

1 **IPCC WGII Fourth Assessment Report – Draft for Expert Review**

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4 **Chapter 11: Australia and New Zealand**

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1 **Executive Summary**

2
3 *Evidence for climate change has become clearer:* Since 1950 there has been unequivocal warming in
4 the region, with more heat waves, fewer frosts, changes in rainfall and biological indicators, loss of at
5 least a quarter of glacier mass in New Zealand, an increase in the intensity of Australian droughts,
6 and sea level rise of 1-2 mm per year (very high confidence). There is substantial evidence that
7 adaptation to these changes has already commenced in such sectors as water, agriculture and
8 horticulture, regional planning and natural systems.

9
10 *Recent climatic trends are very likely to continue:* By about 2050, the entire region is very likely to
11 warm by 1-3°C and by even more in inland Australia (high confidence). Large areas of mainland
12 Australia and eastern New Zealand are likely to become substantially drier, although western New
13 Zealand is likely to become up to 40% wetter. The frequencies of major floods, fires, droughts, heat
14 waves and storm surges are likely to rise (medium confidence). Sea-level is likely to rise 0.04-0.36 m.

15
16 *Potential benefits are likely to accrue for particular sub-regions and sectors:* Up to about 2050,
17 enhanced growing conditions from higher carbon dioxide, longer growing seasons and less frost risk
18 are likely for agriculture, horticulture and forestry over much of New Zealand and Tasmania. There
19 is very likely to be reduced winter energy demand in cities. Flows in New Zealand's largest rivers
20 are very likely to increase, benefiting hydroelectricity generation and irrigation water supply (high
21 confidence).

22
23 *The structure, function and species composition of many natural ecosystems are very likely to alter:*
24 The most vulnerable areas for a 1°C warming include the Great Barrier Reef, south-western
25 Australia, Kakadu wetlands, and rainforests, coasts, and alpine areas of both countries. Adaptation
26 options are very likely to be limited. Impacts are virtually certain to exacerbate existing stresses such
27 as habitat loss and fragmentation, cause a reduction in ecosystem services (e.g. for tourism, fishing,
28 water supply) and lead to management challenges for the conservation estate (medium confidence).

29 *Water security problems are very likely to be exacerbated:* Projections of drier conditions and rising
30 water demand and competition are very likely to adversely affect water supply over large areas of
31 southern and eastern Australia and in areas distant from major rivers in eastern New Zealand. There
32 is considerable scope for short term adaptation, but risk of water shortage is likely to increase after
33 about 2050 (high confidence).

34
35 *Coastal settlements are likely to be highly vulnerable:* About 80% of the population lives within 50
36 km of the coast. Ongoing coastal development is likely to exacerbate risk to lives and property from
37 projected sea level rise, larger storm surges and more intense cyclones. Increased erosion and
38 inundation is very likely along thousands of kilometres of coastline, resulting in loss of high-value
39 land, faster road deterioration, degraded beaches, social and economic trauma, loss of items of
40 cultural significance, and higher insurance costs (very high confidence). There are considerable
41 barriers to implementation of adaptation strategies.

42
43 *Risks to critical infrastructure are likely to increase:* These risks include catastrophic failure of hydro
44 dams in New Zealand; failure of floodplain protection and urban drainage; increased storm and bush
45 fire damage in major cities, and more heatwaves causing higher mortality and peak energy demand.
46 Adaptation involves expensive retrofitting and improved design, more resources for emergency
47 management, and changes in price and availability of insurance (medium confidence).

48
49 *Biosecurity threats are likely to increase:* Climate change projections are likely to favour many
50 invasive/incursive species, pests and disease vectors, leading to impacts on human health,

1 agriculture, forestry and natural ecosystems. Risks to people are likely to be strongly modulated by
2 robust and responsive health care systems (medium confidence).

3
4 *Shifts in agriculture and forestry are very likely:* Production is likely to be vulnerable to projected
5 drier conditions over much of Australia and north-eastern New Zealand. There is considerable scope
6 for adaptation up to about 2050, but changes in crop variety and location and competitive advantage
7 are likely in the longer term at both regional and global scales, placing additional stress on rural
8 economies and societies. Despite this, regional food security is very likely to remain robust (medium
9 confidence).

10
11 *Australia and New Zealand have high adaptive capacity to climate change:* Both countries have
12 developed economies with substantial infrastructure, supported by extensive scientific and technical
13 capabilities and disaster mitigation strategies. Nevertheless, there are likely to be considerable cost
14 and institutional constraints to implementation of adaptation options. Within both countries there are
15 economically and socially disadvantaged groups, especially indigenous peoples, who have less
16 adaptive capacity and are likely to be more vulnerable to additional stresses on health and living
17 conditions (medium confidence).

18
19 *Sustainable development is likely to be threatened in a number of identifiable hotspots:* eastern
20 Queensland (Aus), south-western Australia, Murray-Darling Basin (Aus), Kakadu (Aus), Bay of
21 Plenty (NZ), Northland (NZ), eastern plains and Southern Alps (NZ), and sub-Antarctic islands
22 (medium confidence).

23 24 25 **11.1 Introduction**

26
27 The region is defined here as the lands and territories of Australia and New Zealand. It includes their
28 outlying tropical, mid-latitude and sub-Antarctic islands and the waters of their Exclusive Economic
29 Zones (EEZ). Thus the region spans an area from the tropics to the sub-Antarctic islands of the
30 Southern Ocean, and from the mid-Indian Ocean to the dateline in the Pacific, including the Tasman
31 Sea. Australia is a large, relatively flat continent reaching from the tropics to mid-latitudes, with
32 relatively nutrient-poor soils, a very arid interior, with marked seasonal rainfall. New Zealand is
33 much smaller, mountainous, and is generally better-watered throughout the year. Despite markedly
34 different landscapes and climates, many of the social, cultural and economic aspects of the two
35 countries are comparable, giving a similarity of issues regarding impacts, adaptation and
36 vulnerability.

37
38 The IPCC *Special Report on Regional Impacts of Climate Change* provided a first, extensive
39 assessment of climate change impacts and adaptation options for Australia and New Zealand (Basher
40 *et al.*, 1998). The IPCC TAR built on this review (Pittock and Wratt, 2001). It considered that the
41 region is sensitive to possible changes toward a more El Niño-like mean state and that changes in
42 extreme events are very likely to dominate future impacts. Thus, large areas of mainland Australia
43 are likely to become drier during the 21st century. The westerlies are likely to strengthen, causing a
44 sharper gradient of precipitation across Tasmania and New Zealand. The following impacts were
45 assessed. .

46
47 *Water Supply and Hydrology:* Water resources are already stressed, with intense competition for
48 water supply. Climate change is very likely to increase these pressures and adversely affect water
49 supply, agriculture, and the survival and reproduction of key species.

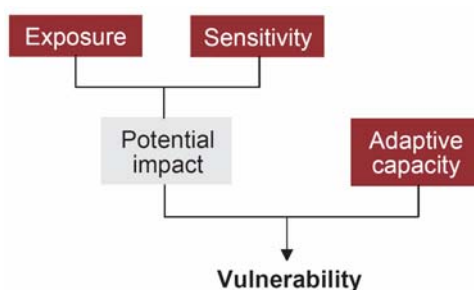
1 *Ecosystems and Conservation:* Warming of 1°C is likely to threaten the survival of species currently
 2 living near the upper limit of their temperature range, notably in alpine regions and south-western
 3 Australia. Species that have restricted climatic niches and are unable to migrate are very likely to
 4 become endangered or extinct. Other ecosystems threatened by climate change include coral reefs
 5 and freshwater wetlands in the coastal zone and inland.

6
 7 *Food and Fibre:* Agricultural activities are considered to be particularly vulnerable to regional
 8 reductions in rainfall in southwest and inland Australia and eastern New Zealand. Enhanced plant
 9 growth and water-use efficiency resulting from CO₂ increases provide initial benefits, although
 10 impacts of climate change become negative with warmings in excess of 2–4°C and the associated
 11 drying. Reliance on exports of agricultural and forest products makes the region sensitive to changes
 12 in commodity prices induced by changes in climate elsewhere.

13
 14 *Settlements, Industry, and Human Health:* Marked trends to greater population and investment in
 15 exposed coastal regions are increasing vulnerability to tropical cyclones, storm surges and sea-level
 16 rise. Increased frequency of high-intensity rainfall is likely to increase flood damage. The spread of
 17 some disease vectors is very likely, thereby increasing the potential for disease outbreaks, despite
 18 existing biosecurity and health services.

19
 20 *Vulnerability and Adaptation:* Climate change adds to existing stresses on achievement of
 21 sustainable land use and conservation of terrestrial and aquatic biodiversity. Within both countries
 22 there are economically and socially disadvantaged groups of people, especially indigenous peoples,
 23 who are particularly vulnerable. There are major exacerbating problems in the region, such as rapid
 24 population and infrastructure growth in vulnerable coastal areas, inappropriate use of water
 25 resources, and complex institutional arrangements. Options are identified for adaptation to climate
 26 change.

27
 28 The overall conclusion of the TAR was that Australia has significant vulnerability to climate change
 29 for the next 50–100 years while New Zealand appears more resilient, except in a few areas. These
 30 conclusions are supported by this AR4 assessment, which reviews a considerable literature written
 31 since the TAR. It also examines vulnerability more closely by placing greater attention on adaptation
 32 options. Vulnerability is assessed as a function of exposure to climate and other factors, sensitivity to
 33 change and capacity to adapt to that change. Systems that are highly exposed, sensitive and less able
 34 to adapt are highly vulnerable (Figure 11.1). Once vulnerable sectors/systems/regions are identified,
 35 vulnerability can be better managed if exposure and sensitivity are reduced, and / or adaptive
 36 capacity is enhanced.



47 **Figure 11.1:** *Components of vulnerability (Allen Consulting Group, 2005).*

48
 49
 50 **11.2 Current sensitivity/vulnerability**

11.2.1 Sensitivity/vulnerability to climate and weather

In Australia, around 87% of economic damage due to natural disasters is caused by weather-related events (BTE 2001.). From 1967 to 1999, these costs averaged US\$719 million per year, mostly due to floods, severe storms and cyclones. The cost of deaths and injuries from natural disasters averaged US\$31 million. The most costly single event was the Sydney hailstorm of April 1999 at US\$1,700 million, of which US\$1,300 million was borne by the insurance industry (Schuster *et al.* 2005). The insurance industry is well aware of exposure to climate change risks (Coleman *et al.* 2004; Salt 2000).

The cost of natural disasters in New Zealand from 1962-98 averaged US\$21.6 million per year (BTE 2001.), when several large events occurred, such as the 1968 Wahine storm (US\$188 million) and the 1984 Southland floods (US\$80 million). The 2004 Manawatu floods cost US\$78 million (Insurance Council of NZ, 2005). No trend in costs can be discerned, but frequency of large natural disasters is increasing. Apart from earthquakes, the most costly are floods (US\$7 million/year and 43% of total events), followed by severe storms (US\$5 million/year) and sub-tropical cyclones (less than US\$1 million/year).

Droughts in both countries have severe impacts. Australian government drought relief averaged US\$76 million from 1992-1999 (SOE 2001). Water shortages in Perth since the 1970s have prompted major infrastructure investment (section 11.6). The El Niño 2002/2003 drought in Australia is estimated to have cost 1.6% of GDP (US\$7.6 billion) and about 70,000 jobs (Adams *et al.*, 2002). Wildfires affected life, property and water supplies, with US\$261 million damage in Australia's capital city Canberra (IDRO, 2004; Lavorel and Steffen 2004). Dam levels were extremely low, water restrictions were imposed and irrigation allocations were significantly reduced. In New Zealand, the 1997/98 El Niño and 1998/99 La Niña droughts caused losses of US\$800 million to agricultural production, with severe impacts on regional economies, more fires, and costly reductions in hydro-electricity generation.

11.2.1.1 Climate trends

New Zealand mean temperatures have risen 0.7°C from 1870-1998, or 0.005°C/year (Folland *et al.*, 2003). From 1951-1996, the number of cold nights and frosts declined 10-20 days, but there is no statistically significant trend in hot days or extreme rainfall (Salinger and Griffiths, 2001). From 1971-2004, the number of tropical cyclones in the southwest Pacific averaged nine/year, with no trend. The frequency and magnitude of extreme westerly winds has increased slightly over New Zealand but with a significant increase to the south. The magnitude and frequency of easterly extremes has decreased over land and increased to the south (Salinger *et al.* 2005). Relative sea level rise is 1.7 ± 0.4 mm/year (Bell *et al.* 2001).

From 1910 to 2004, the Australian-average maximum temperature rose 0.006°C/year and the minimum temperature rose 0.012°C/year, mostly since 1950 (Nicholls and Collins, in press). From 1957 to 2004, the Australian-average shows an increase in hot days (35°C or more) of 0.10 days/year, an increase in hot nights (20°C or more) of 0.18 nights/year, a decrease in cold days (15°C or less) of 0.14 days/year and a decrease in cold nights (5°C or less) of 0.15 nights/year (Nicholls and Collins, in press). North-eastern Australia has become wetter since 1950, and much of southern Australia has become drier (Smith 2004). Droughts have become hotter (Nicholls, 2004). The proportion of total rainfall from extreme rain-days in eastern Australia increased from 1910-1998, while extreme rainfall has decreased in southwestern Australia (Haylock and Nicholls, 2000). The frequency of tropical cyclones in the Australian region has decreased since 1967, but there has been an increase in cyclone intensity (Kuleshov, 2003; Hennessy 2004). Relative sea-level rise averaged around Australia is 1.2 mm/year over the period 1920 to 2000 (Church 2004).

1
2 In the sub-Antarctic islands, Macquarie Island has experienced increased temperature, wind speed,
3 precipitation and evapotranspiration, and decreased air moisture content and sunshine hours since
4 1950 (Frenot *et al.* 2005). Campbell Island mean temperatures have risen by 0.6°C in summer and
5 0.4°C in winter since the late 1960s. Heard Island, shows rapid glacial retreat and loss of ‘permanent’
6 snow cover (Bergstrom 2003).

7
8 *11.2.1.2 Natural systems vulnerability/sensitivity to climate trends*

9
10 Tables 11.2.1.1 and 11.2.1.2 show examples of species and ecosystems where there is evidence of
11 recent climate-associated change. In some cases, contributions of other factors are poorly understood.

12
13 **Table 11.1:** *Examples of observed changes in natural ecosystems and species characteristics in*
14 *Australia and New Zealand linked to changing climate.*

Taxa or System	Observed Change	References
Semiarid woodlands, eucalypt savannas	Increase in woody biomass (“vegetation thickening”), partially linked to increased atmospheric CO ₂	(Hughes 2003)
Rainforest/woodland ecotones	Expansion of rainforest at expense of eucalypt forest and grasslands, linked to changes in rainfall and fire regimes	(Hughes 2003)
Subalpine vegetation	Encroachment by snow gum <i>Eucalyptus pauciflora</i> into subalpine grasslands at higher elevations	(Hughes 2003)
Mangroves	Landward transgression of mangroves linked to sea level rise and changed rainfall	(Hughes 2003)
Coral reefs	Widespread coral bleaching observed in the summers of 1997/1998 and 2001/2002 associated with unusually high sea surface temperatures (SSTs)	(Hughes 2003)
Flowering phenology	Changes in flowering dates of 56 species of Australian plants, over 22 years; 24 species mean advancement of 13.6 days; remaining species mean advancement of 20.8 days	(Keatley; Hudson in review)
Birds	Earlier arrival of migratory birds in alpine zone; range shifts and expansion of several species; reduced productivity in Blue-breasted Fairy-wren related to reduced rainfall in south-western Australia; seabird ranges extending southwards; changes in arrival and departure dates of birds in semi-arid regions; high SSTs associated with reduced reproduction in Wedge-tailed Shearwaters	(Chambers <i>et al.</i> 2005; Hughes 2003)
Mammals	Increased penetration of feral mammals into alpine and high subalpine areas; prolonged winter presence of browsing macropods; rats moving into upland herbfields and breeding more often on Macquarie Island; poleward range shifts in flying foxes	(Frenot <i>et al.</i> 2005; Hughes 2003)
Insects	Change in genetic constitution of <i>Drosophila</i> , equivalent to a 4° latitude shift	(Umina <i>et al.</i> 2005)
Marine invertebrates	Range extension of introduced European shore crab, <i>Carcinus maenas</i> , from Victoria to Tasmania in the early 1990s linked to warming; range extension of sea urchin <i>Centrostephanus rodgersii</i> to the Tasmanian east coast, causing extensive “urchin barrens”	(Edgar 1997; Thresher <i>et al.</i> 2003)
New Zealand		
Sub-alpine vegetation	Treeline habitat has not responded to recent warming but there has been little seasonal trend in snow storage since 1930	(McGlone 2001) Owens and Fitzharris, 2004
Birds	Earlier egg laying in Welcome Swallow	(Evans <i>et al.</i> 2003)
Antarctic beech	Seed production increased (1973-2002) along elevational gradient	(Richardson <i>et al.</i> in

Fish	(1020-1370 m) related to warming during flower development Increasing El Niño frequency associated with westward shift of Chilean jack mackerel in the Pacific and subsequent invasion into New Zealand waters in the mid-1980s	press) (Taylor 2002)
------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-------------------------

1
2 **Table 11.2:** Examples of observed changes in natural ecosystems and species characteristics in sub-
3 Antarctic islands linked to changing climate.

Sub-Antarctic Islands

Birds	Population increases in Black-browed Albatross <i>Diomedea melanophris</i> and King Penguin <i>Aptenodytes patagonicus</i> on Heard Island; population declines on Campbell Island of Rockhopper Penguins, Grey-headed Albatross and Black-browed Albatross related to rising SSTs	(Chambers <i>et al.</i> 2005)
Vertebrates	Population increase in Fur Seals on Heard Is. and Elephant Seals on Campbell Is.	(Budd 2000)
Plant communities	Plant colonisation of bare areas exposed by glacial retreat on Heard Is; expansion and thickening of scrub on Campbell Is.	(Bergstrom 2003; Salinger; Mullan 1999; Wilmschurst <i>et al.</i> 2004)

4
5
6 Recent switches between glacial advance and retreat in New Zealand are largely due to precipitation
7 changes (Salinger; Mullan 1999) caused by circulation changes, including increased ENSO events
8 (e.g. Hooker and Fitzharris, 1999; (Clare 2002) (Fitzharris 2004: -b). There is no discernable trend
9 in seasonal snow in the Southern Alps since 1930 (Owens and Fitzharris, 2004). South-east
10 Australian snow depths at the start of October have declined 40% in the past 40 years, mainly due to
11 warmer temperatures (Nicholls, 2005).

12 13 14 **11.2.2 Sensitivity/vulnerability to other stresses**

15
16 Population growth places stress on most resources. New Zealand's population was 4.1 million in
17 2005, mainly in Auckland, Wellington, Christchurch and Bay of Plenty, and growing at 1% per year
18 (Statistics New Zealand, 2005a). Australia's population was 20.1 million in 2004, with growth of two
19 million since 1995 mostly concentrated in Sydney, Melbourne, Brisbane and Perth and along
20 adjacent coasts (ABS, 2005).

21
22 Increases in water demand have placed stress on supply capacity for irrigation, cities, industry and
23 environmental flows. Increased demand since the 1980s in New Zealand has been due to agricultural
24 intensification (Woods; Howard-Williams 2004). The irrigated area has increased at around 55%
25 each decade since the 1960s (Lincoln Environmental 2000). In Australia, processes such as dryland
26 salinity, alteration of river flows, over-consumption and wasteful use of water resources, land
27 clearing, intensification of agriculture and fragmentation of ecosystems still pose major stresses
28 (SOE 2001) (Cullen, 2002). From 1985-1996/7, water demand has increased by 65%, including a
29 76% rise in irrigation water and a 55% rise in domestic and industrial water (NLWRA, 2001).

30
31 Growing energy demand has placed stress on power supply infrastructure. Over 70% of New
32 Zealand's electricity production is from renewables (MED, 2005). Consumption is projected to grow
33 by 1.2% per year for the period 2000-2025 (MED, 2003). Over 60% of Australian electricity comes

1 from coal, and energy consumption has been growing steadily at 2.5% per year over the past 20 years
2 (PB Associates, 2005).

5 **11.2.3 Current adaptation**

6
7 The current impacts of climate variability, extremes and trends are being managed to some extent by
8 ongoing adaptation (Table 11.2.3.1 and 11.2.3.2).

9
10 **Table 11.3: Current adaptation in natural ecosystems**

Sector	Adaptation strategies
Natural ecosystems	Australian National Action Plan for Salinity and Water Quality and the second phase of the Natural heritage trust (NHT II) covers biodiversity and climate change issues.
	Australia's National Reserve System aims to establish a comprehensive, adequate and representative system of protected areas.
	The Environment Protection and Biodiversity Conservation Act 1999 covers matters of national environmental significance (DPMC 2004).
	Recent changes to legislation in Queensland and NSW to end broad-scale vegetation clearing have been made (NSW Native Vegetation Act 2004, amendments to the Queensland Vegetation Management Act (1999) and the Integrated Planning Act (1997).
	Representative Areas Program Zoning Plan for the Great Barrier Reef Marine Park (2004).
	The Australian National Action Plan on Biodiversity and Climate Change (2003-2007) outlines seven objectives designed to increase knowledge about climate change impacts.
	New Zealand Resource Management Act 1991 promotes the sustainable management of natural and physical resources. The Act governs use and development of land, air and water resources. Amendments in 2003 require local councils to take climate change into account during planning

11
12 **Table 11.4: Current adaptation in human systems**

Sector	Adaptation strategies
Coasts	Protect, accommodate and retreat options have been adopted in different ways through current institutional arrangements for coastal management around Australia (Harvey; Caton 2003) and in New Zealand (Bell <i>et al.</i> 2001)
	State Coastal Management Plan (Queensland Government, 2001) adopts the IPCC approach to coastal adaptation in its coastal policy, stating that planning for the coast must address the potential impacts of climate change through a hierarchy of approaches
	Flood inundation and storm surge studies conducted for local government authorities in both Australia and New Zealand.
	Integrated catchment management in Australia is only recently including the coast (Harvey; Caton 2003)
Fisheries	Modelling to establish quotas for some species in waters under New Zealand's jurisdiction
Settlements	Major financiers have begun to re-evaluate their lending policies to incorporate environmental and climate change risk assessment tools (Baker McKenzie, 2004). BASIX Sustainability Index for buildings in NSW
Tourism	Snow-making at ski resorts, early warning systems for extreme weather
Energy	5-star energy rating required for new buildings in Victoria
Health	Quarantine, biosecurity, early warning systems for extreme weather events
	Vaccination programmes for meningococcal disease
Agriculture	Government drought-support programs for farm households and, in Australia, farm enterprises
	In New Zealand, adoption of more flexible stocking policies has ensured a higher percentage of earlier lambing and better and earlier decision making about destocking of finishing stock. Reservoirs and dams in paddocks and additional water systems have been installed which result in better condition of stock.

	Planning of animal health and production systems improved. Monitoring of internal parasites and other pests and diseases (Salinger et al., 2005b)
	Government-supported capacity-building programs, such as the Australian National Landcare Program, enhance resilience to climate change via mechanisms such as whole-farm planning.
	Research and development on climate effects on agricultural systems and on decision-support and extension activities to integrate this with the farmer's own knowledge.
Forestry	Forestry site and species/provenance selection including more effective use of climate mapping.
	Wider tree spacing, supplementary watering (particularly during establishment) and fire, nutrient, pest, disease and weed management.
Water	Australia's National Water Initiative (2004), Metropolitan Water Plan (2004) for Sydney, Department of Natural Resources and Mines (2004), the South East Queensland Regional Water Strategy (2005), and a State Water Strategy for Western Australia (2003). Engineering solutions (piping channels, reducing losses from channels and dams) and increasing water use efficiency on farms (White et al. 2003)

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11.3 Assumptions about future trends

11.3.1 Climate

Projected temperature and precipitation changes for broad sub-regions of Australia and New Zealand are given in Table 11.3.1. There is little seasonal variation in warming, except for the sub-Antarctic islands, where warming is greater in winter. Ocean areas either become wetter or show little change. On balance, northern Australia tends to have more pronounced wet and dry seasons, while southern Australia and New Zealand become drier, especially in winter.

Table 11.5: Projected temperature and precipitation changes for broad sub-regions of Australia and New Zealand, based on Ruosteenoja et al. (2003). Ranges of values encompass estimates from seven global climate models and the main SRES emission scenarios.

(a) Changes in temperature (°C)

Sub-region		2020	2050	2080
N. Australia.	wet season	+0.4 → +1.5	+1.0 → +3.9	+1.3 → +5.9
	dry season	+0.8 → +1.5	+1.1 → +3.1	+1.6 → +5.9
S. Aus & NZ	summer	+0.4 → +1.3	+0.9 → +3.2	+1.1 → +5.2
	winter	+0.5 → +1.3	+1.1 → +2.3	+1.2 → +4.1
Pacific/Tasman	summer	+0.5 → +0.7	+0.8 → +1.7	+1.0 → +3.1
	winter	+0.6 → +0.8	+0.8 → +1.8	+1.0 → +3.0
S. Ocean & sub-Ant. islands	summer	+0.2 → +1.0	+0.2 → +2.0	+0.4 → +3.3
	winter	+0.3 → +2.3	+0.3 → +4.1	+0.9 → +6.5

(b) Changes in precipitation (%)

Sub-region		2020	2050	2080
N. Australia.	wet season	-6 → +22	-6 → +38	-12 → +28
	dry season	-18 → +18	-45 → +22	-40 → +22
S. Aus & NZ	summer	-8 → +17	-10 → +15	-28 → +23
	winter	-11 → +8	-12 → +12	-28 → +7
Pacific/Tasman	summer	-5 → +3	-5 → +4	-4 → +9
	winter	-1 → +2	-4 → +5	-5 → +7
S. Ocean & sub-Ant. islands	summer	+3 → +11	+2 → +12	+4 → +18
	winter	+1 → +6	+3 → +10	+4 → +19

The scenarios below are based on more-detailed regional projections for Australia and New Zealand developed by (CSIRO 2001) and NIWA (Wratt *et al.* 2004), respectively. They have been used in a number of impact studies. Table 11.3.2 shows New Zealand average warming and precipitation projections. The mean westerly wind component across New Zealand is likely to increase by about 10% by about the 2080s (Mullan *et al.*, 2001a, b). A halving of frost days is likely to occur in the lower North Island and the South Island, and the recurrence interval of high intensity rainfall is likely to decrease, especially in western areas.

Table 11.6: Projected changes in annual precipitation (%) and mean temperature (°C) for the 2030s and 2080s, relative to 1990, in New Zealand (Wratt *et al.* 2004).

Sub-region	2030s (%)	2030s (°C)	2080s (%)	2080s (°C)
Western North Island	-4 to +14	0.2 to 1.3	-6 to +26	0.3 to 4.0
Eastern North Island	-19 to +7	0.2 to 1.4	-32 to +2	0.5 to 3.8
Northern South Island	-7 to +3	0.1 to 1.4	-7 to +5	0.4 to 3.5
Western South Island	-4 to +15	0.1 to 1.3	+1 to +40	0.2 to 3.5
Eastern South Island	-12 to +13	0.1 to 1.4	-21 to +31	0.4 to 3.4

In Australia, a mean warming of 0.4 to 2.0°C is likely by the year 2030, relative to 1990, and 1 to 6°C by 2070, based on the full SRES range and nine climate models (CSIRO 2001). A 10 to 100% increase in days over 35°C is likely by 2030 with a 20 to 80% decrease in days below 0°C. A tendency for less rainfall is likely in the south-west (-20 to +5% by 2030, -60 to +10% by 2070) and in parts of the south-east and Queensland (-10 to +5% by 2030, -35 to +10% by 2070). In other areas, including much of eastern Australia, projected ranges are -10 to +10% by 2030 and -35 to +35% by 2070. Increases in extreme daily rainfall are likely where average rainfall increases, or decreases slightly. For example, the intensity of the 1-in-20 year daily-rainfall event increases by up to 10% in parts of South Australia by the year 2030 (McInnes *et al.*, 2002), 5 to 70% by the year 2050 in Victoria (Whetton *et al.* 2002), and up to 25% in northern Queensland by 2050 (Walsh *et al.* 2001) and up to 30% by the year 2040 in south-east Queensland (Abbs, 2004). Preliminary results from one model (Niall and Walsh, 2005) suggest that decreases in convective available potential energy and hail frequency are about as likely as not for south-eastern Australia (low confidence).

Reduced soil moisture is very likely, producing up to 20% more droughts (soil moisture deficit in lowest 10% from 1974-2003) over most of Australia by 2030 and up to 80% more droughts by 2070 in south-western Australia (Mpelasoka *et al.*, 2005a). By the 2080s in New Zealand, severe droughts (the current one-in-twenty year soil moisture deficit) are likely to occur at least twice as often in the east of both islands, and parts of Bay of Plenty and Northland (Mullan *et al.*, 2005). The drying of pastures in spring is very likely to be advanced by a month, with an expansion of droughts into spring and autumn months.

An increase in fire danger in Australia is likely with climate change (Tapper, 2000; Cary 2002; Williams *et al.* 2001). This is likely to be associated with a reduced interval between fires, increased fire-line intensity, a decrease in fire extinguishments and faster fire spread. In south-east Australia, the frequency of extreme fire danger days increases 10-40% by 2020 and 20-120% by 2050 (Hennessy *et al.*, 2005). By the 2080s, 6-18 more days with very high and extreme fire danger are likely in eastern areas of New Zealand, the Bay of Plenty, Wellington and Nelson regions (Pearce *et al.* 2005), with increases of 1-5 days in some western areas. Fire season length is likely to be extended, starting earlier in August and finishing in May in many parts of New Zealand, compared with the current October to April season.

1
2 Sea-level in the region is likely to rise 0.02-0.12 m by 2020, 0.04-0.36 m by 2050 and 0.06-0.74 m by
3 2080, relative to 1990 (see IPCC WG1 report). These projections take account of both global-mean
4 projections from IPCC SRES emission forcing and the non-uniform spatial distribution of sea-level
5 change (related to ocean circulation and thermal expansion components of change) as produced by
6 climate simulations (Gregory *et al.*, 2001). They do not include vertical land movement components
7 of relative sea-level change, which can be large and locally important for coastal planning and
8 adaptation.

11 *11.3.2 Population, energy and agriculture*

13 In Australia, under medium assumptions (ABS 2003), the population is likely to grow from 20
14 million in 2003 to 26.4 million in 2051, then stabilise. These assumptions include a fall in the
15 number of children per woman from 1.75 at present to 1.6 from 2011 onward, net overseas migration
16 of 100,000 per year, and an increase in life expectancy for males from 75.9 years in 2003 to 84.2 by
17 2051 and for women from 81.5 to 87.7. A greater concentration of Australia's population is likely in
18 the four major coastal cities (Sydney, Melbourne, Brisbane and Perth) and towns in south-east
19 Queensland. The proportion of Australians aged 65+ is likely to increase from 13% in 2003 to 27%
20 in 2051 and 29% in 2101.

22 In New Zealand, under medium assumptions, the population is likely to increase from 4.1 million in
23 2004 to 5.05 million in 2051 (Statistics New Zealand, 2005b). These assumptions include a net
24 immigration of 10,000 per annum, a drop in fertility rate from 2.01 in 2004 to 1.85 from 2016
25 onward, and an increase in life expectancy for men from 77.0 in 2004 to 83.5 by 2051 and for women
26 from 81.6 in 2004 to 87.0 in 2051. The share of the population aged 65+ is likely to grow from 12%
27 in 2004 to 25% in 2051.

29 In Australia, coal is the dominant power generation fuel supply and is very likely to continue to form
30 the backbone of Australia's generation infrastructure for the foreseeable future (PB Associates,
31 2005). Up to at least 2020, Australian energy consumption is projected to grow 2.1% per year on
32 average (giving a total rise of 50%), while gross domestic product is assumed to grow by 3.4% per
33 year (DPMC 2004). Reducing greenhouse gas emissions will be a major driver of new energy
34 technology (e.g. "clean" coal, geosequestration, renewables, hydrogen fuel cells). Petroleum in
35 Australia is being consumed many times more than the rate at which it is being discovered. It is
36 predicted that the level of petroleum imports will increase 20-60% by 2010, but LNG exports may
37 double by 2010 (PB Associates, 2005).

39 Over 60% of New Zealand's electricity production is from hydrodams and 10% is from other
40 renewables (MED, 2005). Future challenges include meeting the growth in demand for energy at a
41 time when gas availability from the Maui field is coming to an end and greenhouse gas emissions are
42 an increasingly important consideration. Total energy demand is likely to grow at an average rate of
43 0.6% per year from 2000-2025. Energy intensity in New Zealand is projected to decline from the
44 current 7PJ to 4PJ per US\$1000 million of GDP. Electricity demand is projected to grow at 1.2% pa,
45 requiring new electricity generation capacity of 3355MW. Modelling indicates that this new capacity
46 is likely to comprise around 890MW of hydro, 630MW of geothermal, 635MW of wind, 350MW of
47 cogeneration, 800MW of gas combined cycle, and 50MW of distillate (MED, 2003). This suggests an
48 even greater reliance on renewable forms of energy for electricity generation - wind, hydro and
49 geothermal, all of which are very likely to be affected by climate change (see section 11.4.9).

1 Agriculture is likely to contribute a continued decreasing proportion of national GDP in both
 2 countries. The decline in terms of trade (the difference between prices received and costs) is likely to
 3 continue. The tendency for high value, often 'niche' products to replace mainstream commodities
 4 such as wheat, meat and wool is likely to continue. Further sophistication and integration of
 5 knowledge of climate and market risk into decision-making is likely, and more related to broader
 6 societal outcomes such as maintenance of water quality and biodiversity.

9 **11.4 Key future impacts and vulnerabilities**

11 This section discusses potential impacts of climate change, without adaptation. Further detail on
 12 impacts is available in the synthesis reports by (Pittock 2003) and (MfE 2001a). Adaptation options
 13 and constraints, and residual vulnerabilities, are discussed in Section 11.5.

16 **11.4.1 Natural ecosystems**

18 The flora and fauna of Australia and New Zealand have a high degree of endemism (80-100% in
 19 many groups), and have evolved in isolation for millions of years. Many species are already
 20 restricted in geographic and climatic range and therefore be predisposed to early extinction or
 21 displacement under climate change. Bioclimatic modelling for selected Australian taxa generally
 22 projects reductions and or fragmentation of existing climatic ranges in the future. Natural
 23 ecosystems/regions identified as being most vulnerable in the short to medium term include the Wet
 24 Tropics and Kakadu World Heritage Areas, alpine areas, coral reefs, south-west Australian
 25 heathlands, and both coastal and freshwater wetlands (Table 11.4.1). The total value of ecosystem
 26 goods and services in the Wet Tropics World Heritage Area in Australia is US\$132-148 million per
 27 year, as at June 2002 (Curtis, 2004). There is little research on the potential impacts of climate
 28 change on New Zealand species or natural ecosystems, with the exception of the alpine zone and
 29 some forested areas.

32 **Table 11.7: Examples of potential impacts of climate change on species and ecosystems**

System	Potential Impacts	Source
Forests	<i>Australia:</i> Distribution of rainforest types in North Queensland Wet Tropics projected to either increase or decrease with warming, depending on direction of rainfall changes. 1°C increase projected to reduce the bioclimatic envelope of many endemic upland vertebrates to ~ two thirds of their existing area; 3.5°C increase likely to result in complete loss of the bioclimate of 30 of the 65 species modelled and the remaining species to retain, on average, only 11% of current area. <i>New Zealand:</i> Fragmented native forests of drier lowland environments in Northland, Waikato, Manuwatu, and in the east from East Cape to Southland are likely to be the most vulnerable, while beech forests on cooler sites less vulnerable; Any increases in fire frequency are likely to have significant impacts because few species have adaptations to survive or tolerate fire.	(Hilbert <i>et al.</i> 2001; Hilbert <i>et al.</i> 2004; McGlone 2001; MfE 2001a; Williams <i>et al.</i> 2003)
Rangelands	Major changes in vegetation composition of Australian rangelands (75% of total land area) are likely to occur via shifts in rainfall pattern; increased runoff distribution is likely to favour establishment of woody vegetation and encroachment of unpalatable woody shrubs in many areas; interactions between CO ₂ and water supply are likely to be critical.	(Hughes 2003)
Alpine regions	<i>Australia:</i> 10-40% reduction in the area of snow cover likely by 2020 and a 22-85% reduction by 2050; species vulnerable due to limited extent of high altitude	Hennessy <i>et al.</i> 2003,

	refuge and sensitivity to snow cover duration and depth; likely expansion of woody vegetation into areas currently dominated by herbaceous species; reduction in area of heath and tall alpine herbfields due to altered nutrient cycling is possible; changed fire regimes in alpine peatlands likely due to drying; some alpine vertebrates likely to be at risk due to dependence on snow cover during hibernation; greater reliance on artificial snow making likely to have negative impacts on alpine species and communities. <i>New Zealand</i> : 3°C temperature likely to result in loss of 33-50% of indigenous vascular plant taxa; additional losses are likely from submersion of alpine islands with about 80% eventually disappearing.	(Halloy; Mark 2003; Pickering <i>et al.</i> 2004; Whinam <i>et al.</i> 2003)
Australian heathlands	Narrow geographic and climatic ranges of many southwestern endemic plant and animal species likely to increase vulnerability to even modest (0.5-1°C) warming.	(Hughes 2003)
Wetlands and estuaries	<i>Australia</i> : Low relief wetlands such as Kakadu National Park at risk from sea level rise; increased drought frequency highly likely to lead to reduced river flows with impacts on freshwater biota; these effects likely to interact with existing stresses such as salinity, increased nutrient input and altered flows; regional scenarios of reduced rainfall and increased evaporation in the Macquarie Valley area indicate mean annual runoff to Burrendong Dam likely to be reduced 12-32% by 2030 resulting in an annual reduction in water flow to the Macquarie Marshes; subsequent reduction in both semi-permanent and ephemeral wetland vegetation by 20-40% by 2030; flow on effects on bird breeding habitat and behaviour likely. <i>New Zealand</i> : An average of 7.4 lakes, wetlands and lagoons per 100 km of coastline likely to be affected by salinization as a result of a 1 m rise in sea level; increased salinity during saltwater intrusion is very likely to decrease species richness and be exacerbated by any decrease in freshwater inputs; in the longer term, these habitats are likely to become suitable for more estuarine and marine taxa and colonisation and shift to estuarine patterns of functioning.	(Hennecke <i>et al.</i> 2004; Hughes 2003; Schallenberg <i>et al.</i> 2003)
Marine species & systems	Phytoplankton production rate and biomass in the eastern tropical Pacific Ocean known to decrease during warm El Niño periods and increase in La Niña; ENSO also impacts on species composition of plankton by disproportionately affecting the biomass of large phytoplankton more than small, leading to cascading impacts on marine trophic structure. Coral reefs such as the Great Barrier Reef (see Box 11.1) and Ningaloo Reef in Western Australia very likely to be sensitive to temperature changes, sea level rises and changes in ocean chemistry	(Hughes 2003; Watters <i>et al.</i> 2003) Glover and Smith 2003
Sub-Antarctic Islands	Increased mortality of burrowing petrels, increased invasions by disturbance-tolerant alien plants, increased abundance of rats, mice and rabbits likely.	(Frenot <i>et al.</i> 2005)

Box 11.1: Climate change and the Great Barrier Reef

The Great Barrier Reef (GBR) is the largest natural feature on earth, stretching more than 2,100 km along the northeast coast of Australia. The GBR World Heritage Area is the world's largest marine protected area. It includes 2900 coral reefs built from over 390 species of corals. It contains over one third of the world's soft coral species, over 1500 species of fish and is an important breeding ground for seabirds and other marine vertebrates such as the humpback whale. Tourism associated with the GBR generated over US\$3.6 billion in 2004-5 and provided employment for approximately 63,000 people.

1 Rising sea level is likely to be beneficial for corals on some reef flats and favours fast-growing
2 species. Declining aragonite saturation (a measure of the availability of ions required for corals to
3 form calcium carbonate skeletons) as a result of increased atmospheric CO₂ concentration is likely to
4 be a serious issue, with rates of calcification projected to fall by as much as 40-60% under a doubling
5 of pre-industrial levels of CO₂. Increased cyclone intensity is likely to cause physical damage to reef
6 structure and increased intensity of rainfall events leading to flooding, with high sediment and
7 nutrient loads, can kill corals near river mouths.

8
9 Of greatest concern, however, is that rising sea surface temperatures (SSTs) is highly likely to
10 increase stress to corals, leading to bleaching and death. SSTs only 0.8°C above the long-term
11 summer maxima can cause mass coral bleaching. In cases of mild exposure, corals mostly recover
12 but if temperatures of 2-3°C above long-term maxima result in widespread mortality. Two recent
13 mass bleaching events (in the austral summers of 1998 and 2002) affected over 60% of all coral reefs
14 within the Great Barrier Reef Marine Park. The 2002 event, the worst on record, was also associated
15 with an outbreak of coral disease that increased mortality of some species. At the worst affected sites,
16 most branching and other fast-growing corals were killed, whilst the older, massive corals had higher
17 rates of survival. Bleaching seriously affected both offshore and inshore reefs, making it more
18 extensive than 1998. Even within reefs, there were complex patterns of bleaching severity related to
19 habitat, water depth and species composition. Even under best-case projections (B2), the current
20 thermal limits for coral bleaching are very likely to be exceeded on most reefs in the GBR on an
21 annual basis by 2030-2050. Under these scenarios, tropical and subtropical reefs are likely to be
22 maintained in an early successional state or shift to communities dominated by organisms other than
23 corals, such as macroalgae or seaweed communities. These changes are likely to be exacerbated by
24 reduced water quality, flooding and over-exploitation of key species. While recent surveys in the
25 Indo-Pacific indicate that algal symbionts in reefs recently affected by high temperatures are starting
26 to show an adaptive response, no similar data are yet available for the GBR.

27
28 Sources: Baker et al. (2004), (Berkelmans *et al.* 2004), (Hoegh-Guldberg 2004), (Jones *et al.* 2004),
29 Hoegh-Guldberg *et al.* (2005), Hoegh-Guldberg et al 1999.

31 32 33 **11.4.2 Agriculture**

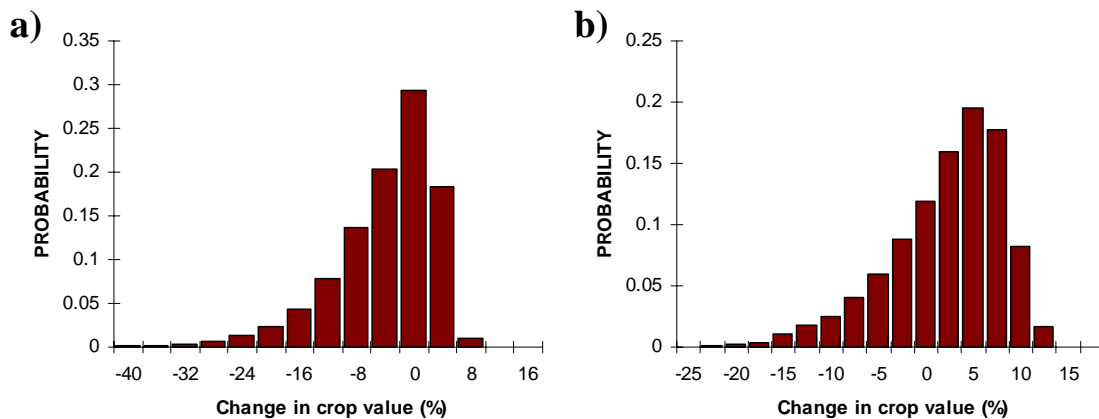
34 35 **11.4.2.1 Cropping**

36
37 Cropping is the most important agricultural activity in Australia. A significant new finding is that
38 adaptations are likely to reduce vulnerability. In New Zealand, for C₃ crops such as wheat, the CO₂
39 response is likely to more than compensate for higher temperatures (Jamieson *et al.*, 2000; Jamieson
40 and Semenov, 2000), but the net impact depends on availability of irrigation water (Bright 2004). For
41 maize production, reduction in growth duration reduces crop water requirements, providing closer
42 synchronisation of development with annual climatic variations (Sorensen *et al.* 2000). Impacts of
43 climate change on pests and diseases of Australian or New Zealand crops remain uncertain.
44 Land degradation is likely to be affected by climate change. Elevated atmospheric CO₂
45 concentrations slightly reduces crop evapotranspiration, increasing the risk of water moving past the
46 root zone of crops (deep drainage) so exacerbating three of Australia's most severe land degradation
47 problems: waterlogging, soil acidification and dryland salinity. Scenarios of climate and CO₂ change
48 for Western Australia show that deep drainage is likely to increase slightly (1 to 10% at 550ppm CO₂)
49 under elevated CO₂ concentrations, but when higher temperatures (+3°C) were also simulated this
50 was reversed (-8 to -29%) (van Ittersum *et al.* 2003). Deep drainage was greatly reduced (by up to
51 94%) in the low precipitation scenarios. However, the changes in deep drainage were not necessarily

1 correlated with changes in productivity or gross margin and so scenarios had both ‘win–win’ and
 2 ‘lose–win’ outcomes.

5 The Australian wheat industry

7 A risk assessment of climate change for the Australian wheat industry was undertaken for the full
 8 range of CO₂ and climate IPCC SRES scenarios (Howden and Jones 2004) in conjunction with a well
 9 tested crop simulation framework (APSIM; Keating *et al.*, 2003) recently validated for its CO₂
 10 response (Reyenga *et al.* 1999) (Asseng *et al.*, 2004). Regional impacts varied markedly, with
 11 Western Australian regions likely to have significant yield reductions by 2070 (increased yield very
 12 unlikely). In contrast, regions in north-eastern Australia were likely to have moderate increases in
 13 yield (unlikely to have substantial yield reductions). Nationally, while median crop yields dropped
 14 slightly (without adaptation) there is a substantial risk to the industry as maximum potential increases
 15 in crop value are limited (to about 10% or US\$0.3 billion p.a.) but maximum potential losses are
 16 large (about 50% or US\$1.4 billion p.a.). Adaptation through changing planting dates and varieties is
 17 likely to be highly effective: the median benefit was about US\$158 million p.a. but with a range of
 18 US\$70 million to over US\$350 million p.a.



32 Change in national gross value of the wheat crop from historical baseline values (%) for the year
 33 2070 as a result of increase in CO₂ and change in temperature and rainfall a) without adaptation and
 34 b) with adaptations of changed planting windows and varieties.

36 Climate change is likely to change land-use in southern Australia with cropping becoming unviable
 37 at the dry margins if rainfall is reduced substantially, even though yield increases from elevated CO₂
 38 partly offsets this effect (Reyenga *et al.* 2001) (Luo *et al.*, 2003). Cropping is likely to expand into
 39 the wet margins as rainfall declines. In contrast, in the north of Australia, climate change and CO₂
 40 increases are likely to enable the recent expansion of cropping to persist (Howden *et al.* 2001a).

42 Grain quality is likely to also be affected. Firstly, increased levels of CO₂ reduce grain protein levels
 43 (Sinclair *et al.* 2000) requiring significant increases in nitrogenous fertiliser application or increased
 44 use of pasture legume rotations to maintain grain protein levels (Howden *et al.* 2003c). Secondly,
 45 there is increased risk of development of undesirable heat shock proteins in wheat grain in the
 46 northern cropping zones and in the southern cropping zones with temperature increases greater than
 47 4°C (Howden *et al.* 1999c).

51 11.4.2.2 Horticulture

1 Australian temperate fruits and nuts are all likely to be affected by prospective climate changes
2 identified in section 11.3.1 because they require winter chill or vernalisation. Like tropical fruit, they
3 are also strongly affected by disease and severe hail, wind and rain damage. These crops are likely to
4 be threatened where irrigation water availability is reduced. Climate change is likely to make a major
5 horticultural pest (the Queensland fruit fly; *Bactrocera tryoni*) a significant threat to southern
6 Australia. Warmings of 0.5, 1.0, and 2.0°C suggest expansion from its endemic range in the north
7 and north-east across most of the non-arid areas of the continent, including the currently-quarantined
8 fruit fly free zone (Sutherst *et al.* 2000). Apple, orange and pear growers in endemic Queensland fruit
9 fly areas are likely to have cost increases of 42–82%, compared with 24–83% in the current
10 quarantine zone.

11
12 Overall, for New Zealand, warmer summer temperatures are likely to increase plant vegetative
13 growth at the expense of fruit growth and quality (Richardson *et al.* 2004). Kiwifruit budbreak is
14 likely to occur later, reducing flower numbers and yield in northern regions (Hall *et al.*, 2001).
15 Production is likely to become uneconomic in Northland by 2050 because of lack of winter chilling,
16 and be dependent on dormancy-breaking agents and varieties bred for warmer winter temperatures in
17 the Bay of Plenty. In contrast, dry matter production is likely to increase in more southern regions of
18 Nelson, Marlborough and Hawke’s Bay (MfE 2001a). Apples, the other major New Zealand
19 horticultural crop, are very likely to flower and reach maturity earlier, especially after 2050. Warmer
20 summers are likely to also affect fruit size (Austin *et al.*, 2000).

21
22 Viticulture is rapidly expanding in Australia and New Zealand.. Earlier ripening dates and possible
23 reductions in grape quality are likely (Webb 2003). In cooler Australian climates, warming is likely
24 to allow alternative varieties to be grown. Distribution of vines is likely to change depending upon
25 suitability compared with high yield pasture and silviculture (Hood *et al.*, 2002). With warming in
26 New Zealand, red wine production is likely to spread south and yields increase (Salinger 1990).
27 Higher CO₂ concentrations increase vine growth and shading, potentially reducing fruitfulness if
28 canopy management is not adapted.

29 30 11.4.2.3 Pastoral and rangeland farming

31
32 In New Zealand, higher temperatures and CO₂ concentrations and less frost are very likely to
33 increase annual pasture production by 10 to 20% by 2030 especially in cooler regions, although gains
34 decline after that (MfE 2001a). Increased drought risk is virtually certain to decrease pasture growth
35 for dryland farms, requiring the adoption of numerous coping strategies to reduce vulnerability to
36 extremes such as more flexible stocking policies, new drought resistant pasture species and
37 installation of more water reservoirs. Subtropical pastoral species with lower feed-quality such as
38 *Paspalum* are likely to spread steadily southwards, reducing productivity (Clark *et al.*, 2001). Higher
39 temperatures are likely to increase the range and incidence of pest and diseases.

40
41 A rise in CO₂ concentration is likely to increase pasture growth in Australia, particularly in water-
42 limited environments (section 5.3.2). However, an average 10% reduction in rainfall counters this
43 effect nationally (Howden *et al.* 1999c, (Crimp *et al.* 2004). A 20% reduction in rainfall is likely to
44 reduce pasture productivity by an average of 15% and live-weight gain in cattle by 12% and
45 substantially increase variability in stocking rates, so reducing farm income (Crimp *et al.* 2004). The
46 nutritional value of pastures is likely to change. Elevated concentrations of CO₂ significantly
47 decrease leaf N-content, increase non-structural carbohydrate, but cause little change in digestibility
48 (Lilley *et al.* 2001). In production systems with high nitrogen forage (e.g. temperate pastures), these
49 effects are likely to increase energy availability, nitrogen processing in the rumen and productivity.
50 In contrast, where nitrogen is chronically deficient such as rangelands, elevated CO₂ and warming
51 are likely to exacerbate existing problems by decreasing non-structural carbohydrate concentrations

1 and digestibility, particularly in tropical (C₄) grasses. Doubled CO₂ concentrations and increased
2 temperature are likely to result in only limited changes in native C₃ and C₄ grass distributions
3 (Howden *et al.*, 1999a).

4
5 Climate changes are likely to increase degradation problems such as erosion and salinisation (section
6 11.4.2.1) and increase the potential distribution and abundance of exotic weeds (e.g. *Acacia nilotica*
7 and *Cryptostegia grandiflora*; Kriticos, 2003a,b) and native woody species (e.g. *A. aneura*, Moore *et*
8 *al.*, 2001). This potentially increases competition with pasture grasses, reducing livestock
9 productivity. However, the same CO₂ and climate changes are likely to provide increased
10 opportunities for woody weed control Howden *et al.*, 2001b).

11
12 Heat stress already affects many livestock in Australia, reducing production and reproductive
13 performance and enhancing mortality (section 5.3.2). Increased thermal stress on animals is very
14 likely (Howden *et al.*, 1999b). In contrast, reduced cold-stress is likely to reduce lamb mortality in
15 both countries, but there has been little research on this topic. Impacts of the cattle tick (*Boophilus*
16 *microplus*) on the Australian beef industry are likely to increase and move southwards (White *et al.*
17 2003). In the absence of adaptation measures, losses in live weight gain are projected to increase by
18 20% in 2030 and by 230% in 2100.

19 20 21 **11.4.3 Forestry**

22
23 Plantation forestry is expanding rapidly in Australia (i.e. over 50,000 hectares per year) adding to the
24 existing native forest area of 18M ha. Additional plantings are occurring to ameliorate land
25 degradation problems such as erosion, waterlogging, and salinisation. Research since the TAR
26 confirms that climate change is likely to have both positive and negative impacts. Productivity of
27 exotic softwood and native hardwood plantations is likely to be increased by CO₂ fertilisation effects,
28 although the amount of increase can be limited by environmental feedbacks such as nutrient cycling
29 (Kirschbaum 1999a,b; Howden *et al.* 1999d).

30
31 Where trees are not water-limited, warming expands the growing season in southern Australia, but
32 increases fire hazard (section 11.3.1.2) and pest damage is likely to negate some gains. The
33 anticipated reductions in average rainfall (section 11.3.1) are very likely to reduce productivity and
34 increase fire risk, whilst increased rainfall intensity is likely to exacerbate soil erosion problems and
35 pollution of streams during forestry operations. In *Pinus radiata* and *Eucalyptus* plantations, fertile
36 sites are likely to have increased productivity for moderate warming, whereas infertile sites are likely
37 to have decreased production.

38
39 Plantation forestry (mainly *P. radiata*) in New Zealand is increasingly economically important. The
40 growth rates of these trees are likely to increase with carbon fertilization and wetter conditions in the
41 south and west. Studies of pine seedlings confirm increases of 20%, but older trees showed very little
42 response (MfE 2001a). East coast areas of the North Island are likely to experience growth
43 reductions under projected rainfall decreases. However, this is about as likely as not to be offset by
44 increased water use efficiency with elevated CO₂. Warmer temperatures are about as likely as not to
45 also increase the occurrence of upper mid-crown yellowing with drying, and fungal diseases in
46 warmer winters.

47 48 49 **11.4.4 Freshwater resources**

1 Drought frequency and intensity are likely to increase in Australia and New Zealand (section 11.3.1).
2 Changes in streamflow and salinity in five parts of the Murray-Darling Basin were examined for two
3 mid-range SRES scenarios (A1 and B1) with mid-range climate sensitivity (Beare and Heaney 2002).
4 By 2050, streamflow dropped 10-19% (B1) or 14 to 25% (A1) and salinity changed -6 to +16 (B1) or
5 -8 to +19% (A1). By 2100, streamflow declined 16-30% (B1) or 24-48% (A1) and salinity changed -
6 16 to +35% (B1) or -25 to +72% (A1).

7
8 By 2030, inflows to Burrendong dam, near Sydney, are likely to change by +10% to -30% across all
9 SRES scenarios, but the 90% confidence interval was 0% to -15% (Jones and Page, 2001). In 2070,
10 the 90% confidence interval was 0% to -35%. For a 10% increase in tree cover in the uplands, a 17%
11 reduction in Burrendong dam inflows is likely (Herron *et al.*, 2002). A mid-case climate change
12 scenario for 2030 caused an additional 5% reduction.

13
14 Using the (CSIRO 2001) climate change scenarios for 2030, changes in Australian annual runoff are
15 likely to be -5 to +15% on the northeast coast, $\pm 15\%$ on the east coast, a decline of up to 20% in the
16 southeast, $\pm 10\%$ in Tasmania, a decline of up to 25% in the South Australian Gulf, and -25 to +10%
17 on the southwest coast (Chiew; McMahon 2002). Reductions in mean annual flow and system yield
18 for Benalla (Victoria) are 12% and 8% in 2030, respectively (Maheepala and Perera, 2002).

19
20 The implications of climate change for the water, sewerage and drainage systems of Melbourne,
21 Australia, have been assessed (Howe *et al.* 2005). Results from ten climate models driven by the
22 SRES B1, A1B and A1F scenarios were used to encompass a wide range of climate scenarios, i.e.
23 warming of 0.3-1.0°C and a rainfall decrease of 0-5% by 2020, and a warming of 0.6-2.5°C a rainfall
24 change of -13% to 1% by 2050. The study indicated that average streamflow is likely to be reduced
25 3-11% by 2020, and 7-35% by 2050. Planned demand-side and supply-side actions are likely to
26 alleviate water shortages through to 2020. Sufficient capacity exists within the sewerage and
27 drainage systems to accommodate moderate increases (up to 20%) in storm rainfall totals with
28 minimal surcharging.

29
30 A rainfall-runoff model was applied to three different catchments upstream of Sydney and Canberra
31 under doubled CO₂ conditions (Schreider *et al.* 2000), showing increases in the magnitude and
32 frequency of flood events. For the Albert-Logan Rivers system near the Gold Coast, each 1%
33 increase in rainfall intensity produced a 1.37% increase in peak runoff (Abbs *et al.* 2001). However,
34 increases in runoff and flooding are partially offset by the reduction in average rainfall, which
35 reduces soil wetness prior to storms. An integrated modelling system which couples a high-resolution
36 atmospheric model of storm events with a non-linear flood event model has been applied to the
37 historic case of flooding around the Gold Coast by Cyclone Wanda. If the same event occurred with a
38 10-40 cm rise in mean sea-level by the year 2050, the number of dwellings and people affected
39 increases to 3-18% (Abbs *et al.*, 2001).

40
41 In New Zealand, two key potential flow regime changes are identified in the climate change
42 scenarios. Firstly, rain events are likely to be more intense, leading to greater runoff during storms,
43 with lower proportions of water in rivers between events. This results in greater erosion, both of land
44 surfaces and in-river redistribution of sediment (Griffiths, 1990), and a diminution of the protection
45 afforded by stop banks. Secondly, there are benefits for the hydro-electricity system. More runoff is
46 likely to be available for generation in winter, when it is most needed for heating. This reduces
47 dependence on hydro storage lakes to transfer generation into the next winter. Increased drought
48 frequency is likely in eastern areas of the country, with potential losses in agricultural production
49 (McKerchar and Henderson, 2003).

50

1 Flood risk using 2050 climate scenarios for Auckland indicate only minor flood level differences
2 within numeric modelling accuracy were observed between existing and future climate rainfall
3 simulations (Dayananda *et al.*, 2005). Future scenarios of groundwater behaviour for Auckland City
4 (Namjou *et al.*, 2005) indicate that the aquifer has spare capacity to accommodate recharge under all
5 scenarios examined. Base flows in principal streams and springs are very unlikely be compromised
6 unless many dry years occur in succession. A major issue to resolve will be to find practical ways of
7 capturing and injecting large volumes of stormwater generated over short, high intensity storms.
8 Little quantitative information is available about potential change in flood risk or groundwater supply
9 in Australia.

10
11 By 2020, the average salinity of the lower Murray River in Australia is likely to exceed the 800 EC
12 threshold set for desirable drinking water about 50% of the time. However, a comprehensive
13 assessment of the impacts of climate change, revegetation policies for ameliorating salinity and
14 sequestering carbon, and water pricing and trading policies on water resources has not been carried
15 out.

16
17 Eutrophication is a major water quality problem in Australia (SOE 2001) (Davis 1997). Toxic algae
18 can pose a threat to human health, for both recreation and consumptive water use, and can kill fish
19 and livestock (Falconer, 1997). Simple, resource-neutral, adaptive management strategies, such as
20 flushing flows, have the potential to substantially reduce the occurrence and duration of algal blooms
21 in a weir pool in the lower Murrumbidgee River under present and projected future conditions (Viney
22 *et al.* 2003).

23 24 25 **11.4.5 Coasts**

26
27 About 80% of the population in the region lives within 50 km of the coast (Hugo 2004). There has
28 been a dramatic increase in non-metropolitan population growth and associated development in both
29 Australia and New Zealand, where the phenomena has been termed ‘sea change’ (Burnley; Murphy
30 2004). This has created demand for coastal infrastructure and coastal protection measures which is
31 virtually certain to be placed under further pressure with climate change-induced impacts.

32 The prospect of a rise in sea-level, and changes to the patterns of mid-latitude low pressure systems,
33 cold fronts, ocean currents, ocean temperature and storm surges are likely to create differences in
34 regional exposure to these events (Walsh 2002). Between 1980-2030 in Pegasus Bay (New Zealand),
35 erosion of up to 50m is likely near the Waipara River with 50% less southerly waves, and erosion of
36 up to 100m near the Waimakarri River with 50% less river sand (Bell *et al.* 2001). Northern
37 Australian coasts are likely to be affected by increased tropical cyclone intensity with predictions of
38 10 hPa deeper average intensities for the more intense cyclones under enhanced greenhouse
39 conditions (Walsh; Ryan 2000). By 2050, the average area of Cairns (Australia) inundated by storm
40 surge events with a return period of over 100 years is likely to more than double (McInnes *et al.*
41 2003) (see also Chapter 6). A major impact in this region is likely to be on coral reefs, particularly
42 the Great Barrier Reef (see 11.4.1). In New Zealand, recent emphasis has been placed on providing
43 information, guidelines and tools to local authorities for risk-based planning and management of
44 coastal hazards as affected by climate change (Bell *et al.* 2001) (MfE, 2004).

45
46 Sea-level rise is virtually certain to cause coastal inundation, erosion, loss of wetlands and
47 mangroves, and salt-water intrusion into freshwater sources (MfE, 2002), in addition to impacts on
48 infrastructure, coastal resources, and existing coastal management programs. Links between beach
49 erosion and the SOI have been demonstrated over a 26 year period at Narabeen Beach, Australia
50 (Ranasinghe *et al.* 2004). Distributive process modelling has been used to assess sea-level rise in
51 South Australia (Bryan *et al.* 2001). For Collaroy/Narabeen beach (NSW), a sea level rise of 0.2m by

1 2050 leads to coastal recession of up to 22 metres, and when combined with a 50-year storm the
2 recession exceeds 110 m, giving a loss of US\$172 (Hennecke *et al.* 2004). Investigations for
3 metropolitan coasts reveal the increased cost of protection on existing management systems (Bell *et*
4 *al.* 2001). In Australia, for example, it has been estimated that a 0.5m sea-level rise increases the cost
5 of sand replenishment program on the Adelaide metropolitan coast by A\$0.5 million (US\$0.35
6 million) per annum (DEH, 2005). Coasts are also likely to be affected by changes in fluvial sediment
7 loads both from climate-related changes in the intensity and seasonality of river flows carrying
8 pollution and sediment, and future impacts of river regulation (Kennish, 2002).

9
10 Notwithstanding debate over indigenous rights in the coastal zone (Schnierer 2002), vulnerability
11 studies in northern Australia indicate large-scale changes in coastal and wetland environments
12 associated with climate change. These are very likely to affect traditional Aboriginal occupants (Eliot
13 *et al.* 1999). In New Zealand, the government has announced that it will legislate to remove Maori
14 customary title in the foreshore and seabed (Ruru 2004). Thus in both countries uncertainty of
15 climate change impacts on coastal indigenous communities is partly related to issues of indigenous
16 rights in the coastal zone (see section 11.4.1 on ecosystems and section 11.4.6 on fisheries).

17
18 Australian and New Zealand studies on coastal vulnerability have underlined some of the problems
19 with the suitability of the original IPCC approach to a ‘Common Methodology’ for coastal
20 vulnerability assessment (Harvey *et al.*, 1999). Subsequently, there has been very little use of
21 globally applicable vulnerability assessment methods in the region, although they have contributed to
22 the use of local and regional studies and scaling-up techniques using the SURVAS methodology
23 (McLean, 2001). At the regional and local level there have been coastal vulnerability studies in both
24 countries, e.g. 21% of the Tasmanian coast is at risk from predicted sea-level rise in the next 50-100
25 years (Sharples 2004).

26 27 28 **11.4.6 Fisheries**

29
30 The key variables expected to drive the climate change impacts on marine fisheries are changes in
31 ocean temperature, currents, winds, nutrient supply, and rainfall. Of the four biological attributes
32 likely to be impacted by climate change, most of the known relationships allow assessments
33 regarding changes in the distribution and abundance of exploited species. Changes in the remaining
34 three areas, phenology and physiology, community composition and interactions, and community
35 structure and dynamics (including productivity) are much less certain. Few impact studies have been
36 undertaken, so this assessment mostly relies on extrapolation of observed relationships between
37 climate variability and fisheries. Overall, several authors believe future climate change impacts are
38 likely to be greater for temperate endemics than for tropical species (Francis 1994; Francis 1996) and
39 on coastal fisheries relative to pelagic fisheries (Matear and Hobday 2005).

40
41 Changes in sea-surface temperature or currents are likely to impact the distribution of several
42 commercial pelagic (e.g. tuna) fisheries around Australia and New Zealand (Lehodey *et al.* 1997;
43 Lyne, 2000; (Sims *et al.* 2001) Matear and Hobday 2005). In particular, circulation changes may
44 increase the availability of some species and reduce others, as has been demonstrated in Western
45 Australia with Leeuwin current relationships and ENSO. Fishers will have to respond with relocation
46 or face reduced catches at a location. Recruitment is likely to be reduced in cool-water species based
47 on evidence for New Zealand species such as hoki where recruitment has been correlated with cold
48 autumn and winter conditions associated with El Niño events (Bull; Livingston 2001) and red cod
49 (Beentjes; Renwick 2001) (Annala *et al.*, 2004). In contrast, relatively high recruitment and faster
50 growth rate of juvenile and adult snapper have been correlated with warmer conditions during La
51 Niña events (Francis 1994) (Maunder and Watters, 2003). A similar pattern of recruitment has been

1 found for gemfish (Renwick *et al.* 1998). With regard to physiological changes, temperature has a
 2 major influence on the population genetics of cold-blooded animals, selecting for temperature-
 3 sensitive alleles and genotypes. In New Zealand snapper, differences in allele frequencies at one
 4 enzyme marker have been found among year classes from warm and cold summers (Smith 1979). If
 5 species cannot adapt to the pace of climate change, then major changes in distribution will be likely,
 6 particularly for species at the edge of suitable habitat.

7
 8 Fish productivity is also linked to wind regimes and ocean currents. A decline in wind due to a
 9 poleward shift in climate systems underlies recent stock declines (Koslow and Thresher, 1999)
 10 (Thresher 2002). This implies that as westerlies strengthen, stocks are likely to increase if quota
 11 management regimes are in place. With regard to productivity, reductions in upwelling of nutrients
 12 and extension of warm water along the east Australian coast may reduce krill and jack mackerel
 13 abundance, upon which many other species, including tuna, seals and seabirds are reliant.

14 15 16 **11.4.7 Settlements, infrastructure, insurance, transport and societies**

17
 18 Settlements and infrastructure, especially those near coasts, are very likely to be placed at greater risk
 19 due to sea level rise, increase in water and air temperature, more extreme rainfall and storm intensity,
 20 larger storm surges, and resulting erosion and inundation (CSIRO 2002;McInnes *et al.* 2003) (Hardy
 21 *et al.*, 2003; PIA, 2004) (high confidence). Potential impacts are summarised in Table 11.4.7.1. The
 22 planning horizon for refurbishing major infrastructure is 10-30 years, while major upgrades or
 23 replacement can be 50 to 100 years.

24
 25 The capital value of the built environment in New Zealand accounts for almost 10% of GDP. There
 26 are 1.4 million homes and 67,000 office building units. The average life of a house is 80 years and
 27 some last for 150 years or more. If buildings are not built or retrofitted now to deal with future
 28 climate, an unsustainable situation is likely to become progressively worse and present problems for
 29 future generations (O’Connell and Hargreaves, 2004). A study for New Zealand’s fourth largest city
 30 (Hamilton) shows that changes in average climate by 2030 are very likely to have little impact on
 31 infrastructure comprising water supply, transport, electricity demand and public health (Jollands *et*
 32 *al.*, 2005), especially when compared with impacts of projected population growth. However,
 33 buildings, stormwater systems and changes in extreme weather were not considered.

34
35
36 **Table 11.8: Potential impacts of climate change on infrastructure and settlements. Adapted from PIA**
37 **(2004), BRANZ (2005) and (SKM, 2005)**

Buildings	<ul style="list-style-type: none"> • Increased fire and storm damage • Structural integrity compromised – more rapid deterioration of materials • Impact on cost of construction to incorporate adaptation measures • Increased energy use for cooling of buildings and increased capital expenditure to provide additional shading, insulation and air-conditioning • Reduced energy use for heating in winter • Reduced water heating loads and costs • Flooding of buildings and underground car parks • Undermining and cracking of building foundations and footings • Increased wind loading and damage, causing airborne debris hazards • More salt-spray and corrosion in coastal areas • Reduced mould and condensation problems due to lower humidity • Impaired functioning of generators • Rising damp and associated health issues
-----------	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Structures	<ul style="list-style-type: none"> • Erosion and undermining of roads • Bridges compromised due to flood levels exceeding design capacity • Changes in water table have a detrimental impact on the foundation material, bearing capacity and footings
Services	<ul style="list-style-type: none"> • Inundation of rail systems and underground telecommunications • Suitability of ground services change in certain localities • Greater demand for health, counselling, insurance and emergency services • Loss or damage to some amenities, leisure and recreation areas • Increased demand for building and repair services
Major infrastructure	<ul style="list-style-type: none"> • Dam storage inadequate for both water supply and flood containment • Dam failure due to higher probable maximum flood • Seawalls, jetties and other coastal infrastructure at risk of erosion (undermining) or flooding • Stormwater systems unable to accommodate increased flows • Sewerage systems adversely affected by stormwater intrusion

1
2 Climate change is very likely to affect property values and investment through disclosure of
3 increased hazards, affecting the price and availability of insurance. This is of concern in coastal
4 settlements in relation to storm surges and sea-level rise, and in places subject to increased risk from
5 riverine flooding, as well as from tropical cyclones. In many jurisdictions, flood hazard liability is
6 not mandatory or is poorly determined (Yeo, 2003).

7
8 The function and capacities of major transport infrastructure, such as roads, rail, ports and airports
9 are very likely to be adversely affected by climate change (PIA, 2004). By the year 2100, for the
10 SRES A2 scenario in a CSIRO climate simulation, costs for road maintenance for Australia rise 31%
11 (Austroads 2004). Increases of 15-25% were simulated in NSW, Victoria, Western Australia and the
12 ACT, with increases of 51% in Queensland, 108% in the Northern Territory and 5% in Tasmania,
13 while a decrease of 15% occurred in South Australia.

14
15 Climate change is very likely to have implications for the economy, amenities, cultural heritage,
16 accessibility and health of communities. These include costs, injury and trauma due to increased
17 storm intensity, damage to items of cultural significance, degraded beaches due to sea-level rise and
18 larger storm surges, and higher insurance premiums (PIA, 2004).

19
20 The number of people exposed to inundation due to sea-level rise in Australia and New Zealand is
21 estimated to approximately double in the next 50 years, with substantial variation in risk according to
22 region (McMichael *et al.* 2003). In addition, immigration to the two countries is likely to rise from an
23 increase of 60,000 and 90,000 people a year from the Pacific Islands exposed to inundation by the
24 2050s (Woodward *et al.* 2001).

25
26 Most Maori people are urbanised, so the impacts on them are likely to be similar to those of other
27 New Zealanders. However, the Maori economy is largely based on primary industries. For example
28 Maori fishing is 37.1% of that sector in the NZ economy and agriculture is 7.5% (NZIER, 2003).
29 Changes in ocean temperatures and currents in the surrounding seas are very likely to affect fishing
30 incomes. The livelihoods of rural Maori are strongly linked to land-use and they face different
31 challenges, e.g. Maori have substantial forests and are becoming actively involved in integrated
32 processing of wood products. Maori decision-making processes are complex (multiple ownership and
33 ancestral whakapapa links). Their capacity to respond to threats of climate change is likely to be
34 limited, especially to increased risks of extreme weather events, and to drier conditions in Northland
35 and on the East Coast. So too is their ability to respond rapidly to new opportunities or policy shifts.
36 Climate change is likely to significantly limit Maori economic growth in agriculture compared to
37 their non Maori counterparts, who suffer significantly less constraints in accessing key resources.

1
2 Water supply for rural Maori is often limited and likely to be threatened. Uncertainties and
3 distortions generated as a result of climate change policies are likely to be damaging (Cottrell *et al.*,
4 2004, MAF, 2001). Important flora and fauna, and coastal features that have cultural and traditional
5 value to Maori are likely to be influenced by climate change, with negative impacts on the Maori
6 economy and the social and cultural positions of rural Maori people. Little research has been done
7 since the TAR on impacts for Australian indigenous people.

10 ***11.4.8 Tourism and recreation***

11
12 Tourism and recreation rely largely on the natural environment. Climate change is likely to lead to
13 winners and losers, depending on adaptive capacity. However, there are very few regional studies
14 that have assessed potential impacts. Building on research in other countries (Becken 2005:Hall
15 2005:Scott 2004:World Trade Organisation 2003), benefits are likely in areas that become drier, e.g.
16 for beach activities, viewing wildlife and geothermal activity, trekking, camping, climbing, wine
17 tasting and fishing. In areas that become wetter, negative impacts are likely for each of these
18 activities.

19
20 Changes in species distribution and ecosystems in National Parks (see 11.4.1) are likely to alter their
21 tourism appeal. Tourism is also at risk from changes in weather and climate hazards like flooding,
22 storm surges, heatwaves, cyclones, fires and droughts. These adversely affect transport, beach
23 erosion, personal safety, communication, water availability and natural attractions like coral reefs,
24 freshwater wetlands, snow, glaciers and forests.

25
26 Tourism in Queensland is likely to be affected, especially where it is dependent on the health of the
27 Great Barrier Reef (Box 11.1) and beaches (PIA, 2004). Coral bleaching and ocean acidification is
28 likely to accelerate death of corals and their replacement by algae and weed-based ecosystems which
29 are less attractive. Similarly, massive shrinkage of glaciers in New Zealand and diminishing snow
30 fields is likely to detract from tourist destinations, many of which are alpine based.

31
32 Victoria's Gippsland Lakes are an internationally recognised wildlife sanctuary under the Ramsar
33 Convention, and a major recreational and tourist attraction, with extensive development of water-side
34 estates. Shore erosion and a revegetation strategy in the Gippsland Lakes region was assessed in the
35 light of increasing salinity and projected sea-level rise due to global warming (Gippsland Coastal
36 Board, 2002). Despite projected sea-level rise, very few high-value infrastructure assets are likely to
37 be threatened by erosion, however, some wetlands separated from the main lakes by narrow sandy
38 barriers are under threat.

39
40 In Australia and New Zealand, ski resorts range from marginal to reliable. For the SRES scenarios,
41 by 2020 in south-east Australia, there is likely to be 5-40 fewer days of snow-cover per year, a rise in
42 the snowline of 30-165 metres, and a reduction in the total snow-covered area of 10-40% (Hennessy
43 *et al.*, 2003). By 2050, the duration of snow cover reduces by 15-100 days, the maximum snow depth
44 reduces by 10-99%, the snowline rises 60-570 m and the total area of snow cover shrinks by 20-85%.
45 Modelling shows that at higher resorts like Mt Perisher, Mt Thredbo and Falls Creek, a good skiing
46 surface is likely to be maintained in 90% of years by increasing the number of snow-guns by 10-
47 140% by the year 2020, with slightly greater increases at lower resorts like Mt Selwyn, Mt Buller
48 and Lake Mountain. No account was made for likely advances in snowmaking technology, water
49 limitations, and impacts on ecosystems (Pickering *et al.* 2004).

1 Similarly in New Zealand, changes in seasonal snow cover are likely to have a significant impact on
2 the ski industry. The snow line is likely to rise by 120-270 m and the amounts of snow decrease by at
3 least 30%, based on scenarios for 2080 (Fitzharris 2004: -a). Besides snow-making, there is the
4 added possibility of extending ski fields to higher elevations or to the west, where snow
5 accumulation increases in some scenarios.

8 ***11.4.9 Energy***

10 Australian energy consumption is projected to grow 50% by 2020 (see section 11.3.3) due to
11 demographic and socio-economic factors. Extrapolating these forecasts to 2030 indicates an increase
12 in peak demand by 150-200%, which climate change is likely to increase by a further 2-7%. This
13 means that about 10% of the existing asset levels are likely to be required to meet climate-related
14 peak demand in future. By 2070, peak demand is likely to increase by 250-350% with climate change
15 adding a further 4-25%, or an extra 10-50% of the existing asset levels (Howden and Crimp, 2001;
16 PB Associates, 2005).

18 Potential impacts of climate change on Australian energy infrastructure are numerous but mostly
19 pose low risk (PB Associates, 2005). Increased peak and average temperature are likely to reduce
20 generation efficiency, transmission line capacity, transformer capacity, and the life of switchgear and
21 other components. Stronger storms are likely to reduce network reliability due to structural damage
22 to lines and sub-stations. Other issues are salt build-up during extended dry periods leading to
23 blackouts and fuel shortages for biomass-fuelled generation plants from crop failure. Reduced output
24 from wind farms is possible in southern Australia due to lower average wind speeds, and excessively
25 high peak wind speeds. Higher temperatures increase the risk of spontaneous combustion of coal
26 stockpiles.

28 Projected higher wind and wave events are likely to affect offshore structures, floating facilities and
29 pipelines off northwestern Australia and in the Timor Sea. Any disruption to gas supply is very likely
30 to cause power generation restrictions for southwestern Australia, and affect liquid natural gas (LNG)
31 production trains at Karratha. LNG is produced in tropical Australia, where a warming of 1°C is
32 likely to reduce production capacity by about 0.2%. Gas transmission and distribution assets are
33 typically buried and are not sensitive to climate change, although higher temperatures can reduce
34 capacity. Increasing extreme wind speeds and wave heights delay berthing, cargo transfer and de-
35 berthing large LNG carriers, and increase the risk of grounding or collision. Assuming the climate
36 changes gradually, both the generation utilities and the equipment manufacturers are likely to have
37 enough time to adjust their standards and specifications. Some impacts are typically insured against.
38 Vulnerability to all of the above impacts is considered low, but there is medium vulnerability to a
39 decline in water supply for large-scale coal, hydro and gas turbine power generation.

41 In New Zealand, increased westerly wind intensity is very likely to enhance wind generation and
42 spill-over precipitation into major South Island hydro catchments and give more winter rain in the
43 Waikato catchment. Furthermore, increased temperatures are virtually certain to increase melting of
44 snow and add to the higher river flows in winter. This is very likely to help both hydroelectric
45 generation and cooling of Waikato geothermal power stations at the time of peak energy demand for
46 heating.

49 ***11.4.10 Human Health***

1 The projected increase in temperature by around 2050 is likely to cause an increase in heat-related
 2 deaths in Australian capital cities (McMichael *et al.*, 2003). Summer-time deaths in people aged over
 3 65 are estimated to increase from a baseline of 1100 per year, to between 1600 and 2000 per year –
 4 assuming no change in population size and structure, and no additional adaptive measures.
 5 Accounting for projected 2050 population change gives a possible 4400-6300 deaths in the capital
 6 cities (Table 11.4.10). Temperate cities are likely to experience higher heat-related deaths than
 7 tropical cities. For Auckland, mortality and hospital admissions for medical conditions peak in winter
 8 (Hope *et al.*, 2005). By 2050, however, this winter peak is likely to be overtaken by additional heat-
 9 related deaths in nearly all cities (McMichael *et al.*, 2003).

10
 11
 12 **Table 11.9:** Summary of impacts from climate change for main health outcomes around 2050 in
 13 Australia, based on the full range of SRES scenarios and three climate models

Health Outcome	Impact studied	Estimated health impact at 2050
Heat-attributable mortality	Deaths in people 65+ in the 8 Australian capital cities	Baseline = 1100 deaths per year 2050 (same population as baseline) = 1600-2000 deaths per year 2050 (projected population growth and structure) = 4400-6300 deaths per year
Dengue	Geographic area suitable for maintenance of dengue vector	Expansion of potential transmission zone south to between Mackay and Gympie (east), and Carnarvon (west).
Malaria	Geographic area suitable for maintenance of malaria	Expansion of potential transmission zone south to between Mackay and Bundaberg (east)

14
 15
 16 The first detectable changes in human health are likely to be alterations in the geographic range and
 17 seasonality of certain vector-borne infectious diseases. The potential for change in vulnerability to
 18 the emergence and establishment of mosquito-borne diseases such as malaria, Ross River virus
 19 (Tong *et al.* 2004; Woodruff *et al.* 2002) and dengue fever is likely to increase through changes in the
 20 exposure, sensitivity in both tropical and temperate latitudes, although some adaptation is expected
 21 (Sutherst 2004). Unless there is a dramatic deterioration in the public health response, it is unlikely
 22 for malaria to become established in Australia (McMichael *et al.* 2003). Dengue, however, presents a
 23 greater threat to Australia: the climate of the far north already supports *Aedes aegypti* (a mosquito
 24 that transmits the dengue virus), and outbreaks of dengue have occurred with increasing frequency in
 25 Cairns, Townsville and Charters Towers over the past decade. The trend of increasing population in
 26 northern parts of Australia increases the risk (a total of 0.3-0.5 million in 2020, and 0.8-1.6 million in
 27 2050) (McMichael *et al.* 2003). In New Zealand, parts of the North Island are likely to become
 28 receptive to populations of the major mosquito vector of dengue fever, while much of the country
 29 becomes receptive to other less efficient vector species (de Wet *et al.*, 2001, Woodward *et al.*, 2001).
 30 The risk of dengue is likely to remain below the threshold for local transmission beyond the 2050s
 31 (McMichael *et al.*, 2003).

32
 33 Warmer temperatures and increased rainfall variability are predicted to increase the intensity and
 34 frequency of summer-time (salmonella) food-borne (D'Souza *et al.*, 2004) and water-borne disease
 35 (Hall *et al.*, 2002) in both countries. Indigenous people living in remote communities are likely to be
 36 at increased risk due to their poor living conditions and access to services. An increase of 10% in the
 37 annual number of diarrhoeal admissions among Aboriginal children living in the central Australian
 38 region is predicted by 2050 (McMichael *et al.* 2003). The impacts on aeroallergens and
 39 photochemical smog in cities are uncertain.

11.4.11 Synthesis

Assessment of the information given in this section leads to the conclusion that the impacts of climate change are likely to give rise to six key vulnerabilities in the Australia and New Zealand region, assuming no adaptation. These are given in Table 11.4.11.1. Impacts of climate change are likely to become critical once warming exceeds 2°C. Depending on SRES scenario, this is likely to occur by as early as 2050 or as late as 2100. However, adaptation has the potential to alleviate or delay vulnerability. Also, some parts of the region are likely to be more affected than others, because of the specific nature of the impact of climate change, the nature of economic activity and/or presence of large populations. These “hotspots” are discussed further in section 11.7

Abrupt or nonlinear responses to climate change cannot be discounted and are identified in the TAR (Pittock and Wratt, 2001), along with confidence levels and possible timing. Most have low probability of occurring, but their potential impacts are serious. Any sudden reduction in bottom-water formation in the Southern Ocean and alteration in ocean circulation in the seas around Australia and New Zealand is likely to lead to chemical, dynamical, and biological changes and vastly changed marine ecosystems and fisheries. Faster than expected melting of Greenland and West Antarctic ice sheets is likely to raise mean sea level by more than one metre, threatening growing coastal populations and infrastructure. A sudden increase in frequency of cyclones and subtropical depressions from a regime switch in ENSO and the PDO is likely to lead to unexpected flooding and erosion.

Table 11.10: Six key vulnerabilities (assuming no adaptation)

System	Impacts	Description/Criteria	Critical Level	Comment
Natural systems	Coral reefs, rainforests, wetlands, montane biomes, snow and glaciers	Climate change very likely to interact and exacerbate existing stresses such as habitat loss and fragmentation. Considered potentially catastrophic (complete replacement of the coral community by algal-dominated community). Substantial species extinctions are very likely.	1-2°C for coral reefs and for some rare species or those with narrow tolerances, Further exponential glacier retreat.	These impacts mean loss of biodiversity, changes in tourism and runoff.
Water security	Decreased river flows, depleted groundwater resources	All Australian capital cities (except Darwin), Auckland and many southern regional centres have experienced low water storage levels since at least 2000, and Perth and Sydney are building desalination plants. Climate change projections for these regions indicate further declines in water supply are <i>likely</i> . Governments and water managers are now including climate change in water resource planning.	A1 and B1 SRES scenarios give a 10-25% reduction in river flow in the Murray-Darling by 2050	In many regions competition for water is already severe. Climate change virtually certain to exacerbate this
Fire and drought	Less rainfall and higher evaporation.	Implications for the economy, social systems and ecosystems, especially dryland agriculture, freshwater wetlands and both rural and indigenous communities. Increased drought frequency and/or intensity very likely to increase fire risk	A 2°C warming by 2080 is projected to result in widespread increase in drought frequency.	Very likely to affect natural and managed systems, including urban areas

Coastal comm.-unities	Sea level rise and storm surges	Accelerating coastal development is exacerbating the risk to lives and property from projected climate and sea level change, particularly increased storm surges and rates of erosion in the short to medium term (2020-2050).	For example, by 2050, the area of Cairns inundated by a 1 in 100 year storm surge is projected to double.	Virtually certain to affect thousands of kilometres of coastline
Bio-security	Higher temperatures	Invasive /incurive species and disease vectors increase (includes both human and animal health, agriculture, forestry and natural ecosystems).	Not known	Stresses other than climate are important
Critical infrastructure and threats to life	Extremes, especially increases in high intensity rainfall, floods and heat waves	Over-topping of hydrodams – includes glacier-lake outburst floods (e.g. in NZ Southern Alps a 30% increase in precipitation by 2080). Increasing threat to floodplain settlements behind protection dykes. Urban drainage is likely to be inadequate. Impacts of heatwaves on lives, urban infrastructure and energy demand.	Not known	Infrastructure design limits are likely to be threatened by more frequent and more intense extreme events

1
2

3 Impacts of climate change are likely to appear abruptly when critical threshold conditions are
4 crossed. Examples include:

- 5 • sudden increases in vector-borne diseases caused by more favourable conditions
- 6 • rapid shifts in land use, landscape and population over large areas caused by both better
7 farming conditions in some regions (benefits of increased CO₂, warming and less frost) and
8 by poorer conditions in others (increased frequency of bad years especially droughts, and
9 onset of salinity)
- 10 • collapse of glaciers leading to mountain slope failure and outburst floods
- 11 • loss of species already threatened by degrading habitat.

12
13

14 **11.5 Adaptation practices, options and constraints**

15
16

17 *11.5.1 Adaptation concepts and strategies*

18

19 Specific adaptation practices or options are automatic or planned activities that reduce adverse
20 effects of climate change and create opportunities. From a broader view, adaptation can also be
21 construed as a *dynamic process* that evolves over time and involves five major components necessary
22 for implementing specific practices or options. Figure 11.2 describes the process, but has also been
23 used as a framework to identify constraints and to promote adaptation in New Zealand, Australia and
24 the Pacific island region (MfE 2004a; Warrick 2004a; Warrick 2000b) (Hay 2004). The process
25 applies at national, regional and local levels of organisation. How well are Australia and New
26 Zealand engaged in the adaptation process?

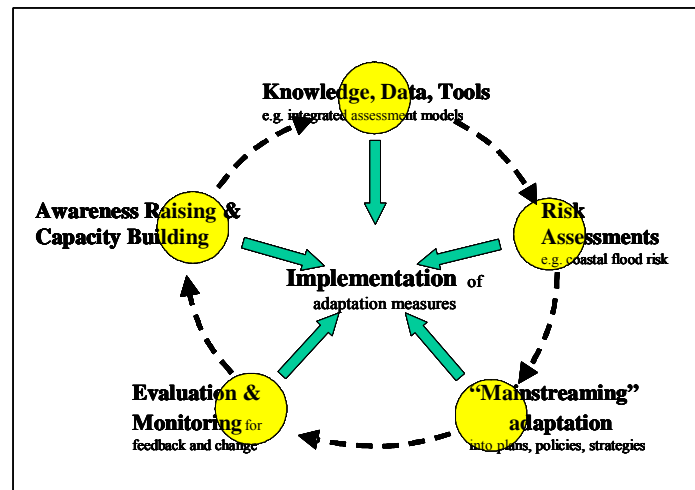


Figure 11.2: Adaptation as a process (MfE 2004a; Warrick 2000a).

Knowledge, data and tools related to climate change and variability (including extremes) and their impacts: Both countries have strong science traditions, which are firmly supported, politically and financially. The New Zealand Foundation for Research, Science and Technology, for example, devotes an entire portfolio of research funding to the Global Change area (FRST 2005). These and other government funds underpin capacity for research related to climate change adaptation that is embedded, to varying degrees, within nine Crown Research Institutes and eight Universities. The Australian Climate Change Science Program and the National Climate Change Adaptation Program are supported by the Australian Greenhouse Office (AGO). These programs address many of the objectives of the National Greenhouse Strategy (Allen Consulting Group, 2005). Australian State and Territory governments also have greenhouse strategies and action plans that include research. Great strides have been made in both countries that directly support decisions to reduce risk.

Risk assessments that translate scientific data and knowledge into information relevant to decision-making on adaptation. Assessments of impacts and adaptation have increasingly been focussing on the risks arising from climatic variability and extremes, as the stimuli to which society adapts as climate changes. A risk assessment approach is a practical starting point and an effective way to identify, assess and evaluate options and establish priorities (PIA, 2004), and there are regionally-relevant guidelines available for use (Australian/New Zealand Standard for Risk Management. AS/NZS 4360:1999). Both countries regularly produce national-scale assessments that provide a foundation for adaptation (e.g. (MfE 2001b;Pittock 2003;Warrick 2001) (Howden 2003a). At the regional and local scale, risk-based assessments including climate change are few in number, but increasing (Shaw 2005).

Mainstreaming of climate change impacts and adaptation into policies, plans and development strategies: At the national level, New Zealand has taken some noteworthy steps to “mainstream” climate issues. For example, as early as 1994 the *Coastal Policy Statement* included Policy 3.4.4 that states, “In relation to future subdivision, use and development, policy statements and plans should recognise that some natural features may migrate inland as the result of dynamic coastal processes (including sea-level rise)” (DoC 1994). Although not binding, some local government authorities followed by developing their own policies and plans. More recently, the *Resource Management (Energy and Climate Change) Amendment Act 2004* made explicit provisions within Section 7 RMA for all persons exercising functions and powers under the Act to have particular regard to the effects of climate change. This is binding, but it is so recent that regional and local government authorities

1 are still grappling with the implications for their roles and functions. In Australia, there are a number
2 of examples of mainstreaming (see 11.2.3), e.g. National Action Plan for Salinity and Water Quality,
3 National Action Plan on Biodiversity and Climate Change, National Water Initiative and Queensland
4 Coastal Management Plan.

5
6 **Monitoring and evaluation for re-assessing risk and response capabilities over time:** It is the remit
7 of the *New Zealand Climate Change Committee*, in existence since 1988, to “...monitor the present
8 state of knowledge of climate science, of climate variability on all time scales, and of current and
9 future climate impacts, for New Zealand...” and “...to make recommendations and provide advice on
10 New Zealand research and monitoring needs, priorities and gaps regarding climate, its impacts, and
11 the application of climate information” (RSNZ 2002). In Australia, the AGO monitors and evaluates
12 Australia’s performance against objectives in the National Greenhouse Strategy. A report
13 commissioned by the AGO outlines current climate change knowledge, gaps and priorities for
14 research on risk and vulnerability (Allen Consulting Group, 2005). At the regional and local levels,
15 the capacity for this kind of monitoring and evaluation in the context of climate risks and climate
16 change has not yet been well developed.

17
18 **Capacity building and awareness raising.** Substantive efforts are underway at the national level to
19 transfer scientific information to, and facilitate exchange of information between, the regional and
20 local government authorities (LGAs). The New Zealand Climate Change Office assumes this role
21 and has, for example, held a number of workshops for LGAs (NZCCO, 2004), supported case studies
22 of “best practice” adaptation by LGAs, and commissioned guidance documents for LGAs on
23 integrating climate change adaptation into their functions (MfE 2004b). In Australia, the AGO and
24 most State and Territory governments are developing and promoting on-line resources for raising
25 awareness about climate change. The Australian Bureau of Meteorology and CSIRO also have
26 awareness raising activities. At present, the regional and local levels of awareness, and capacities to
27 adapt, are relatively low.

30 **11.5.2 Adaptation constraints**

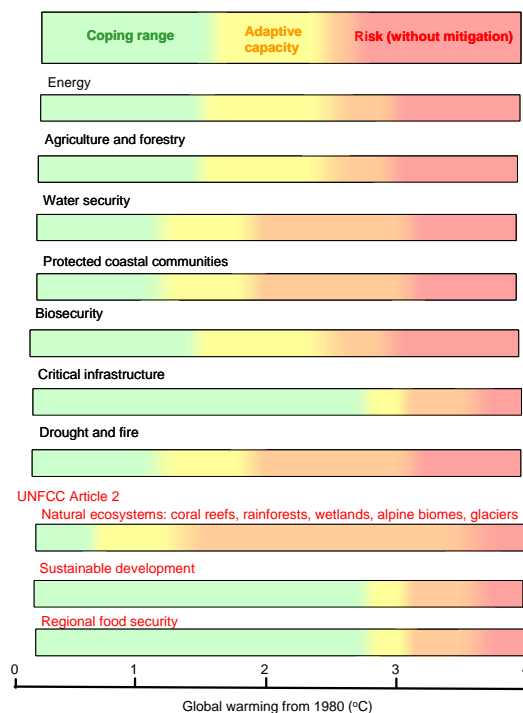
31
32 While the above five components are usually required for implementing adaptation options, they are
33 not necessarily sufficient. As suggested by the arrows in Figure 11.1, there are environmental,
34 economic, informational, social and political barriers or constraints that are very likely to hinder
35 implementation of adaptation options in Australia and New Zealand. For example, environmentally,
36 deleterious impacts on many species and natural ecosystems have limited reversibility. Opportunities
37 for offsetting potential impacts are also limited in many cases due to fixed habitat regions (e.g. the
38 Wet Tropics upland rainforests in Australia and the alpine zone in both Australia and New Zealand).
39 The oft-promoted adaptive strategy of corridors to facilitate migration of species under future
40 warming may therefore not be appropriate for much of the New Zealand biota (McGlone 2001).

41
42 Despite research advances, a number of specific knowledge gaps exist and are constraints to
43 adaptation (see Section 11.8). More generally, obstacles to adaptation are related, firstly, to the lack
44 of integrated regional assessment methods. While sector-specific knowledge and tools have steadily
45 progressed, a good deal of planning and implementation in New Zealand and Australia focuses on
46 regions and areas like watersheds and coastal zones in which sectoral concerns like water resources,
47 agriculture and ecosystems are inter-connected. Secondly, there is a lack of well-developed
48 evaluation tools, like benefit-cost analysis, that have incorporated issues of climate change and have
49 been adapted for regional and local application. Adaptation options that seek to reduce climate
50 change impact, are not affordable for all people, e.g. retrofitting houses for tropical cyclone impacts,
51 installing insulation or air-conditioning, or buying insurance (PIA, 2004). There are also significant

1 constraints to adaptation related land-use capability, location, stage of development, future ability to
 2 develop land, governance, management capability, liquidity and ability to uptake relevant
 3 technology.

6 **11.5.3 Residual risk**

8 Figure 11.3 attempts to synthesize relevant information about coping range, adaptive capacity and
 9 residual risk in each sector. Sectors with a broad coping range and/or adaptive capacity tend to have a
 10 small residual risk, e.g. critical infrastructure. Sectors with a narrow coping broad coping range
 11 and/or adaptive capacity tend to have a large residual risk, e.g. natural ecosystems.



34 **Figure 11.3:** Schematic diagram showing the coping range, adaptive capacity and residual risk due
 35 to the impacts of climate change

37 In general, from the broad perspective of the adaptation process, it can be concluded that:

- 38 • both Australia and New Zealand are fairly well advanced in developing adaptive capacity and
 39 are relatively flexible and well-positioned, in comparison to most other countries, to consider
 40 and adopt adaptation practices over time
- 41 • adaptation is developed most strongly for technical and scientific components of the process,
 42 especially at the national scale
- 43 • major constraints still exist for capacity building, awareness, monitoring and mainstreaming
 44 of climate change adaptation, especially at regional and local scales
- 45 • additional efforts are needed to promote adaptation so as to link, in an integrated manner, the
 46 national, regional and local levels.

11.6 Case studies

Water Security in Perth, Western Australia

The winter-rainfall-dominated region of south-west of Western Australia has experienced a substantial decline in the May-July rainfall since the mid-20th century. Effects on runoff are potentially serious as evidenced by a 50% drop in annual inflows to reservoirs supplying the city of Perth (Figure 11.4). Similar pressures have been imposed on groundwater resources and wetlands. This has been accompanied by a 20% increase in domestic usage in 20 years, and a population growth of 1.7% per year (IOCI, 2002).

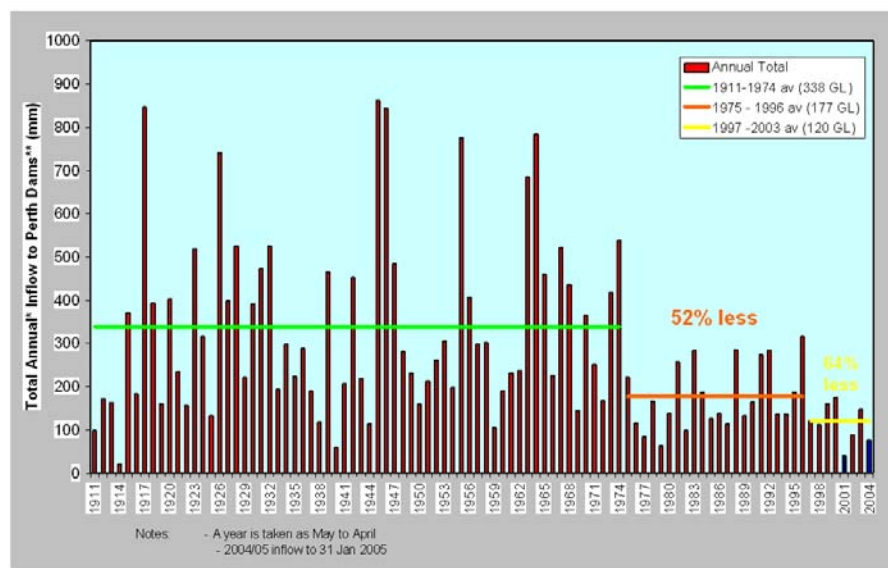


Figure 11.4: Annual inflow to Perth Water Supply System from 1911-2004. Horizontal lines are averages for selected periods

To ensure water security, a US\$350 million program of investment in water source development was undertaken by the WA Water Corporation (2004) from 1993 to 2003. In 2004, the continuation of low streamflow led to the decision to construct a seawater desalination plant, which will provide 45 Gl of water each year, at a cost of US\$271 million, Energy requirements (24 MW) will be met by 48 wind turbines. While climate simulations indicate that some of the observed drying is due to the enhanced greenhouse effect, work is continuing to better understand the causes.

Climate and the Coast

Both Australia and New Zealand have very long coastlines with large concentrations of population living in the coastal zone. Coastal zones of both countries are the foci of rapid population growth and development. These changes are placing intense pressure on land and water resources and are exacerbating vulnerability to climatic variations and extremes, including storm surges, droughts and floods. In both New Zealand and Australia, the major challenge is to achieve sustainable coastal development in the face of rapid development and growing vulnerability to climatic extremes and change. Two examples serve to illustrate these vulnerabilities.

1 *Bay of Plenty, North Island, New Zealand.* This bay is characterised by a narrow coastal zone
2 containing the cities of Tauranga and Whakatane and a few other smaller towns. The Western Bay of
3 Plenty and Tauranga are two of the fastest growing districts of New Zealand, with a combined
4 population growth of 13.4% over the period 1996-2001. By 2050 the population is projected to
5 increase 2-3 times. Beach-front locations demand the highest premiums on the property market and
6 also face the highest risks. The “Wahine Storm” (Cyclone Giselle) of 1968 and Cyclone Bola of
7 1988, for example, are reminders that the Bay is subject to severe storms and the tails of tropical
8 cyclones.

9
10 The reduction of present and future risks is addressed in the regional coastal policy for the Bay of
11 Plenty. IPCC projections of future sea-level rise as they affect coastal erosion and flood events are
12 explicitly included for the purpose of delineation of hazard zones and design of adaptation measures.
13 However, the implementation of policy and plans by local government authorities has been
14 repeatedly challenged by property developers, commercial interests and individual home-owners
15 with different interpretations of the risks.

16
17 *Sunshine Coast-Wide Bay Burnett, Queensland, Australia.* This region is under considerable
18 development pressures. The Sunshine Coast is projected to grow from a present population of about
19 275,000 to 424,000 by 2026; the Wide Bay-Burnett population is predicted to more than double in
20 the next 20 years. This growth has placed extreme pressures on land and water resources, with little
21 understanding by resident communities and local government of the role of future changes in climate.
22 Sandy beaches and dunes are key biophysical characteristics of the coastline. Fraser Island, the
23 largest sand island in the world, is a major geographic feature and World Heritage Area. Such
24 features are vulnerable to extreme storm events and tropical cyclones that can result in shoreline
25 erosion, changes in the position of river-mouth bars and sediment deposition in navigation channels.
26 Some estuaries and adjacent lowlands have been developed as high-value canal estates which are at
27 risk from extreme flooding, as illustrated by the combined effects of high rainfall from sub-tropical
28 low pressure system and king tides in February 1974.

29
30 Awareness of climate change is slowly taking root. For example, the Sea-Change Taskforce, made up
31 of over 60 coastal councils throughout Australia, has recently added climate change to its agenda. At
32 the regional planning level, climate change was recently imbedded at a policy level into the strategic
33 planning processes for the Wide Bay-Burnett region.

34 35 36 37 **11.7 Conclusions: Implications for sustainable development**

38
39 The ultimate objective of Article 2 of the United Nations Framework Convention on Climate Change
40 (UNFCCC) is stabilising greenhouse gas emissions "at a level that would prevent dangerous
41 anthropogenic (human induced) interference with the climate system." It states that "such a level
42 should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate
43 change, to ensure that food production is not threatened, and to enable economic development to
44 proceed in a sustainable manner."

45
46 *Natural ecosystems:* Projected climate change is very likely to threaten iconic ecosystems when
47 warming this century exceeds 2°C. The most vulnerable systems include: the Great Barrier Reef; the
48 heathlands of south-western Australia; Kakadu wetlands, rainforests, coasts, and alpine areas in both
49 countries; and glaciers of New Zealand. Adaptation options are very likely to be limited. This is
50 virtually certain to exacerbate existing stresses such as habitat loss and fragmentation, threatening

1 some species, causing a reduction in ecosystem services (e.g. for tourism, fishing, water supply) and
2 increasing management challenges for the conservation estate and national parks.

3
4 *Food production:* There are very likely to be both positive and negative impacts for agriculture.
5 Climate change is likely to instigate shifts in the geographical distribution of food production at both
6 regional and global scales. However, there is large capacity for adaptation. Both economic and social
7 impacts are likely to be concentrated on particular crops and specific regions. Threats to
8 sustainability are likely to arise from social disruption (due to increasing climate extremes) and more
9 intensive land use. Impacts on fisheries are poorly understood. Regional food security is very likely
10 to remain robust (medium confidence) with both countries able to produce many times the food they
11 require for internal consumption.

12
13 *Economic development:* The key vulnerabilities identified in Table 11.4.11.1 all impinge on
14 economic development and its sustainability. Nevertheless, Australia and New Zealand have high
15 adaptive capacity up to certain limits of climate change. Sustainability is unlikely to be threatened if
16 adaptation options are vigorously introduced, but is contingent on affordability, appropriate planning,
17 mainstreaming of adaptation into decision making and political will. Most susceptible are water
18 resources, low-lying coastal communities, stormwater systems, populated flood plains and dams.

19
20 Main dangers are to property and the built environment. It is unlikely that present growth rates of
21 coastal development and water use can be sustained. Loss of life is not precluded, but is unlikely to
22 exceed a few hundreds per decade. Within both countries there are economically and socially
23 disadvantaged groups, especially indigenous peoples, who have less adaptive capacity and are likely
24 to be more vulnerable to additional stresses on health and living conditions.

25
26 Table 11.11 summarises key residual risks in the region and Figure 11.5 maps key hotspots.

27
28 **Table 11.11: Residual risk summary for Australia and New Zealand: projected impacts after**
29 **adaptation for 2020, 2050, 2080 and for two different development scenarios**

Time slice	SRES B1	SRES A1FI
Near-term impacts (about 2020s)	<ul style="list-style-type: none"> • sea level rise of up to 4 cm • localised coral bleaching • 20% decrease in frost days • 10% increase in hot days (over 35°C in Aus and 30°C in NZ) • 10% less snow area in Australia • 10% more extreme fire danger days in southeast Aus • 0.3 million at risk of dengue in Aus • little change to agriculture 	<ul style="list-style-type: none"> • sea level rise of 13 cm, but property losses limited by adaptation measures • coral bleaching over most reefs • 80% decrease in frost days with benefits to horticulture and viticulture • 100% increase in hot days (over 35°C in Aus and 30°C in NZ) and increase in peak electricity demand • 40% less snow area in Australia • 40% more extreme fire danger days in southeast Aus • 0.5 million at risk of dengue in Aus • increases in crop yields
Mid-term impacts (about 2050s)	<ul style="list-style-type: none"> • sea level rise of up to 5 cm • 22% less snow area in Aus • 20% more extreme fire danger days in SE Aus • 3300 more heat wave deaths • 10-19% decrease in river flow and -6 to +16% change in salinity in the Murray Darling basin • 0.8 million at risk of dengue in Aus • increases in crop yields 	<ul style="list-style-type: none"> • sea level rise of 35 cm with loss of property during storm surges at some sites • coral reefs replaced by macro algae and sea weed • 85% less snow area in Aus • 120% more extreme fire danger days in SE Aus • 5200 more heat wave deaths • 14-25% decrease in river flow (for A1 not A1FI) with stress on water supplies • -8 to +19% change in salinity in Murray Darling basin • 1.6 million at risk of dengue in Aus • drought and shrinking water supplies constrain farming over wide areas

<p>Long-term impacts (about 2080s)</p>	<ul style="list-style-type: none"> • sea level rise of 5 cm • coral reefs replaced by macro algae and sea weed communities • NZ snowline rises by 120 m • drought constrains farming over wide areas 	<ul style="list-style-type: none"> • sea level rise of 75 cm with widespread property loss during storm surges • large scale alteration to coral reefs • NZ snowline rises 270 m with loss of lower ski fields. • frequent and severe drought constrains farming practices and limits water supply works • higher intensity rains cause failure of urban drainage and flood protection • land use changes over wide areas with impacts on rural communities.
-----------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Notes:

- (a) development scenarios are loosely based on SRES storylines for A1 and B1 future worlds
- (b) in some cases, modelling of impacts is not for exact scenario and is based on interpretations
- (c) in some cases, impacts are for slightly different time slices (e.g. 2100 rather than 2080)
- (d) there are large sub-regional differences in impacts across Australia and New Zealand
- (e) no literature available for other likely important impacts at these time slices and scenarios.

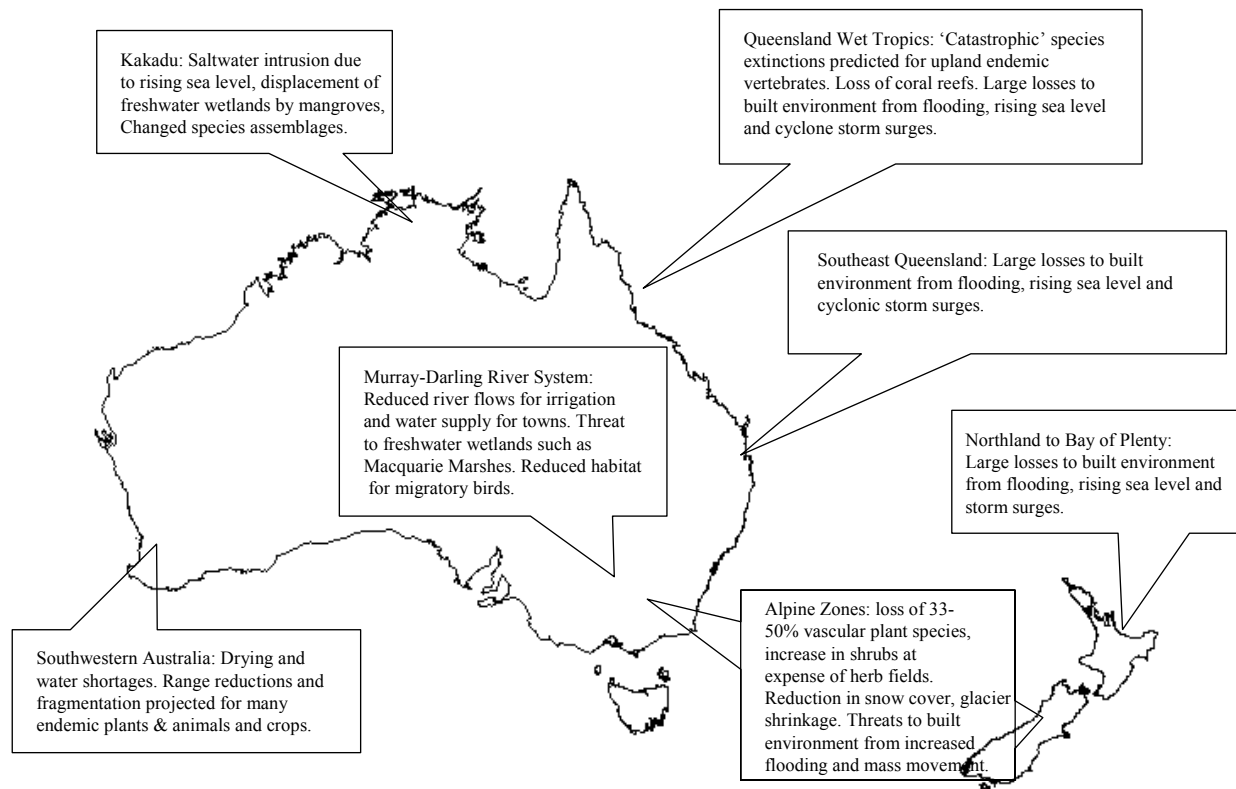


Figure 11.5: Key hotspots, based the following criteria:

- high residual vulnerability (large impacts, low adaptive capacity) to climate change
- other multiple large impacts (e.g. continued rapid population growth, ongoing land degradation, ongoing habitat loss, threats from rising sea level)
- likely ongoing development of substantial exposed infrastructure and economic growth.

11.8 Key uncertainties and research priorities

Uncertainties and research priorities for climate change scenarios are described in the IPCC Working Group 1 Report. Projected changes in climate are virtually certain to exert large impacts by 2100, unless adaptation measures are implemented. The main research priorities can be grouped into four categories:

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11.8.1 Impacts and vulnerability for critical systems

Uncertainties exist in impact assessments for all sectors, but the following are critical.

Natural ecosystems: there is low confidence in identifying relevant climatic thresholds for rapid change. Key areas include rates at which natural ecosystems can adapt autonomously, modelling their structure and functions out to 2100, the role of invasive species and the potential for human intervention to reduce and manage their vulnerability. Identification of potential climatic refugia and landscape linkages is critical. There are insufficient long-term monitoring programmes for key natural ecosystems, especially in national parks and the wider conservation estate, and of those important to indigenous peoples.

Water: impacts and optimum adaptation strategies for projected changes in drought frequency and intensity need further quantification within an integrated catchment framework of multiple uses. Uncertainties remain for impacts on groundwater levels, water quality and environmental flows. Better assessment is required of long term water and power generation requirements taking into account all other water users and environmental needs. Risks from regional flooding need better quantification, but are likely to increase with higher rainfall intensity, requiring a re-evaluation of design floods for dams, river protection works and critical infrastructure in urban areas.

Oceans and fisheries: climate change, including changes in ENSO, is virtually certain to alter the physical nature of oceans that surround Australia and New Zealand, including sea currents, bottom-water formation, upwelling and nutrient supply. Little is known about potential impacts. The impacts of changing oceanography on fish stocks and other marine life need to be better modelled.

Coasts: there is very high confidence of large impacts along significant tracts of coastline in both countries. Comprehensive vulnerability assessments and of adaptation options are needed to provide improved guidance for coastal planning and hazard management. Research is needed into local and regional costs of projected changes in extreme weather events. Sea-level rise is virtually certain to continue beyond 2100, but adaptation planning for these very long-term scenarios needs further investigation.

Abrupt climate change: there is very low confidence about risks from possible abrupt climatic changes and faster than expected sea level rise. Research is needed on if and when they might occur and impacts on both natural and managed systems.

11.8.2 The process of adaptation

There are few integrated sub-regional assessments of impacts and adaptation within the wider context of other multiple stresses, including the respective roles of national, state and local government. Adaptation options for Aboriginal and Maori communities, especially for those on traditional lands, need further investigation. Priority is needed in “hotspot” areas for:

- regional and local policy and governance mechanisms for adaptation
- societal preparedness, including all stakeholders, for adaptation to climate change. Limitations and barriers to adaptation need to be better understood
- costs and benefits for the range of adaptation options to reduce vulnerability, including benefits of impacts avoided, co-benefits, side effects, limits and better modelling. Analysis needs to consider

1 implications of various options for social equity and fairness, the impacts of different discount
2 rates, price incentives, delayed effects and inter-generational equity.

5 ***11.8.3 Assessing threats and opportunities for different scenarios***

6
7 Impact scenarios underpin decisions about adaptation options and emission reduction targets. There
8 is only medium confidence in assessing impacts for the different SRES scenarios, largely because of
9 insufficient research and modelling studies. Uncertainties need to be identified and handled within a
10 risk assessment framework. The following analyses are required for the plausible range of SRES and
11 CO₂ stabilisation options:

- 12 • calculation of the probabilities of exceeding critical biophysical or socio-economic thresholds
- 13 • net costs and benefits of climate change, including regional and sectoral differences
- 14 • impacts on sustainability for sectors and sub-regions
- 15 • better modelling of land use change especially for critical sectors of agriculture, horticulture,
16 viticulture, fisheries, forestry, and tourism and assessment of the implications for regional
17 development and social change.

20 ***11.8.4 Global interactions – trade and immigration***

21
22 Impacts of climate change and adaptation elsewhere in the world are very likely to affect global trade
23 in commodities, which is important for the economies of Australia and New Zealand. However, there
24 is low confidence in potential outcomes. Further studies are needed to assess impacts on the region's
25 competitive advantage. Changing climates and rising sea-level in Pacific Islands are very likely to
26 change the inflow of people to the region and implications for regional population growth and
27 demographics need to be considered.

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