Development Authority works with local and State government, the community and the development industry to help deliver commercially viable developments that include diverse, affordable, sustainable housing, using best-practice urban design[40].

Adaptation planning is a continual process of adjustment to a changing climate. The consortium of stakeholders involved in developing new Urban Development Areas provides a prime opportunity at its planning phase to start to ensure development in the Urban Development Area is flood resilient and adapted to a warmer climate. For example by incorporating permeable and reflective surfaces into the development, capturing rainwater to adapt to more variable rainfall and incorporating green and blue space and shading to reduce heat island effects.

For further information see Appendix 2

Seeking your views

Have you considered any other issues for human settlements in the context of climate change adaptation, and what new initiatives could be considered for Queensland?

1. How can we better empower local communities to plan for, live with and manage climate change risks to human settlements?
2. What more can be done to ensure climate resilience is a key feature of our urban fabric?
3. What are the risks and risk factors that influence the capacity for stakeholders to develop or take up adaptation mechanisms on the ground?
4. What tools, strategies and mechanisms are needed to facilitate effective adaptation to climate change despite of and considering the uncertainties about the timing and extent of impacts?

5 Infrastructure

Key points

- Infrastructure such as transport, communications, energy, water, emergency services, schools, and hospitals, are vulnerable to the long term impacts of climate change.
- Potential impacts include disruption to transport, failure of urban drainage and sewerage systems, more frequent power blackouts and lost telecommunications, damage to buildings, pipes and wires and accelerated degradation of structures and materials.
- A systems approach, which prioritises adaptation for critical infrastructure, to adaptation measures is needed to minimise the chances of a cascade of infrastructure failures, particularly during and following extreme weather events.
- To maintain affordable service delivery, adaptation for infrastructure will need to be cost effective and innovative.
- Adaptation policy responses need to recognise that the drivers for decision making are different for operators of private versus public infrastructure.

5.1 Overview

Infrastructure includes essential physical structures that exist to support human settlements including transport, communications, energy, water, emergency services and social infrastructure (such as schools and hospitals).

The natural disasters that occurred throughout Queensland in the summer of 2010-11 highlight the vulnerability of infrastructure to extreme weather events which are projected to intensify with climate change. During this period, 27 per cent of the state controlled road network and 29 per cent of the Queensland Rail network was damaged by these disasters. Also, more than 478,000 homes and businesses lost power, and 103 water supply schemes, 83 sewage schemes and 411 schools were affected[41].

The vulnerability of infrastructure to climate change varies across the state and is dependent on multiple factors including its location, age, and design and building materials used.

Risks to individual infrastructure assets from climate change should not however be considered in isolation. Infrastructure is part of a whole system where infrastructure sectors are interconnected and reliant on each other to operate. Failure in one sector, such as energy supply, will impact the infrastructure system as a whole. This may result in a cascade of infrastructure failures, including transport, energy and communications infrastructure.

It is important that we work now to address the challenge of climate change impacts on infrastructure assets and systems so that cost effective and innovative ways to adapt can be identified, while maintaining an acceptable and affordable level of service delivery.

5.2 Climate risks

Infrastructure will be impacted by both the gradual long term impacts of climate change, including increased temperatures and sea level, and increases in the intensity of extreme weather events, such as cyclones, storm surge and extreme rainfall.

Increasing the resilience of infrastructure to these threats is an important part of minimising risks to the community and the economy.

Flooding

The projected increased occurrence of coastal, river and flash flooding events represents a major risk to infrastructure.

The damage bill from the 2010-11 natural disasters is estimated to be $6.8 billion[42], most of which is a result of damage caused by flooding. In addition, many community facilities such as pools, museums and sporting facilities were affected. For example, flooding in the basement of Suncorp Stadium damaged the main Stadium switchboard, the entire fire control system, and the telephone system[43].

More frequent extreme daily rainfall events are expected to affect the capacity and maintenance of stormwater, drainage and sewerage infrastructure[44] which could result in increased risk of sewer spills and overflows.

Cyclones

As Queensland's climate changes, cyclones are projected to intensify and occur further south.[45]

Impacts on transport, energy and communication infrastructure have occurred as a result of the wind, storm surge and intense rainfall associated with cyclones. These impacts can create flow-on effects for other services. For example, blackouts can affect the operation of trains, pumps, water treatment plants, hospitals and communication systems – while disruption to transport routes can affect the supply of additional generators, fuel or other essential supplies if the disruption lasts more than a few days.

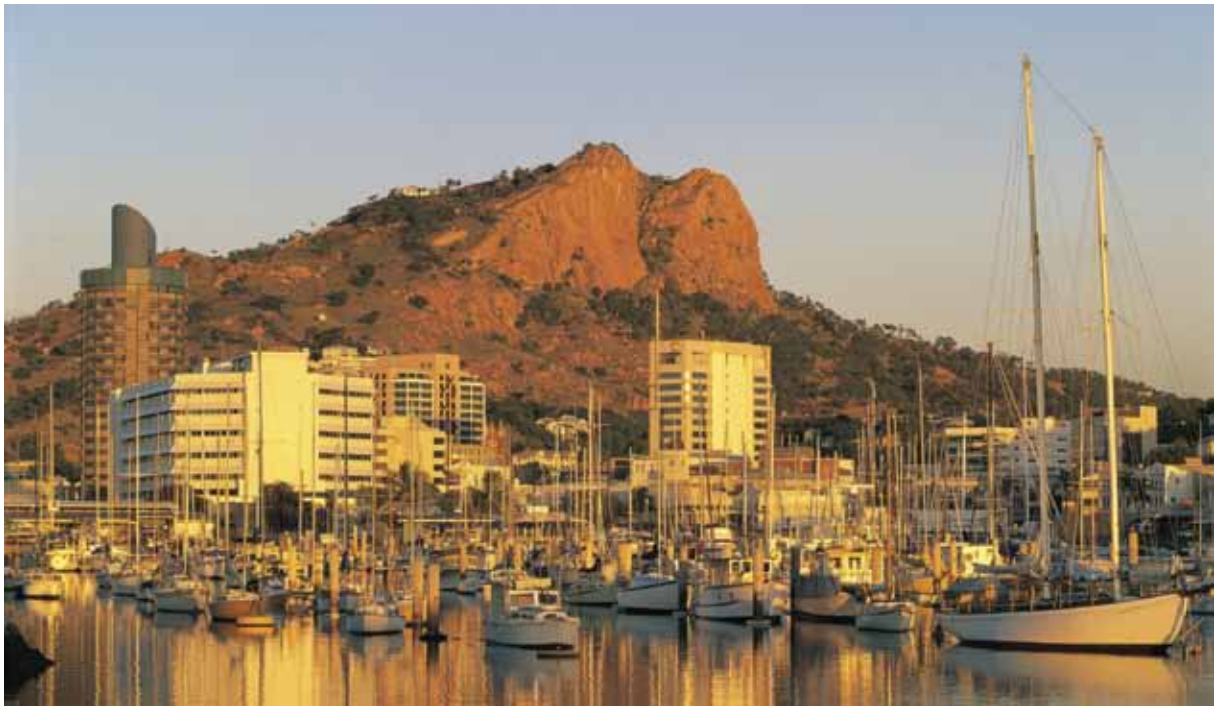
Sea level rise and storm surge

A large amount of infrastructure, including critical infrastructure, is located within the Queensland coastal zone to support coastal settlements. Sea level rise will increase the risk of this infrastructure to permanent inundation, coastal erosion, or increased occurrences of flooding from the sea. A recent report by the Commonwealth Department of Climate Change and Energy Efficiency indicates that of all Australian states, Queensland has the greatest value of road infrastructure potentially exposed to a sea level rise of 1.1m. This value is estimated to be between $9.7 and $12.9 billion[46].

Queensland has between $9.7 and $12.9 billion of road infrastructure potentially exposed to sea level rise

The report also identifies Queensland as having the greatest length and highest estimated replacement value of rail infrastructure potentially exposed to sea level rise[47].

Salt water intrusion into coastal drainage systems and increased corrosion will also result from sea level rise[48].



Increasing sea levels will also impact on ports and harbours. Greater penetration of wave energy into harbours can result from sea level rise and potentially cause navigation difficulties and damage to port infrastructure[49]. Airports located on low-lying coastal land are also vulnerable to sea level rise and associated coastal hazards.

Heat impacts

Energy infrastructure is expected to be impacted by extreme temperatures. This is because higher temperatures reduce transmission efficiency and increase demand in warmer months.[50]

The combination of variable rainfall, increased temperatures and increased evaporation will impact on soil moisture and could lead to greater ground movement which will place additional stress on road and bridge foundations and make them more vulnerable to extreme weather[51]. Additionally, these impacts can increase the risk of failure to sewers and pipes[52] and damage underground cables.

Reduced water availability can affect water and sewer supply infrastructure and electricity generation

Increased temperatures can lead to cracking of bitumen, which when compounded with increases in extreme rainfall events, will degrade road surfaces[53].

Similarly, more frequent and intense heatwaves will impact on transport infrastructure, as shown in Victoria in 2009 when rail tracks buckled during a heatwave[54].

Droughts

Long dry periods can put infrastructure at risk from bushfires and reduced water availability can affect water and sewer supply infrastructure and electricity generation.

5.3 Action so far

To assist in building climate resilient infrastructure, the Queensland Government has undertaken a variety of infrastructure adaptation actions. Primarily these actions have focussed on building the resilience of new government infrastructure.

Climate Change Impact Statements to assist government decision making

Since 2008, the Queensland Government has required that a Climate Change Impact Statements (CCIS) be prepared for all relevant Cabinet and Budget submissions. Along with an assessment of the greenhouse gas emissions associated with a project, the CCIS also helps decision-makers to evaluate the risks and responses to the project from projected climate change impacts.

Building it Back Better

The Queensland Reconstruction Authority (QRA) is working to ensure that as far as practicable, Queensland infrastructure is built back to be resilient to the risks of flood and storm surge associated with extreme weather events. For example, in July 2011, the Queensland Government launched a 20 year master plan for future upgrades to the Bruce Highway[55]. A key feature of the $2 billion State and Commonwealth funded infrastructure plan is for the Bruce Highway to become more reliable and more resilient to extreme wet weather events.

The QRA has also released two guidelines in the series planning for a stronger, more resilient North Queensland to support its 'building it back better' campaign as it applies to housing. They are: *Rebuilding in storm tide prone areas - Tully Heads and Hull Heads*, and the draft *Wind resistant housing*.

New Houghton Highway bridge

The new Houghton Highway bridge connecting Brisbane to Redcliffe has been designed to withstand the waves generated by storm surge and winds of a one-in-2000 year storm event. It is the first of its type in Australia, and among the first in the world. The new bridge is part of the broader $315 million Houghton Highway Duplication Project[56].

Assessment of coastal hazard impacts on the Queensland transport network

In partnership with the CSIRO, the Queensland Government is modelling sea level rise, storm surge and coastal flooding impacts on the Queensland transport network. The modelling will help prioritise work to reduce the vulnerability of key transport assets.

5.4 Rationale for further work

More climate resilient infrastructure will result in less community disruption and lower maintenance and repair costs. Adaptation responses will need to take account of service delivery requirements and the regulatory framework in which private infrastructure owners operate.

Risk assessment for government owned assets

The CCIS requirement for Government submissions has been valuable in raising awareness of the impacts of climate change across the Queensland Government. However, it is important that climate change is considered in the business case, design and implementation stages of all public infrastructure projects. For example, climate change

needs to be factored into transport planning at the network, area, and corridor level and in design standards for transport infrastructure so that essential transport corridors can remain open during extreme events.

Research indicates that climate change will increase the construction and operational costs of infrastructure[57]. Ensuring that infrastructure is built to be resilient to the impacts of climate change now will reduce the costs to taxpayers of recovering or rebuilding damaged infrastructure in the future.

Work is currently underway to assess the value of applying the CCIS process to the government's capital works program.

Ensuring that infrastructure is built to be resilient now will reduce the costs to taxpayers of rebuilding damaged infrastructure in the future

Identify critical infrastructure and interdependencies

In addition to climate change risks on individual infrastructure assets, a significant issue for infrastructure owners and operators is the risk of a systemic or cascade failure of the infrastructure system as a result of our changing climate.

Critical infrastructure in vulnerable areas and the interdependencies of that infrastructure with other services needs to be better understood. Steps to identify the vulnerability and interdependencies of critical infrastructure will need to be taken by both private and public infrastructure owners. This will also help minimise the impacts of more intense extreme events on critical infrastructure, and mitigate the flow on effects of any failure in the infrastructure system.

Collaborate with private owners and operators to assess risk and remove barriers

Climate change represents a major commercial risk, but may not currently be addressed by private infrastructure owners and operators for a range of reasons, such as a lack of understanding and the timeframes of impacts.

There is a need to bring together industry leaders and relevant experts to assist infrastructure owners and operators assess the risk of climate change to their own operations and to collaborate on measures to mitigate the risks of a cascade of failures during and immediately after extreme weather events. This will need to be done in consideration of service delivery and regulatory requirements on infrastructure providers, and be used to identify where barriers and opportunities for adaptation exist.

The need for risk assessment is not only important for privately owned infrastructure but also Government-owned corporations who operate infrastructure on behalf of the public.

Assess the effectiveness of flood mitigation infrastructure

Flooding of Condamine twice over the summer of 2010-11, and Roma three times between March 2010 and April 2011 highlights the need to investigate flood mitigation infrastructure in vulnerable areas of Queensland. However, such infrastructure may not always be the most appropriate response. Costs, geography and impacts on surrounding areas are just some matters that will need to be considered when assessing the suitability of flood mitigation infrastructure. As discussed in the Human Settlements chapter, other measures may also be appropriate, for example the voluntary relocation program proposed for Grantham.

Updating design criteria to incorporate climate change

Australian Rainfall and Runoff is the nationally accepted source of technical information in Australia for designing infrastructure to withstand the impacts of extreme rainfall, flooding and storm surge[58]. Australian Rainfall and Runoff does not presently include climate change considerations, but is currently being reviewed. An updated version of the document is expected to be available in 2014. Filling this information gap will be critical to provide adequate guidance to infrastructure owners and operators by allowing them to factor climate change into hazard risk assessments and therefore into their infrastructure design.

Updating the Road Planning and Design Manual to incorporate the latest climate change considerations presents another excellent opportunity to improve outcomes for the transport system. The Road Drainage Manual may also be updated to better incorporate climate change.

Research and development into new climate-resilient materials and design

Research could be conducted to comprehensively evaluate impacts of higher projected temperatures on the performance of pavement or bridges, and on options for using recycled materials in pavements that withstand climate impacts better, with a potentially reduced environmental footprint.

For further information see Appendix 3.

Seeking your views

Have you considered any other issues for human settlements in the context of climate change adaptation, and what new initiatives could be considered for Queensland?

1. How should the Queensland Government improve adaptation of infrastructure that is privately owned?
2. Where do you see vital connections between infrastructure sectors and systems that could lead to cascade failures if impacted by the climate risks identified above?
3. Do you have any other suggestions or ideas for protecting critical infrastructure in Queensland?

6 Ecosystems

Key points

- Queensland's biodiversity has an intrinsic value and provides ecosystem services which are fundamental to our wellbeing, quality of life and the ongoing strength of the state economy.
- Queensland faces potentially devastating biodiversity loss as a result of long-term changes in temperature and rainfall, the projected increase in the impact of intermittent extreme weather events, and the ongoing impact of non-climatic factors, such as habitat loss, pollution and invasive species.
- Even the most ambitious adaptation program is unlikely to prevent significant impacts on biodiversity hotspots, such as the Great Barrier Reef and the Wet Tropics, and effective mitigation is imperative if the worst impacts on biodiversity are to be avoided.
- The Queensland Government has employed a number of initiatives that will ultimately improve the ability of ecosystems to naturally adapt to change, including the expansion of the protected area estate, the protection of the Great Barrier Reef and a new draft biodiversity strategy.
- Although the general threat posed by climate change to Queensland's biodiversity is clear, much more needs to be understood about specific impacts on ecosystems and how they may respond. A more detailed understanding will help government better prioritise and target future adaptation actions.

6.1 Overview

Queensland is Australia's most naturally diverse state and is home to an outstanding diversity of terrestrial and marine ecosystems, from the well-known Wet Tropics and Fraser Island World Heritage rainforests, to the desert floodplains of the Channel Country, and the iconic Great Barrier Reef. Around 1350 ecosystems support 70 per cent of Australia's mammals, 80 per cent of its native birds and more than 50 per cent of its native reptiles, frogs and plant species. Around 45 per cent of all Queensland's plant species are found nowhere else on earth[59].

The value of this biodiversity – both its intrinsic natural value and the ecosystem services it provides – is fundamental to our wellbeing, quality of life and the ongoing strength of the state economy. Of Queensland's diverse ecosystems, some 222 are currently listed as endangered and 561 as vulnerable[60]. The Queensland Government recognises the immediate and long-term threat climate change poses to much of this natural value, and takes very seriously the task of addressing and minimising its impact.

6.2 Climate risks

Climate change is predicted to cause widespread decline in biodiversity, both as a direct result of climate-driven changes and through interactions with existing biodiversity stressors. The IPCC AR4 predicted that climate change will result in a significant loss of biodiversity in some ecologically rich sites by 2020, including the Great Barrier Reef and the Wet Tropics. In addition to biodiversity loss, climate change will drive significant changes within ecosystems and across the Queensland landscape.

Ecosystem change on a large scale is a real possibility

Changes in average environmental conditions

Biodiversity decline in Queensland's terrestrial and freshwater aquatic ecosystems will be driven by changes in average environmental conditions, including changes in temperature, rainfall patterns and levels of atmospheric carbon dioxide. Marine ecosystems will be affected by changes in water temperature, circulation patterns, water chemistry (for example, pH, salinity and/or nutrient supply), sea level, tropical cyclones and climatic anomalies such as ENSO events[61]. Ecosystems that occur in and around fresh or salt water systems will be affected by a combination of these changes, and other factors such as sea level rise.

A significant number of species will be at increased risk of extinction

For the majority of biological systems, changes in long-term average environmental conditions may affect individual organisms (physiology), timing of life cycles (phenology), population processes (birth and death rates), shifts and changes in distribution (dispersal and shifts in geographic range) and potential for adaptation (rapid evolutionary change).

Interactions with non-climate stressors

In addition to its direct impacts on ecosystems, climate change is expected to compound the impact of non-climate stressors on terrestrial, freshwater aquatic and marine ecosystems. Key non-climatic drivers of biodiversity decline in terrestrial ecosystems include land clearing, pollution and invasive species. Non-climate stressors in marine environments include degraded water quality, habitat loss and over-exploitation of marine resources.

Species loss and ecosystem changes

The unique responses of different species to climate change mean that many ecosystems and communities might change in ways that we currently cannot predict. It is quite clear that climate change will cause local extinctions in some areas and the establishment of new species from other areas, thereby changing community composition, species interactions and species distribution. As the ecological interactions and geographical range of species change, a significant number of species will be at increased risk of extinction[62] and a number of novel ecosystems will emerge.

All these impacts and changes ultimately diminish the resilience of affected ecosystems – that is, their ability to naturally adapt to change. The IPCC AR4 predicts that the resilience of many ecosystems is likely to be exceeded this century, resulting in major changes in the structure and function of ecosystems and potentially putting at risk the ecosystem services they provide.

The range of climate-driven risks to ecosystems is fairly well established, and it is broadly recognised that these risks are significant even if the average global temperature increase is limited to 2°C. However, development of appropriately targeted responses is contingent upon a better understanding of the likely extent of the various impacts, and the spatial and temporal extent of ecological impacts remains highly uncertain, both within and among the range of possible climate outcomes.

Extreme weather events

The impact of long-term ecosystem stressors is expected to be punctuated by increasing impacts of intermittent extreme weather events and natural hazards, such as heatwaves, droughts, fires, cyclones and floods. These periodic events can result in dramatic local effects on biodiversity, and might have a greater long-term impact on the structure and function of ecosystems than changes in average condition.

Queensland's tourism industry

Like many other industries, the tourism industry faces a range of threats from climate change including to key infrastructure. What sets the tourism industry apart, however, is its dependence on Queensland's natural environment. Of particular concern is the Great Barrier Reef, which contributes an estimated $5 billion to the State's economy and is already being affected by climate change. Other biodiversity hotspots, such as the Wet Tropics rainforests, are recognised as being especially vulnerable. Queensland's coastal attractions, such as the Gold and Sunshine coasts, will be threatened by sea-level rise and coastal erosion.

Effective adaptation for the tourism industry will require coordinated responses from the Queensland Government and tourism industry operators, but will particularly depend on efforts to protect Queensland's natural environment from the long-term impacts of climate change.

6.3 Action so far

Adaptation to the impacts of climate change on our natural environment essentially relies on our ability to improve the resilience of ecosystems to the changes that will inevitably occur. The Queensland Government has developed a number of strategies, policies and initiatives to improve the resilience of our natural environment to the future impacts of climate change.

Vegetation management reform

Major reform of Queensland's vegetation management legislation in 2004 phased out broad scale land clearing by the end of 2006, which had previously been identified as the most significant driver of terrestrial biodiversity loss in Queensland.[63] In addition to significantly reducing Queensland's greenhouse gas emissions, this reform laid the necessary foundations for further initiatives to build the resilience of Queensland's natural environment.

Expanding the protected area estate

The Queensland Government has committed to expand Queensland's national park estate to 7.5 per cent of the state's land area by 2020, and to expand the protected area estate to 20 million hectares. Funding is provided through the NatureAssist Program to support landholders in managing and protecting biodiversity in nature refuges, which are managed under conservation agreements and contribute to the expansion of the protected area estate. Conservation agreements entered under the Delbessie Agreement also provide benefits for rural leaseholders and promote sustainable management of rural leasehold land. Long-term protection of these areas that retain high biodiversity value will improve connectivity across the landscape, provide vital refugia for dislocated species and improve the resilience of ecosystems to climate change impacts.

Great Barrier Reef protection measures

The Queensland Government has worked cooperatively with the Commonwealth Government in developing the *Great Barrier Reef Water Quality Protection Plan 2009*, which outlines actions to minimise non-point source pollution (such as nutrients, pesticides and sediment) from broad scale land use and reduce the entry of those pollutants to the reef. The Queensland Government has also recently developed the *Draft State Planning Policy: Protecting Wetlands of High Ecological Significance in Great Barrier Reef Catchments* to protect freshwater wetlands of high ecological significance in the catchments of the reef, which are integral in slowing down and filtering run-off that may contain harmful nutrients and sediment.

Minimising existing stressors on ecosystems will be an important part of our adaptive response to climate change, and this is particularly the case in relation to marine ecosystems where more direct management and adaptation options are not available.[64]

Climate Change Corridors for Biodiversity

The *Climate Change Corridors for Biodiversity* initiative will target the protection and management of landscape corridors, by identifying areas of high potential biodiversity value and restoring vegetation. Protecting and managing biodiversity corridors will be critical to helping ecosystems and wildlife adjust and cope with climate change, and reconnecting fragmented ecosystems will help build resilience to climate change impacts. This initiative will help meet the goals of expanding the protected area estate.

Improved Fire Management in National Parks

Through the Improved Fire Management in National Parks initiative, the Queensland Government is investing an additional $6.5 million to enhance the planned burn program by incorporating climate change projections.

This initiative aims to better utilise one of the most valuable tools for managing fire-adapted ecosystems and habitats for threatened species. It will also identify ecosystems vulnerable to fire in hotter and drier conditions and implement appropriate burning regimes. Managing wildfire is important for reducing the risk to public safety and private property.

Building Nature's Resilience: A Draft Biodiversity Strategy for Queensland

Central to conservation management in Queensland is *Building Nature's Resilience: A Draft Biodiversity Strategy for Queensland*. The draft Biodiversity Strategy articulates Queensland's plan for conserving biodiversity, with a central focus on building the resilience of species, ecosystems and ecological processes.

While it recognises the general threat climate change poses to Queensland's ecosystems, it also identifies the need to develop a more comprehensive scientific understanding of the likely impacts of climate change on Queensland's biodiversity, as a basis for developing and prioritising actionable adaptation policies.

To this end, the Premier's Council on Climate Change is developing a working paper that will review the science on the likely impacts of climate change on biodiversity, ecosystems and landscapes across Queensland, and make recommendations to government based on its findings.

6.4 Rationale for further work

The Queensland Government's response to ecosystem adaptation can be enhanced by developing a better understanding of the impacts of climate change on our natural environment, ensuring land management practices incorporate the most current understanding of these impacts, and ensuring the economic risks and opportunities associated with climate change are fully recognised in government decision making. The Queensland Government's current and future work program can help ensure that spending from the Commonwealth Government's $946 million Biodiversity Fund in Queensland can be targeted to maximise adaptation outcomes.

Improved knowledge base for future initiatives

The draft Biodiversity Strategy highlights that further research is required into the impacts of climate change on Queensland biodiversity, to inform biodiversity management generally and to provide a sound basis for adaptive action. For example, it is widely accepted that expansion of protected biodiversity refugia and corridors will benefit biodiversity adaptation in general terms, but there is a need to better understand likely environmental changes that will affect the efficacy and viability of such initiatives in particular locations.

An improved understanding of climate change impacts at a finer scale will assist the selection and location of biodiversity refugia and corridors to optimise resilience and adaptation outcomes.

Adaptive management practices

Improved understanding of the impacts and ecosystem responses to climate change also has the potential to greatly enhance existing management practices, and help shift from the current paradigm of static ecosystem

management to the more dynamic approach that will be necessary in a changing climate. Adaptive management of biodiversity, as proposed by the draft Biodiversity Strategy, must involve continuous monitoring and adjustment of management practices to reflect and incorporate the most current and reliable information available on climate change impacts.

Ecosystem services risks and economic implications

Current understanding of the likely impacts suggests extensive species loss and ecosystem change on a large scale is a real possibility. In this light, future research should shift from a traditional focus on individual species and ecosystem impacts to better address the whole-of-landscape implications of climate change, as adaptation action at this scale must be considered. The threat that climate change poses to healthy natural landscapes should be better understood in terms of the ecosystem services and economic benefits they provide, such that these considerations can be better incorporated into whole-of-government decision making.

Harnessing carbon market investment to support ecosystem adaptation

The establishment of a national carbon market and the Commonwealth Government's Carbon Farming Initiative is likely to provide a significant future source of investment for reforestation, which if properly managed, represents a unique opportunity to restore biodiversity, build ecosystem resilience and provide a range of ecosystem services. A substantial body of work is underway to realise the potential co-benefits of ecosystem recovery and biosequestration initiatives. Mechanisms should be further developed to ensure that carbon forestry projects are located and designed to optimise ecosystem adaptation outcomes and are resilient to future climate change. This will ensure that funding available under the Commonwealth Government's $946 million Biodiversity Fund can be targeted for optimal adaptation outcomes in Queensland.

For further information see Appendix 4.

Seeking your views

Have you considered any other issues for ecosystems in the context of climate change adaptation, and what new initiatives could be considered for Queensland?

1. What key information gaps must be addressed to inform Queensland's response to climate change impacts on ecosystems and biodiversity?
2. Does the projected scale of climate change impacts on biodiversity warrant significant changes in biodiversity management, such as adopting a triage approach?
3. Should government be seeking to conserve existing ecosystems or manage for change?
4. In what ways might current land use and biodiversity management practices be modified and enhanced to address the need for increasingly dynamic and adaptive management of natural systems in a changing climate?
5. In light of inevitable species loss and ecosystem change, how might the Queensland Government prioritise the use of limited public resources and encourage private investment to protect the intrinsic and economic value of Queensland's biodiversity?
6. How might biodiversity outcomes of carbon sequestration projects be optimised?
7. What mechanisms might be employed to enhance or create markets for biodiversity, or to incentivise improved biodiversity management by private landholders?

7 Water Management

Key points

- Emerging from the longest drought in 100 years, Queenslanders have learned the essential nature of water resources.
- The Queensland Government has already invested heavily in water security policies and infrastructure in recent years, including the South East Queensland Water Grid, Regional Water Supply Strategies, water conservation measures, water recycling and desalination plants.
- Although climate change is projected to result in longer periods of drought in some areas, rainfall may also become more intense, with an increased risk of flooding. Both may place pressures on water resources and the environment.
- Successfully adapting to climate change may require us to conserve and manage water more efficiently.
- While the Queensland Government has made significant progress preparing Queensland's water supplies for the impacts of climate change, issues to be addressed include further diversification of water sources and dealing with post-flood community perceptions about water availability.

7.1 Overview

Water is a critical resource for any country. In Queensland, management of water resources is complicated by highly variable rainfall and stream flow, which can result in incidences of both severe droughts and floods.

The last decade provides a perfect example. South East Queensland suffered a severe drought from 2001 to 2008, which was soon followed in January 2011 by a very wet summer and extreme flooding. Flooding also occurred across various parts of Queensland in the wet seasons of 2007 to 2011.

Climate change is projected to exacerbate the issues associated with natural climate variability and the incidence of extreme events, which together with predicted increases in population growth over the coming decades will present significant additional challenges to the management of Queensland's water resources.

The recent and prolonged Millennium Drought highlighted the value of water resources across the wide range of sectors it affects, including residential, industry, agriculture and the environment.

As a result of the drought and its far reaching impacts, the Queensland Government invested billions of dollars into strategies to help sectors manage through periods of drought. Consequently, the state is better positioned now in terms of adapting to the future climate change impacts on water resources.

However, as more is learned about the likely impacts of climate change, and as the economy and population grows across the state, more needs to be done to secure Queensland's water supplies for the future.

Although climate change is projected to result in longer periods of drought, rainfall may also become more intense, with an increased risk of flooding.

Although climate change is projected to result in longer periods of drought, rainfall may also become more intense with an increased risk of flooding

7.2 Climate risks

The primary climate risk to water supply is the likely change in rainfall beyond Queensland's historical variability. Increasing temperature and evaporation under climate change has the potential to further exacerbate future water availability issues.

Rainfall

Climate change is expected to produce changes to rainfall distribution, frequency and intensity, which will impact on the quantity and distribution of water in Queensland's regions. Depending on the region, there is expected to be a decrease in annual mean rainfall of between 1 and 7 per cent.

Small reductions in rainfall can lead to much larger reductions in available water resources due to large declines in runoff through the influence of soil moisture and evaporation rates[65] which under future climate change can be amplified. For example, models predict that for a 1°C global warming (2030 relative to 1990), average annual runoff (river flows) could decline by up to 30 per cent for central and western parts of Queensland[66].

A general increase in drought frequency associated with global warming has been projected for Australia except for the western part of Australia[67]. Increases in drought frequency would have major implications for natural resource management, water security planning and water demand management strategies.

Although climate change is projected to result in longer periods of drought, rainfall may also become more intense, with an increased risk of flooding.

Temperature and evaporation

Higher temperatures will lead to increased evaporation from open water and soils, and result in increased agricultural and residential water demand. Higher temperatures can also decrease water quality (reduced oxygenation), potentially negatively impacting aquatic life. Extreme rainfall events can also negatively impact water quality and aquatic life through increased sediments, nutrients, and pathogens in waterways from runoff and sewer overflow.

7.3 Action so far

Queensland has instigated a wide variety of adaptation strategies for the water resource sector. They span the various components of water resource management, including water availability, water supply and associated infrastructure, water demand and water quality.

Water resource plans and operation plans

Water resource plans and resource operation plans cover almost all Queensland catchments and provide a structure for the allocation of water, while maintaining environmental flows. They also consider reducing water use through rainwater tanks and desalination plants. These plans also allow a water trading regime which allow water to be traded either for a season or permanently, providing a way for new industries or growing communities to access additional water supplies.

Regional Water Supply Strategies

Regional Water Supply Strategies are the Queensland Government's approach to ensuring short- and long-term water supply security on a regional basis. These strategies balance water demand and supply requirements and provide regional water supply solutions for the next 50 years. Strategies are being developed for all of Queensland, divided into six regions. Strategies for all coastal communities are in development, and the South East Queensland strategy has been released.

The *South East Queensland Water Strategy* consists of a number of key programs aimed at demand management, appropriate infrastructure investment and efficiencies gained through operation of the South East Queensland Water Grid.

South East Queensland Water Grid

The South East Queensland Water Grid is a $6.9 billion treated water supply network that integrates existing water sources with new climate resilient water supplies, such as desalination and purified recycled water. It connects water supplies, storages and treatment plants across SEQ from Noosa to Coolangatta and west to the Lockyer Valley through a network of treatment facilities and two-way pipes that allow the movement of treated drinking water from new and existing sources across the region.

While the network is necessary to ensure continuity of supply across SEQ region, and the System's Operating Plan requires an efficient and cost effective approach to minimise energy use, it still requires substantial energy consumption as a consequence of pumping and water treatment.

Major projects include:

- Gold Coast Desalination Plant at Tugun which can provide up to 133 megalitres[A] per day of fresh water to residents and businesses.
- Western Corridor Recycled Water Scheme which can provide up to 232 megalitres per day of purified recycled water to supplement dams when levels are low, maintaining security of supply. The project includes 208 kilometres of pipeline and three advanced water treatment plants. It also provides purified recycled water to Swanbank and Tarong North power stations.
- Water pipelines that connect to the water gird and provide two-way movement of water within SEQ.
- New water storage facilities including Wyaralong Dam, Bromelton Off-stream Storage and Cedar Grove Weir, which will together yield 26,000 megalitres of water per year into the SEQ Water Grid.
- Site studies have been conducted by the Queensland Water Commission to identify suitable locations for the potential construction of additional desalination plants.
- The Urban Water Security Research Alliance is a $50 million partnership over 5 years between the Queensland Government, CSIRO, Griffith University, and the University of Queensland to research SEQ's emerging urban water issues.

There has also been considerable investment in other areas of Queensland. For example, the state, through subsidies to local governments across Queensland, has provided funds to develop a large number of water sources such as a desalination plant in the town of 1770, a pipeline in Cloncurry, and water treatment and sewerage plants across Queensland.

Hydrological modelling and climate change

The Department of Environment and Resource Management's (DERM) Water Planning Sciences unit incorporates climate change projections into hydrological modelling of Queensland catchments to investigate climate impacts on rainfall, evaporation and stream flows for 2050 and 2070.

[A] 1 megalitre = 1 million litres

Water pressure reduction

Decreasing the pressure in water pipes reduces water loss, as well as minimising pipe bursts and power consumption. A three-year (2007-2010) project undertaken across 10 SEQ local government areas to reduce water pressure and locate leaks has met its target of achieving a collective saving of 60 megalitres of water per day.

Great Artesian Basin sustainability initiative

In western Queensland up to 95 per cent of water from bores tapping into the Great Artesian Basin was wasted through evaporation and seepage from uncontrolled open drainage channels used for stock watering. This resulted in decreasing water availability from this valuable resource over time. Queensland is funded through this initiative to cap and control bores in western Queensland.

Water Efficiency Management Plans

SEQ businesses that use more than 10 megalitres of water per year are required to complete a Water Efficiency Management Plan, and must reduce water use by a minimum of 25 per cent or best industry practice in line with regionally agreed water reductions. Outside SEQ, the plan is at the discretion of the water service provider.

Queensland Government Development Code

Water saving targets can be achieved through a range of approaches, including water efficient devices, effective utilisation of rainwater tanks, greywater treatment plants, dual reticulation and stormwater reuse. Queensland Development Code water savings targets are in place for new residential, commercial and industrial buildings.

Waterwise education program

This provides water efficiency and water cycle education for schools and service providers across Queensland. The DERM "Towards a Water Sensitive Future Handbook" sets out steps communities can take to be more water sensitive. This is aimed at helping people understand the value of water, ways to improve water quality and that using less water, more efficiently, does not compromise our life style – all ways to improve adaption to climate change.

7.4 Rationale for further work

As a result of recent major investments aimed at drought-proofing the state, Queensland is well-placed amongst Australia's states and territories to prepare for the impacts of climate change on water resources. However, the challenges of economic and population growth, shifting community attitudes, and issues raised by recent flooding mean there is need for ongoing work in this area.

Further diversification of water resources

Future rainfall is predicted to be more variable, with longer periods of drought between intense rainfall events. This makes it imperative that Queensland is able to utilise a diverse range of water resources to maximise water security in times of drought.

Queensland is well-placed amongst Australia's states and territories to prepare for the impacts of climate change on water resources

Our previous experience of little rainfall over a prolonged period focused attention on alternative sources of water such as desalination plants. With the recent heavy rainfall, it is now time to consider the best ways to maximise the capture and storage of rainfall when it occurs, particularly the use of stormwater and groundwater.

- **Stormwater:** Much of the rainfall that occurs over our cities and towns is not captured. Investment in improved capture and storage of this important water resource would provide many benefits[68]. Each year, the stormwater runoff experienced by cities is roughly equivalent to the amount they use for drinking, irrigation and industry[69]. Around half the volume of stormwater runoff could be used to bolster existing water supplies, with the remainder being used to maintain necessary environmental flows[70].

  Some Australian cities – for example Adelaide – have already invested in and prioritised stormwater recycling options as part of their broader stormwater management strategies[71]. The potential for stormwater recycling for urban and agricultural use in SEQ is currently being explored[72].

- **Groundwater:** 36 per cent of all water used in Queensland comes from underground water sources, but there is potential to increase this contribution through Managed Aquifer Recharge schemes. Managed Aquifer Recharge is the process of adding water to aquifers under controlled conditions for withdrawal at a later date. Managed Aquifer Recharge schemes in SEQ have the potential to provide economic, social and environmental benefits, such as storing excess water for later use, maintaining wetlands, increasing water availability for irrigation, preventing evaporation losses, and reducing infrastructure costs[73].Further research is necessary to determine the potential of Managed Aquifer Recharge schemes in SEQ, as some previously identified sites proved to be too shallow, too porous or too far from industries that would benefit from the stored water.
- **Recycled water:** The expanded use of water recycling, including greywater, could reduce the consumption of potable water in residential areas, as recycled water could be used for external watering or internal water uses where drinking water quality is not required. Greater use of recycled water could also enable less water to be held in dams without compromising water security, which may help reduce water releases during the next major flood. However, higher energy costs for delivering recycled water, and differing public attitudes to recycled water continue to act as barriers to expanding the application of recycled water.

Public perceptions of water availability and storage

The public responded very favourably to water conservation measures – such as the Target 140 campaign – during the recent drought, with daily consumption remaining low even when the drought had ended.

The Target 140 program saw significant changes in water-use behaviour for SEQ. The promotion and installation of more efficient appliances, for example shower heads and washing machines, helped individuals and households go beyond voluntary water targets and set water restriction levels.

Over the course of the drought, Queenslanders demonstrated their capacity to effectively respond to reduced water availability. It remains to be seen how the more recent wet conditions and easing of restrictions will influence people's water conservation commitment.

Additionally, due to the recent widespread flooding, people had to change their mindset relatively quickly from dealing with water deficit to water surplus. Similarly, the Queensland Floods Commission of Inquiry is considering issues associated with switching dam operations and perceptions from a water resource infrastructure in times of drought to a flood mitigation resource.

Minimising evaporation

It is vital that we retain as much water as possible and minimise that lost to the atmosphere. To overcome increased evaporation rates, we will need to employ strategies such as converting water supply channels to pipelines, covering small dams, or increased use of underground storage.

Managing population growth and climate change

Much of the recent Queensland Government investment (such as desalination plants and the SEQ Water Grid) has been aimed at maximising water security.

While desalinisation plants are energy intensive they may be required where traditional water sources are fully allocated or new supplies require long distance water transfers. Desalinated water may be most valuable at times when we need back-up; for example times of extreme drought or when other drinking water supplies may be unavailable, such as floods or during water quality events.

Current incentives for migration to regional areas and the mining sector mean population growth is expected in these areas, putting a greater stress on existing water resources which will be further exacerbated by decreased rainfall and runoff in the future. Therefore, it is imperative that water resource strategies for these regions meet the needs of both population growth and climate change.

Better integration across sectors

Adaptation strategies will need to ensure that water security is maintained across a variety of sectors, including agriculture, industry, business, residential and environmental. Additionally, better integration is required with ecosystem management strategies that aim to maintain water flows for riparian and wetland ecosystems.

Some of the necessary components for this to work effectively are already in place (for example Queensland's requirement for total water cycle management plans and research utilising sector integration by the Centre for Water Sensitive Cities)[74].

For further information see Appendix 5.

Greater use of recycled water could also enable less water to be held in dams without compromising water security

Seeking your views

Have you considered any other issues for water resourcing and management (including water infrastructure) in the context of climate change adaptation and what new initiatives could be considered for Queensland?

1. Are you aware of initiatives in relation to water sources in Queensland which should be highlighted?
2. How can we achieve better integration across sectors and/or across institutions on water management?
3. Is diversification of water supply resources the key to successful adaptation and, if so, what are the key resources and what new initiatives are required? Are you aware of initiatives in relation to water sources outside Queensland or internationally which should be highlighted?
4. What are the barriers to increasing use of recycled water?
5. What information do you need about how water can be used and managed sustainably?

8 Primary Industries

Key points

- The Primary Industries sector is a significant contributor to the economic and social wellbeing of Queensland and the nation.
- However, the sector is particularly vulnerable to a range of climate risks, particularly increased temperatures that will trigger decreased water availability, increased pest and weed incursions, and greater land degradation.
- Even small long term increases in temperature can lead to a decline in overall production from agriculture and forestry.
- The Queensland Government has already invested in a number of programmes including the $3.2 million ClimateQ initiative Helping Primary Producers Adapt to Climate Change, and the development of a climate risk management matrix to help industry sectors assess climate change risk, impact and adaptation potential for their sector.
- While these investments have focused on increasing the sectors' understanding about potential climate risks, this has translated into limited 'on-the-ground' adaptation actions.
- Feedback from the sector and recent studies indicate significant barriers exist to the uptake of adaptation actions beyond information provision.

8.1 Overview

Climate change poses challenges for all sectors of the Queensland economy but particularly those dependent on natural resources such as the primary sector. In some locations and for some industries these direct impacts will yield improved productivity and profitability, for others it will not.

Queensland's primary industries, industries associated with primary production, and the people they employ make a significant contribution to the state's economic, social and environmental well-being and directly employ about 84,900 people[75]. In 2009-10, primary industries contributed just over $14 billion to the Queensland economy with the gross value of production in the sector forecast to be close to this figure for 2010-11[76].

In Queensland, the beef and sugar industries comprise a large part of the primary industries sector, with fruit, vegetables and nuts also contributing a significant proportion, and the grain industry providing an essential input into the beef industry[77]. Horticulture contributes $3 billion to the Queensland economy every year and is very climate sensitive in terms of crop type and cultivars. Forestry and fisheries are also significant contributors, adding $171 million and $459 million respectively for 2009 to the state economy[78].

Over the past 200 years, Queensland agriculture has evolved within one of the world's most variable climates. Queensland farmers have developed highly adaptive land management systems in response to these varying climate regimes. However long-term climate change could increase this variability beyond the range considered normal and threaten the viability of some primary production systems.

Responding to climate change, through both adaptation and mitigation strategies, will create new challenges but may also bring opportunities for rural enterprises. For example, new opportunities are likely to arise from the introduction of the Commonwealth Government's Carbon Farming Initiative (CFI) where landholders will be able to generate tradable carbon credits from reducing or storing CO_2 in the landscape.

8.2 Climate risks

Primary industries are one of the most exposed sectors to the combined impacts of climate change and changes in global economic activity. While farmers have demonstrated resilience to previous droughts and climate extremes, the IPCC[79] warns that climate change impacts on agriculture in Australia will exceed its adaptive capacity and become vulnerable at 3°C of temperature increase. This has many implications for primary production patterns in Queensland.

Based on detailed regional projections undertaken by CSIRO and QCCCE, primary industry production is projected to decline by 2030 over much of eastern Australia due to increased drought, reduced water resources and higher temperatures.[80] The risks and impacts of climate change will differ across the state and across the primary sector[81], with some areas of Queensland experiencing positive impacts. Key changes and impacts based on those projections are outlined below.

Primary industries are one of the most exposed sectors to the combined impacts of climate change and changes in global economic activity

Changes in rainfall patterns

Changes in average rainfall or seasonal distribution of rainfall will directly affect primary producers. Lower rainfall averages projected over central and southern regions of Queensland will reduce irrigation water availability for the sugar cane, cotton and fruit and vegetable industries, leading to declines in production[82].

Changes to rainfall patterns are also expected to affect fisheries' productivity, leading to a range of positive and negative impacts. For example, changing rainfall patterns are likely to affect the abundance and breeding cycles of some northern fisheries species, while sea level rise will reduce mangrove and wetland habitat for fish and prawn species.

Higher temperatures, drier weather and more frequent droughts

Projected high temperatures, in conjunction with lower average rainfall, will decrease soil moisture. Impacts will vary across Queensland, but the south-east is projected to be particularly affected. Impacts would include poorer grain quality and disruption to the processes necessary to set some horticultural crops such as apples, plums, nectarines, peaches, grapes and pears.

Higher temperatures are also expected to cause increased heat stress in livestock, leading to higher rates of mortality – projections suggest this could be as high as a 34 per cent reduction in beef production by 2050[83].

Biosecurity risks such as invasive pest species and diseases are expected to increase and spread into new areas under a warmer climate. For example, the Queensland fruit fly and cattle tick infestations could move further south, leading to further reductions in production and ultimately farm profitability due to higher costs incurred to manage or control outbreaks.

Land degradation is likely to be exacerbated by both drier and wetter conditions. Changes to rates of evaporation and soil moisture will exacerbate land degradation caused by water logging, soil acidification and dryland salinity, while increased intensity of rainfall events will increase rates of erosion.

More frequent extreme weather events

Although average rainfall is expected to decrease in areas of Queensland, projected increases in the intensity of rainfall will likely lead to greater floods. Changes to the frequency or intensity of extreme events including flooding, cyclone or exceptionally hot years, could result in lower crop yields and stock losses.

For example, northern Queensland's banana crops are highly vulnerable to cyclones, and producers will need to adapt to any future change in cyclone patterns. In 2006, annual banana production fell to less than one-third of normal levels as a result of Cyclone Larry, and less than one-quarter of usual supply levels as a result of Cyclone Yasi in 2011[84].

Primary industry production is projected to decline by 2030 over much of eastern Australia due to increased drought, reduced water resources and higher temperatures

8.3 Action so far

The Queensland Government is committed to working with rural communities to ensure that the necessary resources and skills are available to prepare for greater climate variability. A number of actions have already been implemented and have primarily focussed on increasing the sectors' understanding about the impacts of climate change as well as building skills to manage those impacts. Key initiatives are outlined on the following pages.

Climate forecasting techniques and management tools

Forecasting techniques and management tools such as the regional-scale climate change projections developed by QCCCE, help producers to integrate climate information into their operations. This includes providing information on climate change and variability, the economic, social and environmental impacts and adaptation strategies. This has informed pilot projects in climate risk management and included the application of seasonal climate forecasting for water management, agriculture and health[85].

Climate risk management matrix

Also developed by QCCCE, the climate risk management matrix is a decision support tool to assess climate change risk, impact, and adaptation potential for the Queensland primary sector. A number of workshops have been held with the horticulture, grain, cotton and sugar, fisheries, aquaculture and game, intensive livestock, and beef and feedlot industries.

Extending the Rural Water Use Efficiency initiative

The Queensland Government has invested $6.5 million in a partnership with peak primary industry organisations to provide services to growers to improve water management practices. The initiative has delivered improvements in water use availability of 150,000 megalitres per year with an estimated productivity increase of $197 million.

Helping Primary Producers Adapt to Climate Change

Introduced in 2010, Helping Primary Producers Adapt to Climate Change is an investment of $3.2 million to provide information and tools to help primary producers in Queensland manage climate change risks and take advantage of emerging opportunities. This initiative covers several sub-projects including:

- assessing the vulnerability of major horticultural regions and commodities to climate change.
- identifying what productivity changes will mean for farm businesses, local communities and the Queensland economy.
- investigating how primary producers can manage risks from the physical and financial impacts of climate change, the economic impacts of these changes to enterprises and regional economies and analysis of the costs and benefits of different adaptation options.
- assessing the impacts of sea level rise on marine fish habitats including the development of a fish habitat vulnerability assessment.

The initiative includes stakeholder workshops on how best to manage and mitigate climate change risk.

Feedback from primary producers and surveys show that scientific information is often presented in a way that is too complex

Rationale for further work

Although living with and managing climate variability is an ongoing and everyday experience for landholders and the primary sector more broadly, a disconnect remains between 'policy on paper' and adaptation outcomes on the ground.

Engagement with primary producers through the HPPACC initiative, workshops and national research has indicated that despite the scientific evidence that climate change is happening, the level of acceptance of the need to act, and understanding of how to act, varies substantially amongst the sector and decision-making audiences.

The following section outlines a number of factors that either act to reduce the capacity of individuals (or the sector) to take action, or as barriers to respond appropriately as well as identifying potential future strategies to address these barriers

Improving communication on climate change

Science is the foundation of good policy development, however, feedback from primary producers and surveys show that scientific information is often presented in a way that is too complex, not relevant to the audience's specific circumstances, or delivered by an 'untrustworthy' source.

Using speakers who are trusted and respected within the relevant rural community is vital and could involve the use of local landholders as 'Regional Champions' for adaptation, re-investment in government funded sector-specific extension officers, or the establishment of joint public/industry funded extension services.

Information also needs to be provided in a manner that resonates with specific audiences and which graphically represents the localised climate risks and benefits.

Provide relevant information about localised impacts and opportunities

While effective communication is important, so is providing relevant information. Feedback is that while landholders generally find the 13 regional-scale climate change projections very useful in understanding the risks, information on the localised impacts and improved seasonal forecasting (relevant to sector groups by locality) would assist industry manage climate change impacts in the longer term.

Landholders have also noted they want a greater focus on the adaptation opportunities climate change may offer as well as the risks associated with those opportunities and how those risks can be managed. Better information on local impacts and opportunities could be integrated with sector Farm Management Systems and Industry Action Plans and would align well with the decision mapping needs of farm managers.

Consideration could be given to providing further information on actions that reap multiple benefits such as how to improve soil quality – for example increasing soil carbon – and the opportunities that will exist under the Commonwealth's CFI.

Although more difficult to model, further work is also required on the impacts to fisheries – such as the impact on fish nursery areas from cyclones, flooding and coastal surges – and aquaculture and adaptive options for this sector.

Re-invest in capacity building and support

Several recent studies have noted that a key barrier to landholders taking action is related to social and psychological factors, particularly the lack of support in stressful circumstances and how this reduces an individual's capacity to take action.[86]

A key issue here has been the reduction in funding to rural extension networks and how this has greatly reduced the capacity of the government to assist farmers adopt new research and develop, demonstrate and commercialise new technologies and practices in the field.

Further work is needed to better identify whether specific groups – such as those based on gender, age or financial capacity – require specific interventions or support in order to adopt new practices[87]. Support could be provided through:

- existing farm sustainability extension officers
- key local organisations such as industry bodies, mental health services, rural women's groups, or financial and insurance institutions
- technical working groups between government and key sector decision makers
- an extension of government provided training.

Productivity and risk along the value chain

A significant driver for early action is market forces, particularly maintaining market access for Australian products. It is expected that significant areas of currently unproductive land outside Australia will come into agricultural production under a warmer climate, for example Northern Europe, Russia and areas of North America[88]. Amongst other things, implications for Australia will be dependant on who buys their produce, price competitiveness and carbon foot printing.

To better understand these implications, a risk management approach would:

- identify areas vulnerable to climate change
- identify how geographic changes in world food production will impact on distribution, supplies for manufacturing and food processing
- support producers to diversify their income source via a range of products and production locations
- explore the distribution and location of food precincts and food processing to buffer against transport and other supply interruptions such as floods, drought, cyclones.

Maintaining a secure food supply in urban areas will be a challenge where rural production of food or distribution nodes is disrupted by natural events such as cyclones or flooding. The establishment of urban, urban vertical, and peri-urban gardens would help to address this risk.

Partnering with industry bodies and sector groups to develop industry sector plans and communicate the need for action throughout the value chain would help to prepare industries for future market access.

Cross-cutting adaptation responses

Primary industries have particularly strong links, interactions and potential synergies with other sectors, including terrestrial and freshwater biodiversity, human health, social, and economic themes. For example, a healthy ecosystem provides valuable productive services to primary producers such as pollination.

Equally, many non-climate change policy areas will be affected by changing climate conditions and will need to have the flexibility to incorporate changing circumstances. For example, areas identified under Queensland's *draft Strategic Cropping Land policy* may cease to be suitable food growing areas in the future.

Collaborative initiatives involving multiple sectors and policy areas will both increase the efficiency and productivity of research investment and also reduce the likelihood of maladaptations and perverse outcomes. Therefore actions in the primary

sector that address multiple issues, or provide multiple benefits should be prioritised. For example actions that:

- support Queensland's draft food policy and *draft Strategic Cropping Land policy* objectives
- promote land use practices with the most efficient water use and/or greatest water productivity
- provide habitat for native species via regeneration of regrowth forests or environmental plantings as strategic corridors
- provide the greatest opportunities to align with international market demands (e.g. carbon markets)
- provide support to landholders and local communities (e.g. drought policy)
- link with industry development strategies (e.g. National Agricultural Research, Development and Extension Strategy, National Drought Reform Policy).

Climate change may render existing activities unprofitable or new activities more profitable than existing ones

Preparing for structural change

Climate change may render existing activities unprofitable or new activities more profitable than existing ones. This means that the primary industries sector needs to be prepared for structural change.

Structural change is nothing new to Queensland's primary industries sector, which has adjusted to changes such as deregulation in the dairy industry, the introduction of beef import restrictions in the US and Japan, and the end of the wool floor price. However, it is highly likely that climate change will add further complexity to the current challenges of managing environmental and market risk.

Change can occur in two ways – either as unplanned and unaided as primary production activities become less viable due to the effects of regional climatic change, or, it may be more proactively pursued as primary producers see entrepreneurial opportunities arising from new markets or unfolding or projected climate conditions. Ensuring a strategic and planned approach will likely involve reframing business models or diversifying into completely different markets such as carbon sequestration.[89]

To improve decision-making in preparation for structural change, resources need to be invested in researching the regions, farming systems and downstream processes likely to be affected, as well as the likely success of alternative options.

For further information see Appendix 6.

Seeking your views

Have you considered any other issues for primary industries in the context of climate change adaptation, and what new initiatives could be considered for Queensland?

1. What would be the most effective and relevant way to present information on the risks and impacts of climate change to your sector and/or region?
2. Who would you trust and be willing to work with to assess the risks and identify opportunities for your business under changed climate conditions?
3. What type of support do you, your sector or industry need from the Queensland Government to help take action to ensure your business is able to respond (adapt) to changing climate conditions?
4. What would be the best approach to providing such support services, i.e. publicly, private or industry based, joint public-industry, or some other model?
5. What would you need to make deeper structural changes in how you undertake your business in the event existing types of agricultural production could not continue?
6. What may make such structural change difficult for you, or your sector?

9 Emergency Management

Key points

- Emergency management agencies are responsible for continual improvement in their preparedness for and response to extreme weather events. Recommendations from the Queensland Floods Commission of Inquiry will support this process.
- Climate change will result in increased frequency and intensity, and changes in the geographic pattern of natural disasters and extreme weather events.
- Over time, the main impact of climate change on the emergency management sector will be to increase overall pressure on emergency management resources.
- Effective adaptation through land use planning can help to mitigate the impact of natural disasters on the community, and relieve some of the excess pressure on emergency management resources.
- Measures which encourage greater personal and community responsibility in preparing for, responding to, and recovering from, extreme weather events can also help to relieve excess pressure on emergency management resources stemming from climate change.

9.1 Overview

In Queensland, emergency and disaster response is managed principally through the *Disaster Management Act 2003* and the Fire and Rescue Service Act 1990 and involves the Queensland government working in cooperation with volunteers and private agencies[90]. Effectively preparing for and recovering from a natural disaster involves contribution from elements of the whole community.

Climate change issues are not neatly separable from other issues facing the emergency management sector today. As a result, the Queensland Government maintains its process of continually improving Queensland's preparedness for and response to natural disasters and extreme weather events for all issues affecting the sector.

As a result of climate change, however, disaster events currently considered extreme may become more frequent and may occur simultaneously or in close succession, putting pressure on emergency management resources. Given that there are limits to government's ability to fund additional emergency management resources, alternative measures will be needed to relieve pressure on the system.

Under climate change, effective adaptation actions in other sectors can help relieve excess pressure on emergency management resources, such as land use planning decisions which minimise community exposure to natural hazard risks.

Disaster events currently considered extreme may become more frequent and may occur simultaneously or in close succession

For example, measures adopted in the reconstruction of Innisfail following Cyclone Larry in 2007 helped ensure that the town was relatively undamaged by Cyclone Yasi. The resilience of Innisfail during Yasi enabled emergency management resources to focus on preparedness and recovery in smaller surrounding townships such as Tully.

In addition to this, the Queensland Government is actively involved in local and national initiatives that are enabling climate change adaptation actions and enhancing the resilience of communities to the effects of natural disaster.

The National Strategy for Disaster Resilience (NSDR) is COAG's major initiative for increasing Australia's resilience to natural disasters. It promotes the responsibility of governments at all levels, individuals, communities, and the business and non-government sectors to work together to enhance Australia's capacity to withstand and recover from disasters.

The NSDR acknowledges that climate change effects will likely result in an increased frequency and severity of extreme weather events. It highlights, as a key role for governments, the need to develop and implement effective risk-based land use planning arrangements in the context of climate change, as a way of strengthening the nation's resilience to disasters.

Effective adaptation in other sectors can help relieve excess pressure on emergency management resources

Many of the actions under the NSDR will assist communities and individuals understand their hazard risk and understand what options are available to them to prepare for, respond to and recover from natural disasters.

This chapter discusses potential steps the Queensland Government can take to complement the NSDR to prepare for climate change

9.2 Climate risks

While flooding represents the greatest natural hazard risk in Queensland, the impact of other natural hazards such as tropical cyclones and storm surge, severe storms, bushfire and heatwave on communities also have emergency management implications[91].

Flood

Projected increases in rainfall intensity in some locations throughout Queensland is anticipated to result in a higher prevalence of flooding. In some areas this increases the risk of flooding in what were previously considered low risk areas. In addition, typically mid to higher risk flood areas may also experience more severe flooding. Such events are expected to place greater demand on emergency services and disaster management systems.

Cyclone and storm surge

The increased intensity of cyclones combined with higher sea levels could see a significant increase in coastal inundation from storm surges. In communities with a history of cyclones, there may be a need for additional emergency management resources. In addition, a potential southward shift in cyclones would expose communities that have limited experience of the effects of cyclone and storm surges, including densely populated areas in SEQ.

Heatwaves and bushfire

There is a projected increase in the number of days per year above 35°C throughout Queensland, with more dramatic increases expected to occur in inland areas and in dense urban areas (due to heat island effects). Prolonged periods of excessively hot days constitute a heat wave and will potentially increase demand for emergency services. Regions predicted to experience lower rainfall and increases in the consecutive number of days above 35°C also face an increased risk of bushfires.

Flooding represents the greatest natural hazard risk in Queensland

9.3 Action so far

In addition to supporting the ongoing operation of Queensland's key emergency management systems, the Queensland Government has taken a number of actions to increase the preparedness of communities for natural disasters and for the impacts of climate change.

ClimateSmart Adaptation 2007-12

Of the 62 actions implemented under ClimateSmart Adaptation Strategy, a number are focussed on improved disaster preparedness. The Department of Community Safety:

- conducts natural disaster summits annually in communities at risk
- develops and updates volunteer recruitment and retention initiatives under the Department of Community Safety's *Volunteer Management Strategy 2009-2013*
- undertakes planning processes with local government to quantify local SES requirements into the future.

Support our heroes

The Queensland Government is strengthening the response capacity of the SES and Rural Fire Service to respond to natural disasters and fires by providing $13 million over five years (commencing 2009-10) for additional equipment and resources such as vehicles, flood boats, and rural fire appliances.

Disaster preparedness in vulnerable communities

This five year $6.93 million program (commencing in 2009-10) is developing community awareness, and improving the capacity of individuals, families and businesses to contribute towards their own safety and wellbeing in the event of a natural disaster.

Bushfire community training package

This $4.6 million program over five years (commencing 2009-10) is developing and supporting a network of Volunteer Community Educators to deliver bushfire education and natural disaster community education to their local communities.

Disaster management warehouses and caches

In response to a heightened risk of natural disasters the Queensland Government has established a warehouse in south east Queensland and is establishing a warehouse in north Queensland to store stockpiles of emergency equipment. The Queensland Government is also further equipping existing disaster management caches in Cairns, Rockhampton, Toowoomba and Beenleigh.

Keeping our mob ClimateSafe

The Queensland Government is helping remote Indigenous communities prepare for the impacts of extreme weather events by providing training, resources and exercises in disaster management. Funding of $2 million over a three year period commencing in 2010 has been allocated.

Natural Disaster Resilience Program

The Commonwealth and State Government Natural Disaster Resilience Program is a disaster risk reduction and community resilience grants program which is jointly funded ($22 million Commonwealth and $22 million State funding) for four years, beginning in 2009-10. In order to obtain funding, applicants are required to demonstrate that the effects of climate change have been considered and where possible, propose strategies to adapt. In Queensland, the program's focus is to build community resilience to flooding, cyclones, severe storm, storm surge and bushfires.

Cyclone shelters

As a joint initiative with the emirate of Abu Dhabi, the Queensland Government will construct 10 new public cyclone shelters and multi-purpose facilities in north Queensland. The shelters will be designed and constructed to Category 5 standard and will each provide protection from winds up to 300km/h, wind-borne debris and storm tide inundation, for more than 500 people. The construction of these 10 additional cyclone shelters along the coast between Weipa and Yeppoon will bring the total number of Category 5 shelters in Queensland to 14.

Increased preparedness for extreme weather events

The Queensland Government has allocated $10.3 million in the 2011-12 State Budget to strengthen Queensland's disaster management and response capability in Brisbane and the regions. Ten staff will be employed at Emergency Management Queensland's State Disaster Coordination Centre to help enhance the coordination of information for natural disaster events.

A further seven staff will be employed across the state – one in each of Emergency Management Queensland's seven regions – to support the critical work of preparing for and recovering from disasters including overseeing recovery and planning and supporting local governments and other disaster response agencies[92].

9.4 Rationale for further work

Despite the Queensland Government's actions so far, and the launch of the NSDR, the damage inflicted by the disasters of 2010-11 highlight the importance of Queensland taking additional steps to improve the effectiveness of its emergency management systems.

The Queensland Floods Commission of Inquiry is currently considering the effectiveness of emergency management responses to the 2010-11 floods.

However, the Inquiry is not expected to address the central adaptation issue: how to minimise the additional pressure that climate change is likely to place on emergency management systems in the future, in an environment of finite government resources.

Beyond the important role for adaptation in land use planning and building design (which is addressed in the Human Settlements chapter) as a means of relieving pressure on emergency management, greater personal and community responsibility will be required.

NCCARF has prepared a *National Adaptation Research Plan for Emergency Management* which highlights the infancy of planning for climate change risks in Australia's emergency management sectors.

Effective emergency management requires seamless integration and coordination of responses between the private and public sectors and emergency management volunteers. Individual and community actions are also critical components of effective emergency management response and recovery.

The NSDR is based on this premise and through its associated Implementation Plan, jurisdictions are working together to facilitate whole of community contribution to strengthening Australia's resilience to the effects of natural disasters.

Implement recommendations from the Queensland Floods Commission of Inquiry

The Queensland Floods Commission of Inquiry will generate many recommendations with the intention to improve the state's preparedness for, and response to floods. The Inquiry will look at a range of issues including measures taken to inform the community about the flood risk, flood forecasting and early warning systems and the measures taken to protect life and property.

In order to be effective in the longer term, actions arising from the recommendations will need to take account of the changing nature of Queensland's climate. For example, suburbs at lower risk of flooding today could become high risk areas if land use planning decisions and building regulations do not consider climate change effects.

There is a need help communities become more self-reliant during extreme events

New models for community engagement and education

The value of government assistance to communities impacted by disasters is undeniable. However, with climate change and the potential for extreme events to increase in frequency and intensity, there is a need to help communities become more self-reliant during extreme events and throughout the recovery phase.

Programs and activities that advise people both individually and as community members about the actions they can take to be better prepared for extreme events are recommended. Effective programs will:

- incorporate plans to inform and assist vulnerable community members such as the aged, homeless, disabled and people for whom English is a second language
- encourage people to volunteer
- engage communities in discussion as to how they might coordinate community resources to increase resilience to effects of disaster events.

Innovative ways for embedding disaster resilience and emergency management preparedness and recovery across all sections of society should be actioned. Consideration could be given to using existing communication networks such as schools, health centres, community centres, sporting facilities, charities, businesses and government services (for example the ClimateSmart Home Service) to engage with people.

Awareness raising measures also need to be regularly updated to reduce complacency once the impacts of disasters are forgotten or new people move into vulnerable areas.

Central repository for flood and storm tide data

Local governments undertake flood studies and storm tide studies in accordance with guidance provided by State Planning Policies. Although this data is available for other users, there is no central repository for its easy access in times of need, for example when a flood warning is issued and the public wish to access flood maps to determine if their property will be affected.

An easily accessible and central database providing different levels of information for end users could be a useful communication and education tool to support whole of community involvement in managing extreme weather events.

Maintaining business continuity

Extreme events, such as the flooding that occurred over most of Queensland in 2010-11, closely followed by Tropical Cyclone Yasi and flooding events in parts of New South Wales and Victoria, demonstrates how emergency services can be stretched when multiple extreme events occur simultaneously or in close succession. Such events require all three levels of government to respond by providing extra resources during the event and to assist recovery afterwards.

For the future, public and private sector agencies, in collaboration with the not-for-profit sector, will need to demonstrate leadership to ensure business continuity through emergency events. This includes maintaining the operation of physical assets, business systems and supply chains and the availability of human resources[93].

Community indicators and markers of resilience

The NSDR highlights the characteristics of a disaster resilient community. Examples include communities that:

- understand local risks and those most vulnerable to the risks
- take proactive steps to anticipate and respond to disasters to protect themselves, others, assets and capital
- work together using their local knowledge, networks and resources
- work collaboratively with emergency services, local governments and other organisations before, during and after emergencies
- have resilient emergency management plans and a strong volunteer emergency management sector
- include continuity planning for businesses and service providers
- adopt land management and building codes that reduce risks to life and property, and
- have a system that achieves fast disaster recovery.

Building community resilience to disasters will be critical to the success of future emergency management. There is a need therefore to identify vulnerable communities to natural disasters, engage them in identifying locally specific indicators of resilience, and establish targets and actions to achieve these markers of resilience over time.

For further information see Appendix 7

Seeking your views

Have you considered any other issues for emergency management in the context of climate change adaptation, and what new initiatives could be considered for Queensland?

1. To what extent are adaptive and continuous improvement processes in existing emergency management systems sufficient to accommodate increasing risk and uncertainty from a changing climate?
2. How do agencies and systems prepare for the possibility of simultaneous and serial emergency events in Queensland, Australia and the region as a result of climate change, including for recovery efforts following the emergency phase?
3. What are the opportunities and responsibilities for the private sector, civil society and community members to take account of risk and uncertainty from a changing climate in their preparedness and response for emergencies?
4. To what extent are institutional and governance arrangements for emergency management covering local, regional, and state levels sufficient to accommodate increasing risk and uncertainty from a changing climate?

10 Human Health

Key points

- Climate change is unlikely to generate new health conditions or diseases, but is expected to vary the incidence, pattern, range and seasonality of illnesses and disease.
- Climate change poses direct threats to human health through changes in weather patterns and an increase in extreme events such as heatwaves, cyclones and flash flooding.
- There are also indirect threats to health steaming from the impact of climate change on social and economic systems.
- The Queensland Government not only provides health services, but also implements a wide range of programs across a number of agencies to protect the health of Queenslanders.
- The effectiveness of the Queensland Government's adaptation in the health sectors will be dependant on the ability of the states existing health care and protection systems to prepare and respond to increased pressure caused by climate change.
- Vulnerable members of the community, including the sick, elderly and low socio-economic members of the community, are more likely to suffer health impacts as a result of climate change.

10.1 Overview

As global warming continues to change our climate and alter natural systems, the way in which humans interact with the environment is predicted to come under increased stress. This presents a number of human health challenges, with the most significant being how to minimise any negative impact that future climate change will have on human health.

Current research indicates that climate change is unlikely to generate new health conditions or diseases. What is more probable is that existing health threats will manifest themselves at greater levels and in different ways. This will be driven primarily by alterations to the incidence, pattern, range and seasonality of extreme events, illnesses and disease[94].

The threats to human health posed by climate change can be categorised as either direct or indirect threats. Direct threats are extreme events such as heatwaves and flooding, which cause direct physical injury to humans. Indirect threats are more complex and occur through a chain of events where climatic influences alter ecological, biological and social systems, resulting in an adverse impact on human health. An example of an indirect threat is an increase in mental health issues with farmers due to failing crops caused by an increase in average temperatures.

The Queensland Government has a range of existing systems and regulations in place to protect human health. These include basic health services such as immunisation and communicable disease control, clinical services, aged care, as well as sector specific policy and regulations to prevent the development of health risks. These sectoral policies and regulations are outlined in Table 1 and address issues such as food safety, drinking water quality and mosquito breeding. Collectively, these systems aim to minimise the impact that both direct and indirect health threats have on the physical and mental well-being of Queenslanders.

The successful adaptation of human health in Queensland is dependant on the ability of existing clinical and health protection systems to cope with additional pressures caused by climate change[95]. In addition, effective adaptation in the sectors identified in Table 1 will assist to minimise the impact that climate change has on human health, as well as relieve pressure on current and future demand for health services. However, it is not yet clear how prepared these cross sectoral services are to deal with changes to the incidence and patterns of physical and mental health issues.

Table 1: Sectoral Policy and Regulations that protecting elements Human Health

Mechanism	Function	Ensures	Health Outcome
Queensland Health Infrastructure Program	Upgrading and developing health infrastructure	Better access to heath services	• more hospital beds • decrease in waiting times • increase in health service availability
Environmental Protection Act 1994	Regulates land, water and quality	Uncontaminated air and uncontaminated land waste management	Lower incidence of illness and disease caused by environmental hazards
Water Act 2000	Regulates water quality	Clean drinking water	Reduction in water-borne illnesses such as: • Ross River virus • Dengue Fever
Water (Safety and Reliability) Act 2008	Regulates: • water and sewerage services • recycled water • drinking water quality	Safe drinking water	Reduction in water-borne illnesses such as Gastroenteritis
Public Health Act 2005	Preventing, controlling and reducing risks to public health	Control of basic public health risks, for example: • vermin • drinking water standards • limits to mosquito breeding	Control of the spread of diseases such as • Dengue fever • Ross River virus • Gastrointestinal disease Control of disease risks such as mosquitoes and vermin
Food Act 2006	Regulates food production, processing and storage.	Safe food	Prevention of food-borne illnesses
Food Production Safety Act 2000	Regulates the production of primary produce	Primary produce (dairy, meat, fresh produce) is fit for human consumption.	Prevention of food-borne illnesses
Queensland Health Disaster Plan 2008	Provide and coordinate emergency health services	People have guidance and support during disasters	Reduction in injuries and loss of life during disasters

The health of some members of the community such as the sick, elderly and poor is more vulnerable to climate change. In addition, the health of some communities is more vulnerable to climate change. Supporting the most vulnerable people and communities to minimise the impact of climate change on their health and well-being will need to be a critical part of Queensland's future updated adaptation strategy.

Existing health threats will manifest themselves at greater levels and in different ways

10.2 Climate risks

Variability in weather patterns and an increased likelihood of extreme events are the key climate change risks to human health. As mentioned above, the direct threats to human health are the more obvious risks which result in physical or mental injury, however indirect health threats also pose a major risk to human health. The main alterations to weather patterns that threaten human health in Queensland are heatwaves, extreme events such as cyclones, flooding and storm surge, and changes in rainfall patterns.

Heatwaves

Heatwaves and extreme heat can present a significant risk to human health. The IPCC AR4 states that climate change is almost certain to increase the intensity and frequency of heatwaves[96].

Between 1994 and 2004, heatwave conditions were experienced in south east Queensland on two or more days every year. Dehydration and hyperthermia leading to shock, organ failure and death, are all risks that can result from heatwaves. In the event of a heatwave, it is the most vulnerable that are at greatest risk and for people aged 65 and over the mortality rate under these conditions increases by 15-17 per cent.[97] Brisbane's 2004 heatwave led to a loss of 75 lives.[98]

Extreme events and sea level rise

Under climate change, extreme events such as floods and storms are projected to increase in intensity and frequency.[99] Flooding is already a critical issue for many Queensland communities, and for northern Queenslanders. Cyclones also present a considerable threat to human health in Queensland, and are expected to increase in intensity as the climate continues to change.[100]

Over the summer of 2010-11, these disasters took a tremendous toll on the lives and health of many people across the state. Along with the loss of 35 lives, the physical injuries and psychological impacts experienced by people over this period was significant.

In early 2011, the Australian Medical Association Queensland presented survey results that indicated 72 per cent of Queensland residents had been impacted to some degree by a natural disaster in the preceding six months. Of those surveyed, 35 per cent were very concerned or extremely concerned about the mental health of family and friends after these disasters.

Communities such as those in the Torres Strait are becoming increasingly vulnerable to permanent land loss due to sea level rise. For Torres Strait Islanders – and many other Traditional Owner groups along the Queensland coast – sea level rise will significantly impact current social, cultural and economic practices, and heavily influence the health and well being of individuals and communities.[101]

Australian Medical Association Queensland survey results

24 per cent of Queensland residents were very concerned about the mental health of family and friends and a further 11 per cent were extremely concerned following the natural disasters of the past six months.

72 per cent of Queensland residents said they'd either been personally affected, had friends and family who'd been affected, or had been living in a community affected by a natural disaster in the past six months.

27 per cent of Queensland residents said although they were not directly affected they watched coverage of the disasters on television, listened to the radio and read about it in the newspaper. Only 5 per cent said it was easy to tell if someone was experiencing mental health difficulties.

Source: Australian Medical Association Queenland survey results, May 2011

Changes in rainfall

Heavy rains and floods can flush greater numbers of pathogens – for example Cryptosporidium and Giardia – down waterways and into our water supplies, raising the risk of disease outbreaks.

Combined with higher temperatures, heavy rains can also encourage algal blooms such as cyanobacteria, or blue-green algae as it is commonly known, which can potentially harm the liver or the central nervous system.[102]

Changes in rainfall are also expected to increase risks associated with vector-borne disease. Altered breeding patterns and distribution of mosquitoes through changed climate conditions will influence diseases such as dengue fever, Ross River fever, and malaria.[103] The emergence of new diseases may also appear where conditions are amenable.[104]

Decreased average rainfall leading to longer periods of drought in some regions may impact on the mental health of primary producers, for example, increased depression and suicide rates. Drought conditions will also contribute to an increase the salinity of water supplies.[105]

10.3 Action so far

Maintaining and improving the health of Queenslanders is a high priority for the Queensland Government. Managing the impact of climate change on human health is an important component in keeping Queenslanders healthy. In addition to the range of measures to protect human health outlined in Table 1, the Queensland Government has already begun to implement a number of initiatives to address health risks which are expected to worsen under climate change.

Queensland Heatwave Response Plan 2004

To ensure service providers are able to address the health risk posed by heatwaves, the Queensland Government developed the Queensland Heatwave Response Plan 2004. The Heatwave Response Plan provides a framework for delivering a coordinated response to extreme heat events.

Queensland Joint Strategic Framework for Mosquito Management 2010-2015

Each year in Queensland, there are more than 3000 cases of mosquito borne disease, with the most common being Ross River Virus, Barmah Forest Virus and dengue.[106] The Queensland Joint Strategic Framework for Mosquito Management 2010-2015 provides a strategic direction for the management of mosquitoes and mosquito-borne diseases in Queensland. Through its priorities the Framework recognises that climate change will impact on vectors of mosquito-borne disease and, as an objective, will increase the focus on climate change and its effect on mosquito management programs in Queensland.[107]

Counselling for flood affected people

Following the flash floods that occurred in January 2011, affected residents in Toowoomba and the Lockyer Valley have been provided with access to eight specialist counselling teams who have been deployed to the area to offer emotional support to residents. The teams are made up of specialist Queensland Government counsellors and counsellors from Lifeline.[108]

10.4 Rationale for further action

The Queensland Government already implements a wide range of programs across a number of agencies to protect the health of Queenslanders. However, the future effectiveness of this health system will depend on its ability to respond to climate change impacts.

The future effectiveness of this health system will depend on its ability to respond to climate change impacts

As the greatest direct risk from climate change, heatwaves should be the first priority for further action. The growing population in Queensland and the concentration of people in city areas will accentuate the risks associated with climate change due to heat island impacts and the easy spread of vector-borne diseases.

Heatwave early warning systems

The health impacts of heatwaves are considered, to some extent, to be avoidable by ensuring that those most vulnerable are effectively prepared.

Preparedness can be improved, for example, by developing a heatwave early warning system, based on thresholds informed by the latest health and climate change science. A warning system can enable those particularly vulnerable to heatwaves (for example, the sick, the elderly and the very young), and those that live in areas projected to be at greater risk of increased heatwaves (for example, inland and dense urban areas) be better protected against extended hot periods.

Targeted advice on preventative measures for heat

Early warning is not the only way of minimising the health impacts of heat – there are practical steps that can be taken to make residential dwellings cooler and less susceptible to extreme heat. Vulnerable members of the community could be helped to adapt their homes by linking in with existing community groups (such as Good Shepherd, Meals on Wheels, schools and other essential service providers). The Queensland Government's ClimateSmart Home Service also provides an opportunity for the provision of advice on practical preventative measures in people's homes.

Health protection services will need to be prepared to cope with the increased level of risks caused by climate change

Extreme event counselling

Recognising the tremendous pressures that extreme weather events such as floods, fires and droughts can have on individuals, there is a need to provide easy and affordable access to counselling services for those affected. The psychological impacts of extreme events – whether from abrupt incidents such as cyclones or from enduring periods of drought – may not be immediately evident and therefore community-based support is needed for the longer term. There is a need to consider how counselling assistance can be provided to Queenslanders, which is tailored to the particular needs of affected or at risk individuals and considers gender, age and cultural differences.

Better preparedness of health care and protection services

Better preparedness of the health system and emergency departments for extreme weather events such as heatwaves and floods will help the health sector adapt to the impacts of climate change. Health care services (such as doctor surgeries, child or elderly health centres, clinics and hospitals) provide a network of services that can assist in both preparing for and managing responses to extreme weather events. There is, therefore, a need to understand how this network can best be utilised and armed to deal with the health issues associated with a changing climate.

Health protection services will need to be prepared to cope with the increased level of risks caused by climate change. This includes responding to issues such as disease outbreaks from mosquito breeding, or health threats caused by damage to water or sewerage infrastructure.

Minimising health impacts through infrastructure protection

As identified in the Infrastructure chapter, there is a need to better understand climate change risks to critical infrastructure. Any such assessment will need to have regard to infrastructure that contribute to the protection of human health. An example of a potential climate change induced health issue from impacts to infrastructure include damage or overflow of sewerage infrastructure due to flooding.

For further information see Appendix 8.

Seeking your views

Have you considered any other issues relating to health in the context of climate change adaptation, and what new initiatives could be considered for Queensland?

1. What more can be done to reduce preventable disease, morbidity, and mortality in the event of extreme weather events for our most vulnerable members of the community?
2. How can we improve our current practices to ensure the vulnerable are better protected during heatwaves?
3. What do Aboriginal and Torres Strait Islander people feel is needed to improve individual and community health and well-being in the face of climate change impacts?
4. In what ways can we minimise the spread of disease in the event of climate change?
5. How can we improve our health care system and health protection services to better prepare for the impacts of climate change?

Next steps

Through the earlier *ClimateSmart Adaptation Plan 2007-12*, and more recently *ClimateQ*, the Queensland Government outlined strategies to better respond to climate change impacts. Since then, much of the work identified in these strategies has been implemented as part of core government business.

Given recent extreme flooding and cyclonic activity, and experiencing the repercussions of such disasters, it is timely that Queensland now reviews the current adaptation work program to ensure the state is in the best position possible to withstand future impacts.

This paper provides an opportunity for stakeholders to provide input and ideas on further programs and policy to support adaptation to the impacts of climate change. Comments will be used to shape the new programs under the updated adaptation strategy.

How can you get involved?

You can attend climate change adaptation seminar or provide feedback online or via post.

There are sector-specific questions posed throughout this paper but you don't have to limit your comments to these. You can also comment on other adaptation issues that you consider important.

Your feedback will help shape the development of an updated adaptation strategy for Queensland, which will build on the government's previous adaptation initiatives and complement mitigation actions under *ClimateQ*. It will include practical actions developed to help us adjust to the potential environmental, social and economic impacts of climate change. The adaptation strategy will be reviewed as necessary because adaptation will be an ongoing process.

Details on where and when stakeholder seminars are being held, along with an electronic copy of this discussion paper, can be found at: www.climatechange.qld.gov.au.

You have **until 20 October 2011** to lodge a submission through www.climatechange.qld.gov.au.

or via post to:

Adaptation consultation team
Office of Clmate Change
GPO Box 2454
Brisbane Qld 4001

Abbreviations

AR4	Intergovernmental Panel on Climate Chang Assessment Report 4
AR5	Intergovernmental Panel on Climate Chang Assessment Report 5
BoM	Bureau of Meteorology
CO2	Carbon dioxide
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GDP	Gross Domestic Product
GSP	Gross State Product
IPCC	Intergovernmental Panel on Climate Change
ML	megalitres
NCCARF	National Climate Change Adaptation Research Facility
NSDR	National Strategy for Disaster Resilience
PPM	Parts per million
QCCCE	Queensland Climate Change Centre of Excellence
SEQ	South east Queensland
SES	State Emergency Service

Glossary

Term	Description	Reference
Adaptation	Adjustment in natural or human systems in response to actual or expected climatic changes or their effects. Adaptation includes the actions of adjusting practices, processes, and capital responses to the actuality or threat of climate change. It refers to planned or autonomous adjustments in the system (natural, production, human) and can reduce harmful effects or exploit opportunities	Climate Q
Biodiversity	The variety of all life forms: the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form	Climate Q
Bleaching (of coral)	A process that occurs when the coral host expels its symbiotic zooxanthellae (microscopic algae that live in the coral's tissues and provide energy to the coral) in response to stress. Most commonly resulting from prolonged high water temperatures, but also from high light levels, sedimentation, pollutants and changes in salinity. The pigments of the zooxanthellae give corals much of their colour and when the zooxanthellae are expelled, the coral's white skeleton is visible through the transparent tissues of the coral, hence the term 'bleaching'.	What the Science is Telling Us
Carbon cycle	The term used to describe the movement of carbon in various forms (for example, as carbon dioxide or methane) through the atmosphere, ocean, plants, animals and soils.	Climate Q
Carbon footprint	A form of carbon calculation used to calculate the total amount of greenhouse emissions caused directly or indirectly by an individual, organisation, even or product. Direct emissions include the burning of fossil fuels for energy and transportation. Indirect emissions result from the lifecycle of products, which range from procuring raw materials to waste management. An individual, organisation's or country's carbon footprint is measured by undertaking a greenhouse gas emissions assessment.	Climate Q
Carbon sink	Part of the carbon cycle that store carbon in various forms	Climate Q
Climate	The atmospheric conditions over a long time interval, generally referring to the average state of the weather for a particular area.	
Climate change	A change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.	Climate Q
Climate variability	Climate variability refers to variations beyond the mean state of the climate on all scales of time and space beyond that of individual weather events.	Climate Q
Cost-benefit analysis	An analysis that compares present values of all benefits less those of related costs when benefits can be values in dollars the same way as costs. A cost-benefit analysis is preformed in order to select the alternative that maximises the benefits of a program.	Climate Q
Dryland salinity	Where water balance has been altered due to changing land use (for example clearing of native vegetation for broad acre farming or grazing), excess water entering the watertable mobilises salt which then rises to the land surface. Movement of water drives salinisation processes and may move the stored salt towards the soil surface or into surface water bodies.	Climate Q
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.	Climate Q

Term	Description	Reference
El Niño – Southern Oscillation (ENSO)	This refers to the widespread year-to-year oscillations in atmospheric pressure, ocean temperatures and rainfall associated with El Niño (warming of the oceans in the equatorial eastern and central Pacific) and its opposite La Niña. During the El Niño phase parts of Australia may experience drought while during La Niña more tropical cyclones around Australia may be generated.	Climate Q
Evapotranspiration	Water loss from the combined effects of evaporation from the soil and surface water bodies and transpiration from vegetation.	
Evaporation	Water loss from soils and and surface water bodies	
Extreme weather event	Extreme weather event – an infrequent weather event, at the high or low end of the range of values for a particular variable.	
Global warming	An increase in global average surface temperatures due to natural or anthropogenic climate change.	What the Science is Telling Us
Greenhouse gas	Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases covered by the Kyoto Protocol include carbon dioxide, nitrous oxide, methane, sulphur hexafluoride, perflurocarbons and hydroflurocarbons.	Climate Q
Gross Domestic Product (GDP)	The total market value of all goods and services produced in a country in 1 year. GDP is a key measure of the value of all economic production in the economy. It does not include income from overseas investments and earnings.	Climate Q
Gross State Product (GSP)	The total market value of all goods and services produced in the state economy in 1 year.	Climate Q
Impacts (of climate change)	The effects of climatechange on natural, productive and human systems	Climate Q
Intergovernmental Panel on Climate Change	A United Nations scientific body that provides the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.	Climate Q
La Niña	The extensive cooling of the central and eastern Pacific Ocean. It is the convention al meteorological label for the opposite of El Niño. In Australia (particularly eastern Australia), La Niña events are associated with increased probability of wetter conditions.	Climate Q
Mitigation	A reduction in the source of, or enhancement of the sinks for, greenhouse gases.	Climate Q
Natural disaster	A natural disaster occurs when a natural hazard has an impact on a human population, infrastructure and/or economic assets and is beyond the day-to-day capacity of the prescribed statutory authorities, requiring mobilisation and organisation of resources other than those normally available to those authorities.	
Natural hazard	A natural hazard is a geological, meteorological, hydrological, volcanic or seismic phenomenon, or other process in the natural environment which has potential to cause loss; cause harm to people; or damage property or the environment.	
Ocean Acidification	Increased uptake of atmospheric CO_2 emissions by the oceans changes the seawater chemistry, increasing the seawater's pH (increasing acidity) and reducing the concentration of carbonate ions, which are utilised by many marine organisms to form their shells and skeletons.	What the Science is Telling Us
Sequestration	Removal of carbon from the atmosphere by, and storage in, terrestrial or marine reservoirs.	Climate Q
Sink	See carbon sink.	Climate Q
Stabilise	In the climate change context means keeping constant the atmospheric concentrations of one or more greenhouse gases (such as carbon dioxide).	Climate Q

Term	Description	Reference
Storm surge	A temporary increase, at a particular location, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). A storm surge is the excess above the level expected from the tidal variation alone at hat time and place.	Climate Q
Storm tide	The absolute combined mean water level reached when storm surge is combined with the normal astronomical tide variation and the wave contribution at the coast. It is the storm tide level which must be accurately predicted to determine the extent of coastal inundation.	What the Science is Telling Us
Tipping point	A specific threshold point or unstable state where the response of a climate effect or perturbation can be sudden, severe and have long-term consequences for the climate system.	What the Science is Telling Us
Transformational change	Change that is not usually part of routine action that requires significant changes of practice. Transformational adaptation may be required in cases of extreme or high vulnerability.	Climate Q
United Nations Framework Convention on Climate Change	The United Nations Framework Convention on Climate Change is the primary forum for negotiating a global agreement on how the world should deal with climate change.	Climate Q
Vulnerability	Vulnerability to climate change reflects situations where components of a natural, human or production system are (1) likely to be more highly exposed to climate change; (2) relatively sensitive to adverse climate change; and (3) have adaptive mechanisms that are either ineffective or unlikely to be applied at the necessary scale.	Climate Q
Weather	The state of the atmosphere at a particular place, at a particular time	What the Science is Telling Us

* Definitions are taken from the Garnaut Climate Change Review and IPCC wherever possible.

Further information

Appendix 1: Science

Australian Government, and State and Territory Government Initiatives	• Australian Climate Change Science Program covers a broad range of climate change science research activities with an aim to improve our understanding of the causes, nature, timing and consequences of climate change. The program is administered by the Department of Climate Change and Energy Efficiency and conducted in partnership with CSIRO, the Bureau of Meteorology and leading Universities. http://www.climatechange.gov.au/government/initiatives/accsp.aspx • The Australian Antarctic Division leading Australia's Antarctic program is working on understanding the role of Antarctica in the global climate system. http://www.antarctica.gov.au/ • The Centre for Australian Weather and Climate Research is a partnership between Australia's leading atmospheric and oceanographic research agencies, the Bureau of Meteorology and CSIRO. The Centre undertakes weather, climate and oceans research. The objectives of CAWCR are to lead the Australian science community in the development of a world-competitive coupled climate and earth system simulator and modelling system, to transform current observational science into a comprehensive, integrated information system and to advance scientific knowledge of the major drivers of Australia's water cycle and their predictability. http://www.cawcr.gov.au/ • Geoscience Australia is a world leader in providing first class geoscientific information, which includes providing key spatial information on Australia with an emphasis on response to rapid and slow onset hazards, the detection of change, emergency management requirements, natural risk assessment and marine zone management. http://www.ga.gov.au/ • CSIRO Marine and Atmospheric Research (CMAR) aims to advance Australian atmospheric, climate, marine, and earth systems science. http://www.cmar.csiro.au/ • ARC Centre of Excellence for Climate System Science focuses on process-level climate system science –this includes the mathematics, physics, and biology of the climate system, integrated via information technology. http://www.climatescience.org.au/index.html • The Australian Academy of Science objectives are to promote science through a range of activities and education and public awareness. http://www.science.org.au/ • The Bureau of Meteorology (BoM) is Australia's national weather, climate and water agency. It provides regular forecasts, warnings, monitoring and advice spanning the Australian region and Antarctic territory, the Bureau provides one of the most fundamental and widely used services of government. http://www.bom.gov.au/ • CSIRO Climate Adaptation Flagship is conducting research to help Australia address the challenges in adapting to climate change by providing the scientific basis to support sound adaptation decisions. Adaptation Research Initiative. http://www.csiro.au/org/ClimateAdaptationFlagship.html • Integrated Marine Observing System (IMOS) provides equipment and data-information services which collectively contribute to meeting the needs of marine and climate research in Australia . http://www.imos.org.au/ • CSIRO Marine National Facility takes observations of the ocean around Australia and undertakes process studies central to increasing our understanding of the ocean's roles in climate variability and climate change. http://www.marine.csiro.au/nationalfacility/application/index.htm • The Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC) is a partnership dedicated to the study of atmospheric, cryospheric and oceanic processes of the Southern Ocean, their role in global and regional climate change, and their impact on sustainable management of Antarctic marine ecosystems. The ACE CRC's Sea Level Rise program estimates sea level rise this century, including increases in storm surges for coastal areas in Australia and its neighbours. http://www.acecrc.org.au/

Australian Government, and State and Territory Government Initiatives	• The Pacific Climate Change Science Program (PCCSP) is Australian Government's commitment through the International Climate Change Adaptation Initiative to meet high priority climate change research needs that will inform adaptation in vulnerable countries in the Asia-Pacific region. http://www.cawcr.gov.au/projects/PCCSP/South Eastern Australian Climate Initiative (SEACI)-Phase 2 is a three year, $9 million research program investigating the causes and impacts of climate change and climate variability across south-eastern Australia. Phase 2 of SEACI2 is a partnership between CSIRO, the DCCEE, the Murray–Darling Basin Authority, the Bureau of Meteorology, and the Victorian Department of Sustainability and Environment. The current SEACI2 program follows Phase 1 which concluded in 2009. • Indian Ocean Climate Initiative (IOCI) is a research partnership between the Western Australia State Government, CSIRO and the Bureau of Meteorology. IOCI investigates the causes of the changing climate in WA and develops projections of the future climate in WA. IOCI formally began its Stage 1 program in January 1998; Stage 3 commenced in 2008. http://www.ioci.org.au/ • The South east Queensland Climate Adaptation Research Initiative (SEQ-CARI) is a three-year, $14 million research project being conducted by CSIRO, Griffith University, the University of the Sunshine Coast and the University of Queensland. The group examines how climate change is likely to impact on people living and working in urban and rural areas, agriculture, energy demands and energy supply, forestry and marine industries, and coastal and inland ecosystems. http://www.csiro.au/partnerships/seqcari.html • Monash Weather and Climate uses expertise in mathematical, geographical and environmental sciences to conduct research in predicting the weather and climate over timescales from days to weeks to months to years and centuries ahead. The group is broken up into the following research areas: climate science, micrometeorology, numerical modelling, tropical meteorology and dynamical meteorology. http://www.monash.edu.au/research/climate/ • Universities across Australia have dedicated research units looking at various areas of climate change science covering, the land, oceans and atmosphere. For example the UNSW Climate Change Research Centre (CCRC) houses research expertise in key areas focussing on the earth's climate: atmospheric, oceanic and terrestrial processes http://www.ccrc.unsw.edu.au/
International Science Initiatives	• U.S. National Oceanic and Atmospheric Administration (NOAA) is a government run agency that provides daily weather forecasts, severe storm warnings and climate monitoring/research. (NOAA) http://www.climate.gov/#climateWatch/images • National Centre for Atmospheric Research (NCAR) is devoted to service, research and education in the atmospheric and related sciences. NCAR aims to understand the behaviour of the atmosphere and related physical, biological and social systems. http://ncar.ucar.edu/labs-observatory • National Aeronautics and Space Administration: Goddard Institute for Space Studies encompasses a broad study of global change, addressing natural and man-made changes in our environment that occur on various time scales, from one-time forcings such as volcanic explosions, to seasonal and annual effects such as El Niño, and on up to the millennia of ice ages. http://www.giss.nasa.gov/ • Met Office Hadley Centre aims are to understand physical, chemical and biological processes within the climate system and develop computer models of the climate which represent them. The Met office monitors global and national climate variability and change. http://www.metoffice.gov.uk/climate-change/resources/hadley • Walker Institute for Climate Research has a focus on the fundamental processes that govern the climate system and how it changes. The Institute conducts research on predictions of climate on a range of timescales, this includes the development better climate models to explore weather and climate extremes. http://www.walker-institute.ac.uk/index.htm

Appendix 2: Human Settlements

Australian Government, and State and Territory Government Initiatives	**Cyclones and building standards**	• A national review is being undertaken of the mapping of current cyclonic regions and building standards that apply within those regions. Tis review has been specifically undertaken to help ensure building standards are adapted to account for the likely impacts of climate change. • The Australian Building Codes Board has conducted a National Regulation Impact Statement on proposed changes to cyclone regions and building standards and has commissioned James Cook University's Cyclone Testing Station to undertake a study of the impacts of Cyclone Yasi on buildings in North Queensland and develop recommendations for further improvement of community resilience to future cyclonic events. • The Queensland Reconstruction Authority is preparing a series of guidelines – *Planning for a stronger, more resilient North Queensland* – to help North Queensland residents rebuild and repair their homes following Cyclone Yasi. Part 1 in the series Rebuilding in storm tide prone areas - *Tully Heads and Hull Heads* was released on 15 July 2011. The draft Part 2, Wind resistant housing, was also released on the same date for public comment.
	Transferable development rights	• Transferable development rights compensate land owners for land restricted by regulation by providing an alternative site or providing additional development rights on non- regulated land as an alternative to a buy back scheme. Transferrable development rights schemes in New South Wales include the Wellington shire Council concessional rural allotment policy and the Gosford City Council coastal land acquisition policy[109].
	Land Swap	• A master plan which will provide an alternative site for the 2011 flood affected residents of the Lockyer Valley Regional Council has been developed as part of a land swap arrangement. The plan identifies residential blocks outside the 2011 flood zone for a voluntary land swap on a like-for-like basis. The master plan will also deliver sites for a new community hall, market place and showgrounds, provide essential services to the new residential blocks and provide for new parklands. Flood devastated land will be retained as memorial gardens, agricultural land and potential commercial use. Grantham Master Plan Factsheet – Lockyer Valley Regional Council www.lockyervalley.qld.gov.au
	National Urban Policies	• The Commonwealth Government has released a number of reports relating to land use planning which has implications for Australia's adaptation policy framework. These include recent reports on a sustainable population, sustainable urban policy and the Productivity Commission Report on planning, zoning and development assessment[110]. The Productivity Commission report recognises adapting to climate change and ensuring adequate energy and water supplies are key issues confronting planners and that the planning, zoning and development assessment systems are able to positively influence challenges associated with climate change adaptation.
	Coastal Risk disclosure	• Risk disclosure: In New South Wales councils are able to include a notation on section 149 planning certificates advising land purchasers that the land has been identified as being affected by projected sea level rise of 40cm by 2050 and 90cm by 2100.[111]
	Coastal adaptation strategy	• The Commonwealth Government commissioned a cost benefit analysis of adaptation options for increasing flood risks associated with climate change to settlements on Narrabeen Lagoon New South Wales[112]. The report identified possible adaptation options (such as widening the lagoon entrance, levees, floodgates, warning systems and planning controls) as well as optimal timeframes for implementation.
	Integrated climate change adaptation	• South East Queensland Climate Adaptation Research Initiative - An integrated multi-sectoral study of climate change adaptation options for human settlements in SEQ is being undertaken as part of the 3 year South East Queensland Climate Adaptation Research Initiative. The project will develop and test adaptation options to address climate change risks to settlements in SEQ.
	Building design for heat impacts	• Queensland University of Technology in conjunction with State and local government has developed a subtropical design handbook that outlines design measures for building homes suitable for a sub-tropical climate. Focusing on South East Queensland, it provides guidance on making the most of topographic features and natural drainage processes in determining the optimal pattern of development and design features suitable for a warm climate including shelter and shade, indoor/outdoor living spaces, roof overhangs, hoods on windows and building orientation for sunlight and breezes.

International Adaptation Initiatives	**Floodplain Retreat option**	• Waitakakere City Council, New Zealand – successful implementation of managed retreat from over 80 houses facing increasing risk from flooding[113].
	Soft infrastructure coastal defence options	• Planting and protecting mangroves is being used as a mechanism to protect against cyclones and flooding events in Bangladesh and Vietnam [114]. • Creating artificial sand dunes, rehabilitating existing dunes and buy-back of undeveloped land as a shoreline buffer are approaches used in Avalon, New Jersey, USA to protect low-lying houses and roads from coastal flooding and climate change[115]. • Managed realignment – using land as a place to store floodwater by allowing drained farmland to return to salt marsh, lagoons and mudflats is an adaptation response to rising sea levels and increased storm surges used in Hasketh Out Marsh in the United Kingdom[116]. • East Riding (Yorkshire, UK) has a rollback program for caravan sites and has developed guidelines, standards and policies for re-locating caravan parks inland away from the eroding coastline[117].
	Heat island and flood reduction policies	• The City of Chicago used satellite maps to identify heat island hot spots in the city and has planted over 500,000 trees and introduced reflective roof standards to reduce its impacts. The city's Green Urban Design Plan also manages flooding through projects that use permeable pavements and rooftop gardens[118].
	Integrated climate change adaptation	• The North-West Europe Future Cities project aims at making city regions fit to cope with projected climate change impacts. It combines green structures, water systems and energy efficiency to transform existing urban structures to adapt to climate change [119].

Appendix 3: Infrastructure

Australian Government, and State and Territory Government Initiatives	**Priority research plans**	**National Adaptation Research Plan: Settlements and Infrastructure** A National Climate Change Adaptation Research Plan for Settlements and Infrastructure has been developed to identify critical gaps in the information available to address the full range of issues arising from the potential impacts of climate change on settlements and infrastructure. The Plan sets out the priority research agenda for 5-7 years to inform a better understanding of climate change risks and impacts on settlements and infrastructure and how these risks can be managed and impacts reduced through planned adaptation interventions (http://www.nccarf.edu.au/sites/default/files/NARP%20S&I%20Summary%20G.pdf).
	Design handbook Rainfall and flooding	**Update Australian Rainfall and Runoff handbook** The Commonwealth Government is funding an update to the Australian Rainfall and Runoff handbook to ensure that all future construction takes into account future changes to heavy rainfall and flooding events. The update will be completed in three stages over four years. (House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts, Managing our coastal zone in a changing climate, 2009)
	National risk assessment.	**Climate Change Risks to Australia's Coasts: a first pass national assessment** The first pass national assessment, Climate Change Risks to Australia's Coast, draws together existing and new information to highlight the scale and range of issues Australia faces as a vulnerable coastal nation. The Climate Change Risks to Australia's Coast report identifies the key risks to Australia's coastal areas and infrastructure and outlines the role of adaptation as part of a balanced and staged response to manage these risks (DCC, 2009, Climate Change Risks to Australia's Coasts). Climate Change risks to Coastal Buildings and Infrastructure: a supplement to the national first pass risk assessment This report supplements the Climate Change Risks to Australia's Coasts first pass national assessment mentioned above and presents additional data on the exposure of commercial buildings (for example retail precincts), light industrial buildings, and transport infrastructure (road, rail, tramways).
	State level Infrastructure Risk Assessment	**Infrastructure and climate change risk assessment for Victoria** In 2007 the Victorian Government commissioned a report to assess the climate change risks to infrastructure Victoria. The report considered the worst-case scenario for low and high climate change predictions for the years 2030 and 2070 and how they would impact on infrastructure services, social amenity, governance and costs of maintenance, repair and replacement. The report also suggests some adaptation responses to climate change risks (Vic Govt, 2007, Infrastructure and climate change risk assessment for Victoria).
International Adaptation Initiatives	**Sea level rise and storm surge**	**The Thames Barrier, UK** The Thames Barrier is one of the largest movable flood barriers in the world. The barrier spans 520 metres across the River Thames near Woolwich, and it protects 125 square kilometres of central London from flooding caused by tidal surges. http://www.environment-agency.gov.uk/homeandleisure/floods/38353.aspx
	Sea level rise and flooding	**The Delta Programme, Netherlands** The Government of the Netherlands is currently preparing the Delta Programme, which will comprise a number of measures and initiatives over the long term to provide guidance about flood risk management and the supply of sufficient freshwater in the face of climate change. http://www.deltacommissaris.nl/english/Images/Deltaprogramma_ENG1_tcm310-286802.pdf

Appendix 4: Ecosystems

Australian Government and State and Territory Government Initiatives	**Landscape-scale connectivity**	**The Great Eastern Ranges Initiative, NSW** The Great Eastern Ranges Initiative aims to maintain and improve long-term connectivity conservation of mountain ecosystems running the length of eastern Australia. The initiative aims to retain the natural habitats that connect established protected areas in order to mitigate the destruction of plant and animal habitat, and manage for changes caused by climate change and other threats. http://www.greateasternranges.org.au/
		Trans-Australia Eco-Link, South Australia and Northern Territory The Trans-Australia Eco-Link is a joint initiative of the South Australian and Northern Territory Governments to establish a wildlife corridor extending more than 3,500 km from Arnhem Land to Port Augusta. The initiative aims to deliver a range of economic, social and environmental benefits, including increased resilience of natural systems to climate change. http://www.environment.sa.gov.au/naturelinks/ecolink.html
	Biodiversity adaptation planning	**Priorities for Biodiversity Adaptation to Climate Change, NSW** The NSW Government developed a report, Priorities for biodiversity adaptation to climate change, which outlines the State's priority measures to minimise the impacts of climate change on the state's native species and ecosystems. http://www.environment.nsw.gov.au/biodiversity/climatechange.htm
	Protected areas impacts	**National Reserve System implications** The Commonwealth Government, in collaboration with the CSIRO and others, is engaged in an ongoing assessment of the impacts of climate change on the National Reserve System and developing an adaptation response. http://www.environment.gov.au/parks/nrs/about/protected-areas/climate-change.html
	Climate change impacts and adaptation research	**National Adaptation research plans, NCCARF** The NCCARF has developed National Adaptation Research Plans for Terrestrial Biodiversity, Marine Biodiversity & Resources and Freshwater Biodiversity. These research plans identify critical gaps in the information available to decision-makers in key vulnerable sectors and regions, set national research priorities, and identify science capacity that could be harnessed to conduct priority research. http://www.nccarf.edu.au/national-adaptation-research-plans
International Adaptation Initiatives	**Landscape-scale connectivity**	**The MesoAmerican Biological Corridor** The MesoAmerican Biological Corridor is a natural corridor of tropical rainforests, pine savannas, montane forests, and coastal wetlands that extends from Mexico to Colombia. This project provides a range of conservation benefits and also benefits indigenous communities by providing tenure over indigenous lands and assisting these communities to develop livelihoods based on sustainable management of natural habitats and resources.
	Disaster mitigation	**Protecting Natural Forests for Flood Control, Argentina** A flood protection program in north eastern Argentina has been developed incorporating extensive areas of natural forest as part of the flood defence system. This provides a low-cost alternative to costly infrastructure, with the added benefit of high biodiversity gains. http://siteresources.worldbank.org/INTBIODIVERSITY/Resources/Biodiversity_10-1-08_final.pdf

Appendix 5: Water Management

National initiatives	• $82 million **National Groundwater Action Plan** to improve knowledge and understanding of groundwater, including hydrogeological investigations to overcome critical groundwater knowledge gaps. • **Great Artesian Basin Sustainability Initiative:** $140 million investment over fifteen years (1999-2014) to repair uncontrolled artesian bores and replace open drains with piped water reticulation systems. • **Sustainably Manage Water Resources and Extractions** through: » Establishing Water Planning Guidelines, which take into account future climate impacts on water resources, » Developing tools to assist with implementing the Guidelines, » Conducting risk assessments of water resources • Supporting **Water Information and Capacity Building** through developing strategies and research priorities, including climate change assessments and tools. • Developing a national strategy for innovative supply solutions including recycling, stormwater harvesting market-based instruments, and desalination that includes assessment of climate change impacts.
Australian States and Territories Adaptation Initiatives	• **Climate Futures for Tasmania: water and catchments technical report released** in Tasmania in March 2011 sets out projected river flows to 2100 for catchments that cover more than 70 per cent of the state by area. The future operations of Tasmania's hydro-electric system and 14 major irrigation storages were also simulated to 2100. • **Managed Aquifer Recharge.** A pilot study in Western Australia uses infiltration trenches to add treated wastewater to the sandy aquifer under Perth. The research includes assessing the human health and environmental risks of Managed Aquifer Recharge from contaminants and pathogens during infiltration and storage.
International Adaptation Initiatives	• **UK: Adaption and Resilience in a Changing Climate:** a three-year project which aims to design robust water-supply systems at a regional and local scale to improve the performance of the water supply and demand system under future climate change impacts. A **Regional Water Systems Model** will simulate supply intakes, demands and raw and potable water transfers within and between water service areas, and will be used within a Multi-Criteria Robust Decision Analysis to identify vulnerabilities under uncertain system drivers and help design robust solutions. • Water Supply company **UK South East Water** developed a Water Resources Management Plan for 2010-2035 which includes modelling to assess the region's vulnerability to climate change[120]. Key features include: » further metering, leakage management and water efficiency measures, which help reduce total demand » schemes to strengthen water infrastructure, to enable water to be transferred between areas of surplus and deficit, » new resource development schemes, including improvements to existing sources and treatment works, enhancements to source capabilities and new sources • **Singapore's Four National Taps** strategy, introduced in 2002, moved from a conventional single water supply system (i.e., reservoir) to a diversified system using water from local catchments, imported water, recycled used water, and desalinated water. Key factors in the strategy's success include the use of an integrated regulatory framework, public–private partnership in water services delivery and stakeholder participation at all levels[121]. • **California:** the Inland Empire Utilities Agency, in conjunction with RAND Corporation, utilised Robust Decision Making tools, in place of traditional analytical methods to characterise uncertainties, to determine the vulnerabilities of their existing Regional Urban Water Management Plan under different scenarios of climate and water demand. • **Arizona:** store surplus water in aquifers for later use; utilise recycled water for irrigation and potable water; written agreement to pump desalinated water from California coast to Arizona if/when required. • **Seattle (USA) Public Utilities** uses downscaled global climate models and incorporated the outputs in hydrological models. A tiered system of adaptation actions was established to address the projected water supply decreases out to 2075 including plans to maximise the use of current usable storage capacity, expanding storage capacity and additional conservation programs after 2030[122]. • **China:** In 2002 China introduced the Water Law, which aimed to enhance the sustainable use of water resources, particularly for agricultural development. • **Netherlands:** the Delta programme explores strategies for future flood risk management and fresh water supply. It includes 36 projects focused on altering the city to make room for the river. The programme adopts an adaptation tipping point method in which several adaptation strategies are developed, and modelling used to identify at which point in the future existing strategies will become ineffective, necessitating a shift to a new strategy (for example, from resisting to accommodating soil salinisation by using salt-tolerant crops). The programme also advocates using a combination of different kinds of measures to maximise adaptive capacity.

Appendix 6: Primary Industries

Australian Government, and State and Territory Government Initiatives	**Commonwealth Government**	**Australian Government Adaptation Framework** A section of the Australian Government Adaptation Framework addresses adaptation in the agriculture, fisheries and forestry sectors. This focuses on: (i) building understanding and adaptive capacity and filling knowledge gaps to enable effective adaptation action at the national and regional levels; and (ii) reducing vulnerability in agriculture, fisheries and forestry.
		CSIRO Climate Adaptation Flagship The Flagship is undertaking research and working with primary industries, enterprises and communities on how best to adapt to climate change. It is focusing on: (i) providing practical adaptation strategies that will ensure the long term viability of rural enterprises and communities threatened by climate change; (ii) exploring adaptation options and tools for agriculture, forestry, fisheries and mining industries and communities that can assist policy makers to minimise negative consequences of climate change and take advantage of new opportunities; and (iii) developing new management techniques and technologies that enable industries and enterprises to adapt to climate change.
		National Adaptation Research Plan for Primary Industries Prepared by NCCARF, the National Adaptation Research Plan for Primary Industries identifies the climate change research required for national primary industry adaptation policy and industry development. The NARP for primary industries also provides a research investment framework and prioritisation of adaptation activities in the primary industry sector.
		Australia's Farming Future The Commonwealth Government's climate change initiative for primary industries. It provides funding over four years to help primary producers adapt and respond to climate change. The initiative: (i) provides funding for climate change research projects and on-farm demonstration activities; (ii) assists farmers in financial difficulty to manage the impacts of climate change; (iii) provides short-term income support, advice and training opportunities to farmers in serious financial difficulty due to climate change; and (iv) increasing the leadership and representative capacity of target groups including women, young people, Indigenous Australians and people from culturally and linguistically diverse backgrounds.
		Climate Change Research Strategy for Primary Industries Australia's primary industries have developed a national research strategy to address climate change and emissions management and trading. The strategy targets six research areas: (i) Understanding future climates; (ii) Managing emissions; (iii) Preparing industries; (iv) Accessing information; (v) Facilitating change; and (vi) Linking decision makers.
		National drought reform policy The Commonwealth Government, in partnership with the Western Australian Government, is conducting a pilot of drought reform measures in part of Western Australia. A pilot is currently being run to move from a crisis management to more of a risk management approach. The aim is to better support farmers, their families and rural communities in preparing for future challenges, rather than waiting until they are in crisis to offer assistance.
	Australian Capital Territories	**Weathering the Change – The ACT Climate Change Strategy 2007–2025** This strategy sets out the approaches the Government will pursue between now and 2025 to support the broader community response to climate change. Action Plan 1: 2007-2011 doesn't focus particularly on primary industries, with the exception of an urban forest regeneration program
	New South Wales	**Current climate change research projects: adaptation** The NSW government has undertaken a range of climate change adaptation initiatives in the primary industry sectors. These include: • Farmer education and adaptation assistance • Breading and trailing more resistant plant varieties • Research on how increased atmospheric Co_2 will impact forests • Assisting the irrigation industry adapt to the changing conditions

Australian Government, and State and Territory Government Initiatives	**Northern Territories**	**Northern Territory Pastoral Industry and Climate Change Overview** The adaptation response of the NT pastoral industry is to increase the resilience of pastoral production against the effects of climate change. Their focus is to make better use of: • Climate risk management technology using Bureau of Meteorology forecasting (Seasonal Outlooks, ENSO, MJO) and education for climate-dependent operations. • Innovative technologies developed by scientists to combat climate change. • Producer participatory research and demonstration of adaptive technologies. • Adaptive management with transitional change and alternative practices as part of operational planning (for example more shade trees, responsive stocking rates, new breed selection criteria). • New business opportunities integrating or replacing existing commodities with other products that are better suited to the changing environment (for example forestry, camels, etc). • Animal health and disease control programs to monitor diseases for early intervention.
	South Australia	**Climate Change Management Framework** Primary Industries and Resources South Australia have developed a climate change management framework, which outlines their strategy and action in primary industries and the resources sector. The adaptation component of the framework aims to support primary industries to plan for production - or withdrawal - under changing and variable climatic conditions. An action plan for this framework will be developed during 2011.
	Tasmania	**Climate Futures for Tasmania** A key project run by the Tasmanian Government is *Climate Futures for Tasmania*. The programme covers local level information about climate projections. In December 2010 a report outlining local level climate impacts on the agriculture sector was released.
	Victoria	**Victorian Climate Change Adaptation Program** The Victorian Climate Change Adaptation Program has a range of actions for understanding the potential impacts of climate change and developing Victoria's ability to respond. The Department of Primary Industries has developed a research program to help the agricultural industries adapt to a changing climate. The program focuses on increasing the knowledge and capabilities of government, the agriculture sector and farming businesses to better undertake and respond to climate risks.
		South west climate change forum The Forum is a unique group of primary industry and planning groups formed to help south-west Victoria's primary producers adapt and prepare for changes in climate and climate variability. The Forum is supported by its members, primary producers, Commonwealth and state Governments to help distribute producer-relevant (and regional relevant) climate change information and encourage more primary producers to prepare their business for future climate changes.
	Western Australia	**Climate Change Response Strategy** In 2010 WA developed this strategy which focused on a whole of government response to climate change. The response focuses on reducing emissions, capturing excess carbon, adapting to climate change, and an appropriate climate change governance systems. The strategy also identified the need for a Climate Change Adaptation Framework, particularly for the agricultural sector, which is currently being developed with action plans.

International Adaptation Initiatives	**United Kingdom**	***Climate Change Act 2008*** Created a framework for building the UK's ability to adapt to climate change. It established an adaptation sub-committee to provide advice, analysis, information and assistance on adaptation activities, vulnerability and risk assessments, and implementing adaptation activities. For the primary industry sector, the Department for Environment, Food and Rural Affairs is supporting industry bodies to assess and communicate the priority adaptation actions to farmers and other value chain members.
	China	**China National Climate Change Programme** The adaptation component of this program addresses adaptation in agriculture and forestry. The adaptation programme focuses on more efficient irrigation systems, piloting dry-land farming techniques in arid and semi-arid areas, breeding stress-resistant crop varieties, prioritisation of adaptation forage and economic crops, and the reduction of desertification through more controlled grazing and cultivation practices.
	New Zealand	**Climate Change Plan of Action and Technical Working Groups on Adaptation** Under the *Plan of Action*, the NZ Government is working with representatives from the land sectors, local government and MĐori to develop a five-year adaptation programme to help the primary sectors adapt to climate change. The Plan of Action includes forming partnerships with industry via the formation of a 'Peak Group'. The Peak Group consists of key representatives from MĐori, the forestry and agriculture sectors and local government. Its members set the strategic direction on the development and implementation of the Plan of Action. Technical Working Groups have been established under the Plan of Action to provide a level of partnership with the sectors. These working groups provide practical and technical advice and coordinate joint implementation of the work programmes. They have specialist and sectoral representation from forestry and agriculture, local government and MĐori.
		Climate Change Adaptation Toolbox The Climate Change Adaptation Toolbox is a practical tool designed to help landholders find out information about a changing climate, what it might mean for their business and what individuals can do to prepare. The Toolbox uses a five step risk-based process, providing information and resources to work through the process.
		Sustainable Farming Fund The Sustainable Farming Fund invests in farmer, grower and forester-led projects that deliver economic, environmental and social benefits to New Zealand's land-based primary industries. The purpose of the Sustainable Farming Fund is to support Communities of Interest to undertake applied research and extension projects to tackle a shared problem or to develop a new opportunity. Sustainable Farming Fund projects are lead by rural land owners and managers often with the support of industry organisations, agribusiness, researchers or consultants. Most successful projects are able to leverage a high proportion of other funding or in-kind support to complement the Sustainable Farming Fund grant.

Appendix 7: Emergency Management

Australian Government, and State and Territory Government Initiatives	• Victoria flood database. The Victorian Government has developed a database to be used as a central repository for flood related data (including up-to-date flood mapping) for the state. The database is available to the public and relevant agencies. The responsibility for maintaining the information within the database rests with catchment management authorities. Any new or updated information to be added to be database must be obtained in accordance with standard mapping specifications. This provides a consistent and easily accessible source of flood information for all Victorians[123]. • The 2002 COAG report, *Natural Disasters in Australia*, established a national disaster mitigation grants program and modernised relief and recovery arrangements. • The 2011 *National Strategy for Disaster Resilience* reiterates well known principles used by the sector to improve national coordination of disaster resilience across government. • The NCCARF prepared the 2010 National Climate Change Adaptation Research Plan for Emergency Management
International Adaptation Initiatives	• A Canadian initiative links agencies at the local government level to atmospheric hazards publications, and a web site providing information on climatological, extreme weather and air quality information, customizing atmospheric hazards maps for their localities and in linking hazards maps[124]. Information on climate trends for the hazard variables is presently available on the site, and future plans for the site include climate change trend projections, where appropriate.

Appendix 8: Human Health

Australian Government, and State and Territory Government Initiatives	• The Victorian Department of Health is undertaking research projects into climate change including reducing harm to older persons from extreme heat, scoping the climate change impacts on population health and vulnerabilities and temperature thresholds for Melbourne and rural Victoria. Further, the Department published the Heatwave plan for Victoria in 2011 and Heatwave Planning Guide for Victorian local councils in 2009. • The Western Australian Department of Health published a report in 2008 into the human health impacts of climate change and the adaptation strategies that could be implemented to prevent or minimise these impacts. • The National Climate Change Adaptation Research Facility prepared the 2010 National Climate Change Adaptation Research Plan for Human Health and Adaptation Research Network for Human Health.
International Adaptation Initiatives	• The World Health Organization focused World Health Day 2008 on climate change. In 2009, it released its work plan on climate change and human health, identifying its priorities and areas of work. The four main objectives of the work plan are to advocate and raise awareness, strengthen partnerships, enhance scientific evidence and strengthen health systems.

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