Water Futures for Western Australia 2008-30

Accounting for Climate Change in Water Demand Scenarios

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WATER FUTURES FOR WESTERN AUSTRALIA
2008-2030

ACCOUNTING FOR CLIMATE CHANGE IN WATER DEMAND SCENARIOS

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EXECUTIVE SUMMARY

Although climate change will cause widespread environmental stress and autonomous environmental change, its impacts and possible policy responses are currently foreseen mostly through ***supply*** side accounting. More likely than not the net effects of hydro-climatic forcing resulting from warming and rainfall changes will have a negative effect on water availability in most WA regions. The most likely exception is the Kimberley Region. However, regional rainfall projections in the north are based on much less comprehensive downscaling investigation and synoptic interpretation than for the south and will need regular review as scientific opportunity develops. The Demand Tool will allow the Department to explore supply demand balances under alternative hydro-climate scenarios.

The supply side of the demand-supply equation is to be picked up in water availability inputs to the Water Demand Scenario Modeling Tool. These inputs are currently being assembled by DoW.

However, climate change will also potentially affect the ***demand*** for water, and that is the subject of this paper. Based on our interpretation of and our inferences from recent literature it is suggested that the principal impacts on water demand that are likely to result from climate change within the time-horizon of this study (i.e. by 2030) are as follows.

- Four principal kinds of impact that climate change may have on water demand have been identified:
    - Regionally ubiquitous (mostly negative other than in agriculture) impacts on economic growth rates resulting from (i) climate driven influences on the global economy, and (ii) climatic influences on agricultural productivity in Western Australia
    - Climate driven change in unit water demand (mostly positive), particularly the agricultural, urban, self supplied and commercial impacts of drying and warming
    - Regulatory changes driven by attempts to deal with environmental change. Reduction of available water resources in most regions will progressively cause regulatory capping of water use: in particular through Statutory Water Allocation Plans to be developed in line with the *Blueprint for Water Reform* in Western Australia, and through water conservation initiatives backed by regulation across a wide range of user sectors The Demand tool will allow the Department to explore alternative regulatory scenarios.
    - Structural economic changes associated with adaptive responses to regional development, sustainability thresholds and rising water values
- The likelihood of climate change having a significant impact on water demand over the next quarter century varies markedly between regions. As a generalization, the biggest climate change impacts are apparent in the greater south west of the State where a drying climate is already manifest and where many aspects of water demand are climate sensitive. Outside of the south west, sparse populations and a predominantly mining economy limit the effect of climate on water demand in many regions, including regions of most severe warming.
- In the Perth/Peel Region unit demands of households and civic uses (from both public water supply and self-supply from bores), will be affected by rainfall declines, raised temperature and evapostranspiration (ET). Some small downward revision of water demand from export

industries might follow negative change in global GDP, while the growth rates of industries servicing agriculture in the State could decline.

- Climate change has the potential to depress productivity and activity levels *relative to trend*, in all regions where rain-fed agriculture is a dominant economic activity. The affected Demand Regions include Pallinup, Upper Great Southern, Midlands, Moore and Greenough Demand Regions. These regions will be strongly affected in terms of agricultural output and productivity, suggesting a downward revision of water demand estimates compared to trend, ***unless*** unit water use increases as a defensive measure by hard-pressed farmers and townships.
- In the South West Region work will be needed on potential impacts of raised temperature and ET on unit water use of different irrigation activities in order for the DoW to make some quantitative assessment. The prospects for rainfall affecting water demand are less of an issue. The irrigated dairy and beef industry in the south west is likely to experience even stronger competition from New Zealand, which is likely to benefit from climate change, and experience a small decline in overseas markets *relative to trend* as a result of a negative net impact of climate change on global GDP. Carbon constraints would impose significant costs on these industries, changing their product mix and lowering their marginal values for water.
- Reduced water availability in the south west coupled with new water reform initiatives, in particular water trading and the setting of allocation limits in Statutory Water Allocation Plans, may lead to continuing transfers of water out of those irrigation activities having low marginal values for water, thus changing the mix of irrigation activities and water demands.
- The South West is where forestry initiatives in response to carbon trading may have an impact on unlicensed use (draw down of aquifers), depending on prior land use.
- The East and West Pilbara and the Murchison are regions with the highest projected levels of warming in Australia. This may increase unit water requirements for wash down, dust suppression etc in response to higher temperatures, and ET. There could also be a small impact on the level of activity relative to trend in mining regions from reduced rates of growth of global GDP. Global economic effects of climate change, notably a depressed rate of increase in global GDP, could shave up to 5 per cent off Year 2030 outcomes for the mineral and energy sectors.
- Kimberley projections are equivocal for rainfall and temperature and are complicated by possible positive forcing of the monsoon from the “dimming” effects of Asian aerosols. The net consequence is that no significant change in unit water demand is foreseen as likely in the next few decades. Our biggest concern is the competitive standing of the sugar industry. International repercussions of climate trends on the sugar industry include reduced yields in India and ASEAN countries, but a strengthening of Brazil’s competitive position. The implications for water use in the East Kimberley are as yet unclear.

ACCOUNTING FOR CLIMATE CHANGE IN WATER DEMAND SCENARIOS

1. INTRODUCTION

1.1 Objective and Approach

The objective of this paper is to develop a set of assumptions that can be used in an application of the Water Demand Scenario Modelling Tool to explore the implications of prospective climate changes for water demand in Western Australian regions.

The paper draws on: (i) a review of selected recent publications on the economic impacts of climate change internationally and within Australia, and (ii) a detailed review and interpretation of the most recent information and analysis on prospects for climate change in WA regions (Sadler ed., 2008). These sources are used to compile a set of working assumptions for each of the 59 user groups represented in the Water Demand Scenario Modelling Tool.

1.2 Definitions of Demand and Water Availability

For the purposes of this paper:

- Water demand includes all consumptive uses of water including (i) that obtained directly by abstraction from surface water and groundwater, (ii) dewatering requirements of mines or construction sites, and (iii) that obtained through any supply scheme operated by the Water, Sewerage and Drainage Services sector. The Water, Sewerage and Drainage Services sector includes both urban water suppliers and irrigation cooperatives.
- The term “Water Availability” is used occasionally in the paper. This equals the sum of water allocation limits on abstractive use that have been set within a region plus water production from desalination plants or reclaimed water schemes.
- Non-abstractive uses, such as the water use of forests, are excluded. Environmental allocations are also excluded.

1.3 Types of Climate Change Impacts on Demand

We distinguish four kinds of demand impact:

- Global impacts on regional economic structures: resulting, for example, from changes in global GDP, or shifts in comparative advantage for Australian producers resulting from climate change, leading to a changed water use scenario for an industry;
- Impacts that are dependent on local climate scenarios: for example changes in the water use per unit output of an agricultural industry;

- Impacts on regional economic structure that may result from Australian climate policy, including carbon trading and introduced constraints on carbon emissions; and
- Changes in water allocations or new regulations affecting the way in which water is used, due to revised estimates of water availability.

This paper deals mainly with the first three of these impacts. The report does not consider changes in regional economic structure that could result from revisions to the official estimates of water availability due to climate change, together with any consequent changes to allocation limits under the new Blueprint for Water Reform in WA. This is because the Water Demand Scenario Modelling Tool will itself play a part in water allocation decisions. This approach provides a clear separation between demand and water availability.

1.4 Sources of Information

The following recent publications have been used in developing the paper:

- The Stern Report
- ABARE Review of Climate Change Impacts on Australian Agriculture
- Garnaut Review Interim Report
- Regional Climate Change and Risk Management of Water Resources in Western Australia (Sadler ed., 2008 for Department of Water)

The Garnaut Climate Change Review is an independent study by Professor Ross Garnaut, commissioned by Australia's State and Territory Governments on 30 April 2007. The Review will examine the impacts of climate change on the Australian economy, and recommend medium to long-term policies and policy frameworks to improve the prospects for sustainable prosperity. The Review's final report is due on 30 September 2008, with a draft by 30 June 2008. A number of forums are being held around Australia to engage the public on various issues relating to the Review.

The Regional Climate Change Report (Sadler ed.) produced for the Department of Water in parallel with this study draws upon the recent IPCC Assessment and national derivatives to produce climate scenarios for regions (See Annex A) which envelop and are readily related to the more geographically divided Demand Regions of this study.

1.5 Creating a Climate-dependent Scenario in the Water Demand Scenario Modelling Tool

There are a number of places within the Water Demand Scenario Modeling Tool where assumptions about climate-induced changes may be expressed. These are as follows.

- ***Demographic and economic growth rates for may be changed.*** Climate change will force structural adjustments in some regions. For example: (i) rain-fed crops and pastures are facing productivity and output reductions, compared to trend as a direct result of local climate changes; (ii) national or global loss of production in some products will create opportunities for regions that are able to offer increased irrigation supplies; and (iii) downward revisions of growth in global GDP could lead to slightly reduced growth for WA mineral and energy exports. The Demand tool will allow the Department to explore alternative scenarios. All that is needed in order to express the potential structural effects is to specify a change in growth rate for the prime industry in the MONASH-TERM economic model. The underlying input-output economic model will then change the output levels of all related industries. Resulting growth rates across all industries are then re-entered into the Water Demand Scenario Modeling Tool

- ***Water use coefficients might be changed.*** Water use coefficients in the Water Demand Scenario Modeling Tool express water demand per unit of the indicator value for a user group; this might be value added, employment, area irrigated, number of livestock, human population etc. The coefficients reflect prevailing climate, water use technologies and water using practices. In the absence of counter-measures climate change will impact on water use coefficients. However, there is not much basis for predictive economic modeling of counter-measures and a sensitivity approach is needed.

- ***Inter-regional transfers:*** Regions with capacity for water export may find increased demand for their water as a consequence of climate shortages in adjacent regions. The Demand Tool will allow the Department to explore alternative water development (including desalination or wastewater re-use) and regional export/import scenarios.

2. PROJECTED HYDRO-CLIMATE - GLOBAL, NATIONAL AND STATE SCENARIOS

2.1 International and National Scientific Judgement and Scenario Material

There is now unequivocal evidence that global climate has been changing (warming), a strong likelihood that its prime underlying cause has been anthropogenic and a strong expectation that global warming will continue through this century driven primarily by carbon emissions.

There is now a substantive body of recent international and national scientific reporting available to assist in making judgements on future climate risks in Western Australia. This includes: the 2007, Fourth Assessment Report (4AR) of the IPCC; the 4AR based *Climate Change in Australia* Report of CSIRO/BoM later in 2007; and the various more specific regional studies which have spun off from the Indian Ocean Climate Initiative in Western Australia.

Whilst, in such recent scientific reporting, there is growing confidence in the broad direction and scale of projected change there is, and will always be, uncertainty attached to detail. This uncertainty, is a consequence of:

1. the noise of natural variability (which increases at concentrated geographic scales);
2. the uncertainty of future human behaviour; and
3. the complexity of the climate system and associated scientific limitations.

Climate affected sectors need to respond to this circumstance in some form of risk management approach.

2.2 A Scenario Based Risk Management Approach for Western Australia

The climatic range of Western Australia, from wet tropical in the far north, through the dry sub-tropics to a temperate climate in the south west, imply that the nature of projected climate change and impacts differ markedly in different parts of the State.

In response the Department of Water has recently completed a review which sets out a scenario based framework for risk management of water resources in Western Australia (Sadler ed., 2008). This review draws on the latest available climate science.

2.3 Global Emission Scenarios as the Starting Point

The starting point for definition of water oriented climate scenarios has been in selection of global emission scenarios. These scenarios are regarded as representing, from *optimistic* to *pessimistic*, a range of plausible emission outcomes labeled *low*, *medium* and *high* respectively.

The chosen scenarios are from the wider set of scenarios developed by the IPCC and are scenarios for which a substantial range of recent modeling is available. The chosen scenarios are shown in the Table hereunder (Table xx) and the corresponding, end of century Greenhouse Gas concentrations are shown in Table 1. (See Sadler ed. 2008. Section 1).

Table 1: Preferred High, Medium and Low Emissions Scenarios for the Department of Water's adaptive planning

<table>
<tr><th colspan="5">Preferred High, Medium, Low Emissions Scenarios -
to represent the range of risks for adaptive management planning at different Time Horizons</th></tr>
<tr><th>Scenario Classification</th><th>2030</th><th>2050</th><th>2070</th><th>2100</th></tr>
<tr><td>High Emissions</td><td rowspan="3">A1B</td><td>A1FI</td><td>A1FI</td><td>A2</td></tr>
<tr><td>Medium Emissions</td><td>A1B (or A2)</td><td>A1B</td><td>A1B</td></tr>
<tr><td>Low Emissions</td><td>B1</td><td>B1</td><td>B1</td></tr>
</table>

Table 2: Carbon Dioxide equivalents of key scenarios. (IPCC , Feb 2, 2007)

SRES Scenario	Approx. CO_2 Equivalent at 2100*
A2	**1250**
A1FI	**1550**
A1B	**850**
B1	**600 (~550)**

* Approximate CO_2 equivalent concentrations ppm corresponding to the computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100

2.4 Scenario Likelihoods

From Table 2 it is important to note, in the context of this demand modeling study, that only one emission scenario (A1B) is currently adopted by the Department of Water to represent the high low and medium emission scenarios for 2030. This is because there is very little differentiation amongst scenarios up to that time. This fact is convenient for this study which is primarily concerned with developing modeling tools for projections to 2030.

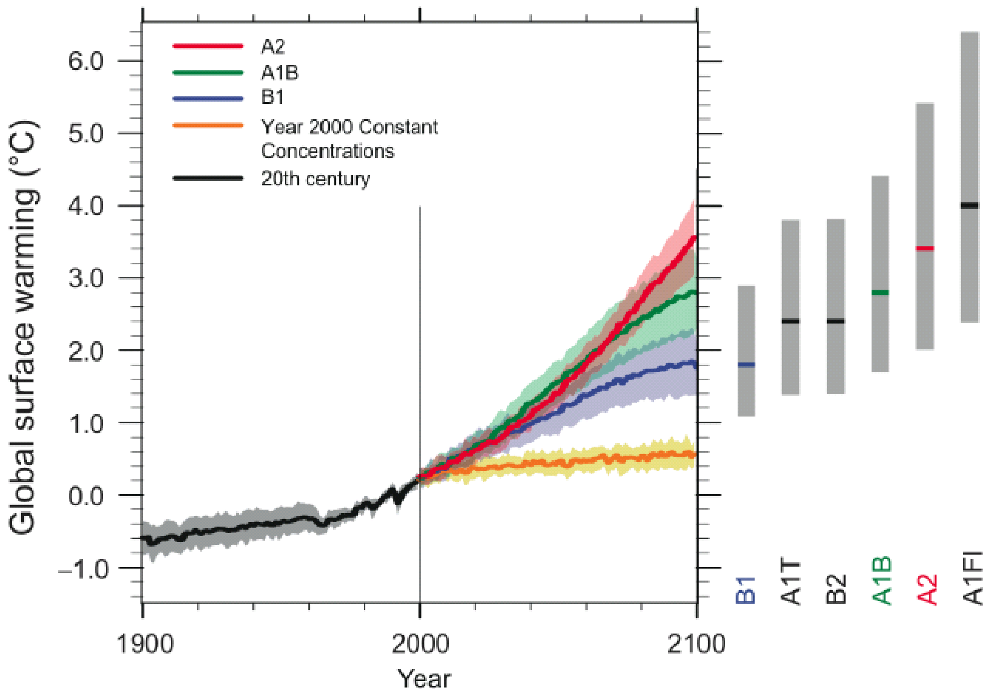
Beyond 2030 the *low* scenario B1 is the *aspirational* goal of current mitigation negotiations and the target needed to have some prospect of avoiding *dangerous global change*. A1FI/A2 the *high* scenario, reflects *business-as-usual* expectations to 2070 with tokenistic mitigation. To achieve B1 would need urgent and strong global action. As much as B1 is desirable, there is little happening at global level to suggest it is any more likely as an outcome than is the *high scenario*. From the adaptive viewpoint there is a risk that global outcomes may be anywhere in the range of B1-A1FI up to 2070.

2.5 Climate Outcomes for the Scenario Range

The climate outcomes for the various scenarios as currently assessed for the Department's planning are given in its recent report (Sadler ed., 2008). Because on natural variability and model diversity these judgements are presented in *confidence* bands.

For the application of the climate effects to demand modelling tools of this study it is assumed that the scenario report (Sadler ed., 2008), or its subsequent updates will be used for regional climate projection. However, as an indicator of the ranges involved, Figure 1 and Table 3are included hereunder to show the range of (temperature) outcomes potentially associated with alternative scenarios.

Figure 1: Multi-model averages and assessed ranges for surface warming.



Solid lines are multi-model global averages of surface warming (relative to 1980–99) for the scenarios A2, A1B and B1, shown as continuations of the twentieth-century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the gray bars included the sources employed in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. Source: Summary for Policy Makers - IPCC Fourth Assessment Report. Paris: WMO/UNEP Intergovernmental Panel on Climate Change http://www.ipcc.ch/SPM2feb07.pdf. (IPCC , Feb 2, 2007 , p. 4)

Table 3: Scenarios of Cumulative Mean Annual Temperature Change in Western Australian Regions of greatest and least projected warming – Best Estimate of Underlying Cumulative GHG Warming °C - ***Nominally relative to 1910***

Region	Scenario	Horizon				
		1990	2007	2030	2050	2070
10. East Pilbara Region: *Region of greatest projected warming in WA*	B1				2.2	3.0
	A1B	**0.7**	**1.2**	**2.0**	**3.0**	**3.7**
	A1FI				3.2	4.7
3. South Coast Region: *Region of least projected warming in WA*	B1				1.3	1.8
	A1B	**0.5**	**0.8**	**1.4**	**1.8**	**2.3**
	A1FI				2.0	2.8

3. ECONOMIC IMPACTS OF CLIMATE CHANGE

Climate impacts will be felt world-wide (Stern 2006; Garnaut, 2007), but with different "signatures" in different parts of the globe, and within Australia (CSIRO, 2007; Sadler, this study).

3.1 Global economic impacts.

As ABARE (2007) points out, modeling the overall impact of climate change is a formidable challenge, involving forecasting over a century or more as the effects appear with long lags and are very long-lived. The limitations to our ability to model over such a time scale demand caution in interpreting results, but projections can illustrate the risks involved.

Most formal modeling has used 2 - 3°C warming (B1 or A1B in Sect. 2.2 above) as a starting point. According to Stern (2006) the cost of climate change for this range of temperature increase, could be equivalent to around a 0 - 3% loss in global GDP from what could have been achieved in a world without climate change. Poor countries will suffer higher costs.

However, according to Stern (2006), in the absence of ameliorative measures, termed business as usual (BAU), temperature increases may exceed 2 - 3°C by the end of this century (A1FI or A2 in Sect. 2.2 above). This increases the likelihood of a wider range of impacts than previously considered, which are more difficult to quantify. For example, with 5 - 6°C (high end of A1FI ensemble estimates - Fig. xx above) warming, models that include the risk of abrupt and large-scale climate change estimate a 5 -10% loss in global GDP, with poor countries suffering costs in excess of 10%. The risks, however, cover a very broad range and according to Stern (2006) involve the possibility of much higher losses.

3.2 Developing Countries

According to Stern (2006), developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive economic sectors such as agriculture. Many developing countries are already struggling to cope with their current climate. For low-income countries, major natural disasters today can cost an average of 5% of GDP.

Health and agricultural incomes will be under particular threat from climate change. For example:

- Falling farm incomes will increase poverty and reduce the ability of households to invest in a better future and force them to use up meagre savings just to survive.
- Millions of people will potentially be at risk of climate-driven heat stress, flooding, malnutrition, water related disease and vector borne diseases. For example, dengue transmission in South America may increase by 2 to 5 fold by the 2050s.
- The cost of climate change in India and South East Asia could be as high as a 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change.
- Up to an additional 145-220 million people could be living on less than $2 a day and there could be an additional 165,000 to 250,000 child deaths per year in South Asia and sub-Saharan Africa by 2100 due to income losses alone.
- In some parts of the developing world, severe deterioration in the local climate could lead to mass migration and conflict, especially as another 2-3 billion people are added to the developing world’s population in the next few decades:
- Rising sea levels, advancing desertification and other climate-driven changes could drive millions of people to migrate: more than a fifth of Bangladesh could be under water with a 1m rise in sea levels – a possibility by the end of the century.
- Drought and other climate-related shocks risk sparking conflict and violence, with West Africa and the Nile Basin particularly vulnerable given their high water dependence.

Stern (2006) asserts that these risks place an even greater premium on fostering growth and development to reduce the vulnerability of developing countries to climate change. However, little can now be done to change the likely adverse effects that some developing countries will face in the next few decades, and so some adaptation will be essential.

3.3 Developed countries

Climate change will have some positive effects for a few developed countries for moderate amounts of warming, but will become very damaging at the higher temperatures that threaten the world in the second half of this century.

- In higher latitude regions, such as Canada, Russia and Scandinavia, climate change could bring net benefits up to 2°C or 3°C (B2 to A1B in Section 2.2 above) through higher agricultural yields, lower winter mortality, lower heating requirements, and a potential boost to tourism. But these regions will also experience the most rapid rates of warming with serious consequences for biodiversity and local livelihoods.
- Developed countries in lower latitudes will be more vulnerable. Many regions where water is already scarce will face serious difficulties and rising costs as a consequence of changed water regimes. Recent studies suggest a 2°C (B2) rise in global temperatures may lead to a 20% reduction in water availability and crop yields in southern Europe and a more erratic water supply in California, as the mountain snowpack melts by 25 – 40%. In the USA, one study predicts a mix of costs and benefits initially (± 1% GDP), but then declines in GDP even in the most optimistic scenarios once global temperatures exceed 3°C.

- The poorest will be the most vulnerable. People on lower incomes are more likely to live in poor quality housing in higher-risk areas and have fewer financial resources to cope with climate change, including lack of comprehensive insurance cover.

The costs of extreme weather events, such as storms, floods, droughts, and heat waves, will increase rapidly at higher temperatures, potentially counteracting some of the early benefits of climate change. Costs of extreme weather alone could reach 0.5 - 1% of world GDP by the middle of the century, and will keep rising as the world warms.

- Damage from hurricanes and typhoons will increase substantially from even small increases in storm severity, because they scale as the cube of wind speed or more. A 5 – 10% increase in hurricane wind speed is predicted to approximately double annual damages, resulting in total losses of 0.13% of GDP each year on average in the USA alone.
- The costs of flooding in Europe are likely to increase, unless flood management is strengthened in line with the rising risk. In the UK, annual flood losses could increase from around 0.1% of GDP today to 0.2 – 0.4% of GDP once global temperature increases reach 3 to 4°C.
- Heat waves like 2003 in Europe, when 35,000 people died and agricultural losses reached $15 billion, will be commonplace by the middle of the century.

At higher temperatures, developed economies face a growing risk of large-scale shocks.

- Extreme weather events could affect trade and global financial markets through disruptions to communications and more volatile costs of insurance and capital.
- Major areas of the world could be devastated by the social and economic consequences of very high temperatures. As history shows, this could lead to large-scale and disruptive population movement and trigger regional conflict.

3.4 Discussion

It is important to note that the Stern report is written in the framework of benefit-cost analysis. In some cases economic costs of climate change, e.g. the costs of increased flooding or hurricane damage are expressed as GDP-equivalents. Put another way, in these cases the implication of climate worsening is that a greater proportion of global GDP would need to be used in defensive or rehabilitation expenditures as opposed to alternative, income and welfare increasing investments. The mechanism by which such a diversion would reduce the level of global GDP is not explained. It is clear, however, that reductions in the agricultural productivity of developing countries would certainly affect global economic growth prospects, and through that would potentially affect global export markets on which the Western Australian economy depends.

The Stern Report says relatively little on global impacts in the shorter-term (i.e. 30 years or less). Therefore, it provides little evidence to support any change in the MONASH-TERM assumptions about the overall growth of the Western Australian economy to the year 2030. However, the Stern Review clearly sets out the nature of future impacts and these will occur earlier if climate change is more rapid.

4. AGRICULTURE

4.1 Overview

ABARE (2007) indicates that future climate changes and associated declines in agricultural productivity and global economic activity may affect global production of key commodities. ABARE suggests that *global* wheat, beef, dairy and sugar production could decline by 2–6 per cent by 2030 and by 5–11 per cent by 2050, *relative to what would otherwise have been the case (the 'reference case').* Cline (2007), quoted by ABARE, estimates that world agricultural production could potentially fall by 16 per cent (without carbon fertilization) and by 3 per cent (with carbon fertilization) by 2080 (Cline 2007).

These changes would also have significant implications for Australian agricultural markets. Exports of key commodities are projected by ABARE to decline by 11–63 per cent by 2030 and by 15–79 per cent by 2050, *relative to the reference case.* Agricultural trade impacts of future changes in climate are likely to arise from the interaction of two forces — first, from a potential reduction in agricultural output in key producing countries and, second, from a slowdown in global economic activity brought about by climate change related effects leading to a decline in demand for agricultural products in some regions. In this context it is important to recognise that the likely change in demand for agricultural commodities, such as grains, in response to changes in income is likely to be relatively low across many regions given their importance in meeting dietary requirements. For these commodities supply shortage mean steeply rising prices. On the other hand, the likely change in demand for dairy and livestock products in response to changes in income is likely to be relatively high, particularly in a number of developing countries.

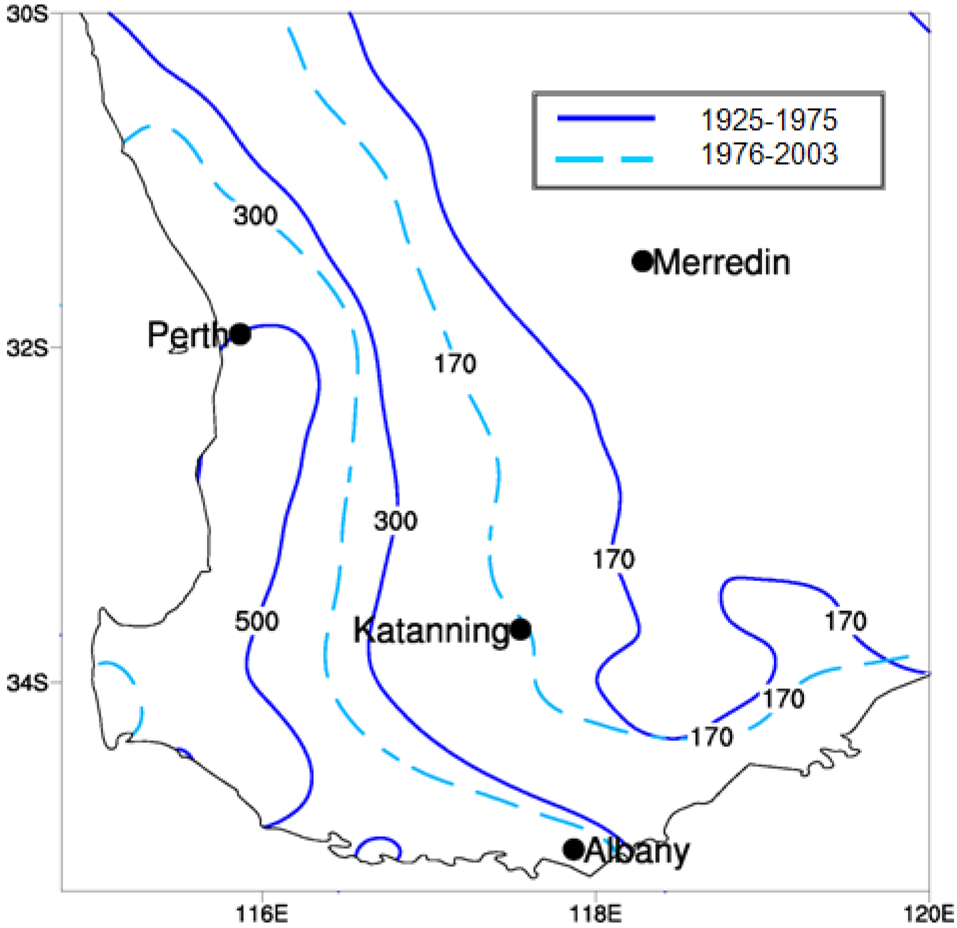
According to ABARE, Australia is projected to be one of the most adversely affected regions from future changes in climate in terms of reductions in agricultural production and exports. Cline (2007) projects that, by 2080, potential climate change could lower agricultural productivity in Australia by 27 per cent (without carbon fertilization) and by 16 per cent (with carbon fertilization).

Projected higher temperatures and lower rainfall are expected to reduce Australia's agricultural production relative to the reference case. Increases in carbon dioxide concentration could have positive carbon fertilization effects by increasing the rate of photosynthesis in some plants (Steffen and Canadell, 2005). However, higher concentrations of carbon dioxide could also reduce crop quality, by lowering the content of protein and trace elements (EEA, 2004). The positive impacts of carbon fertilization are likely to be restricted by high temperatures and low rainfall, which are both expected to occur in Australia (CSIRO, 2007).

Climate change will affect the comparative advantage of different countries in agricultural production as compared with Australia. For example, given the assumed increases in New Zealand's agricultural productivity, as reported in Cline (2007), output of New Zealand dairy and beef is expected to expand, relative to the reference case, while Brazil is expected to take an increasing share of world sugar production.

In the south west of Western Australia declines in rainfall are already a fact of life for farmers. This is illustrated in Figure 2, (from Department of Agriculture and Food, 2008) which suggests a contraction of the wheat belt in a south westerly direction.

Figure 2: Average May-July rainfall in 1975 to 2003 (dotted isohyets) compared to 1925 to 1975 (solid isohyets)



Source: P. Hope, 2005, Indian Ocean Climate Initiative Notes on Changed Climate in SWWA Number 5/05 www.ioci.org.au

4.2 Impacts on Agricultural Productivity

ABARE quotes several studies of the productivity impacts of prospective climate change. The main effects occur through changes in *average* conditions, notably from changes in rainfall, temperature and ET. *Extreme events* such as flooding and droughts are also likely to impact on agricultural productivity and production by decreasing crop yields and increasing stock losses (Ecofys, 2006). Flooding has not been indicated as a rising source of loss in WA, but the effects of drought are likely to become more severe. Changes in temperatures are projected to alter the incidence and occurrence of pests and diseases, in some cases benignly, in others adversely. Relevant studies giving implications for agriculture in Western Australia are summarized in Table 4.

Table 4: Potential climate change impacts on Western Australian agriculture (for given changes in temperature relative to 1990)

Temperature Change	Sector/Impact	Source
< 1°C	Annual milk production per cow falls by 250–310 litres, or 6 per cent	Preston and Jones, 2006
	Total factor productivity of wheat in WA falls by 7.3 per cent, relative to the reference case	Heyhoe et al., 2007
	Total factor productivity of sheep meat in WA falls by 6.1 per cent, relative to the reference case	Heyhoe et al., 2007
1–2°C	Pasture productivity falls 15 per cent with 20% lower precipitation	Crimp et al., 2002
	Liveweight gain in cattlefalls 12 per cent with 20 per cent lower precipitation	Crimp et al., 2002
3-4%	Tick-related losses in net cattle production weight increase by 128%	Crimp et al., 2002

4.3 Impacts on Agricultural Output

ABARE has assessed the combined impacts in Australia of (i) assumed global developments (slowdown in global economic activity and a decline in agricultural productivity) and (ii) domestic developments (a decline in agricultural productivity in key growing regions) using its GTEM–Ausregion modelling interface. Overall, the modeling results indicate that the output effects on key agricultural industries are broadly in line with the productivity impacts. With assumed changes in climate, Australian production of key agricultural products is estimated to decline relative to the reference case, as follows:

- ***Whea***t: production is estimated to decline by 8.3–9.6 per cent at 2030 and 12–13 per cent at 2050, *relative to the reference case*, in New South Wales, Victoria, South Australia and Western Australia.
- ***Sheep meat***: output in the sheep meat industry in New South Wales, Victoria, South Australia and Western Australia is estimated to decline by 6.4–8.1 per cent at 2030 and 12–13 per cent at 2050, *relative to the reference case.*
- ***Beef:*** output in New South Wales, Victoria, Queensland, Western Australia and Northern Territory is estimated to decline by between 0.7–20 per cent at 2030 and 3.0–34 per cent at 2050, *relative to the reference case*, as a result of potential changes in climate.
- ***Dairy industry:*** output is also estimated to fall *relative to the reference case*, at 2030 and 2050.

ABARE emphasizes that there is a continuing need for the agriculture sector to maintain strong productivity growth in order to cope with the potential pressures emerging from climate change. In this context, adaptation measures, including improved agricultural technologies (including irrigation systems), will be particularly important in reducing the potential impacts. There is also an urgent need for policies that encourage rather than impede adjustment in vulnerable sectors in agriculture, including already marginal farming enterprises.

4.4 Irrigation Prospects

ABARE projections refer to wheat, sheep meat, beef and dairy production, without any differentiation of irrigated versus rain-fed production. They take account of rainfall and water availability in a lumped manner. Therefore, the ABARE results are of little help in assessing impacts on irrigated agriculture. This is probably due to the importance of the Murray Darling Basin in total Australian agriculture. In that basin climate impacts on irrigation enterprises are likely to be at least as bad as those for dryland farms, given a scenario for lower rainfall and runoff.

However, in areas where irrigation can be substituted for dryland farming, or where water can be accessed to maintain the viability of animal production in dryland farming areas, there could be substantial pressure for increased access to water entitlements. The availability and cost of water will then become critical for farm viability in existing agricultural areas. Cline (2007) suggests that under a “baseline” global warming scenario the ratio of irrigated crop area to total harvested crop area in the U.S.A. could rise by some 20.3% by 2080, water availability and cost permitting.

4.5 Western Australian Farming

Kingwell (2007), writing before the publication of *Climate Change in Australia* (CSIRO and Bureau of Meteorology 2007) suggested the following potential impacts for Western Australia (our notes are added in parenthesis):

- Changes in the seasonal distribution of rainfall with some regions becoming drier whilst others, particularly some pastoral regions, becoming wetter. *The latest CSIRO/BoM paper implies widespread rain decrease in pastoral areas as more likely than increase (Kimberley excluded). In current projections for the State as a whole the spatial prospects of beneficially wetter change are significantly less than for drying.*
- Rising temperatures that have implications for all agricultural crops via potentially large changes in heat or chill accumulation and the frequency of temperature extremes. A

potential benefit for grain and horticulture crops would be the reduced risk of frost. However, conversely more hot days during grain or fruit filling could reduce yields.

- An expected decline in the rate of spread of salinity under a drier, more evaporative climate.
- Increased demands on farm water storage and irrigation water. These resources will be affected by changes in temperatures and the incidence of rainfall. Combined with higher evaporation rates, it is likely that farm and regional water storage capacity will need to be increased.
- Maintaining environmental water flows and providing water for irrigation farming may become increasingly difficult in some regions.
- More frequent extreme weather events (e.g. consecutive days of extreme heat, extreme thunderstorms) will affect rural and urban communities and potentially cause additional crop and stock losses. *Not sure about thunderstorms in terms of frequency. South Western Australia is anomalous in rainfall extremes*
- The risk from insect pest and weed competition will probably change. Higher temperatures are favourable to many insects, though their ultimate activity will be dependent on any changes to summer rainfall. A warmer climate might also favour many plant diseases.
- Native species with restricted climatic ranges or limited mobility face the possibility of extinction in some rural regions.
- However, as many of the effects of global warming on agriculture are gradual, it is expected that incremental technological improvement and plant breeding improvements will lessen the severity of many of the impacts for agriculture. Appropriate farming systems are likely to be able to emerge gradually in response to climate change. *This interpretation might warrant more qualification at the margins*

The following sections provide an interpretation of the implications of the Stern, ABARE and Kingwell studies for agriculture in the study Demand Regions.

4.5.1 Wheat-Sheep Zone

The most directly-applicable results from ABARE in the Water Demand Scenario Modeling Study are those that relate to the wheat-sheep zone, namely the Pallinup, Upper Great Southern, Moore, Greenough and Midland Demand Regions. Here, in the absence of any countervailing technical change, the productivity impacts of climate change on the cereals, sheep and beef industries are likely to be correlated with production declines, and associated reductions in regional populations and economic activity relative to the reference case.

Climate change seems likely to negatively affect northern and eastern parts of wheat belt, and particularly areas that currently experience 350mm or less rainfall at present (Kingwell, 2007). These thresholds of marginality are likely to move southwards and westwards as global warming progresses. Thus, agriculture in much of the Greenough and Midland Demand regions seems likely to face yield reductions of between 10% and 50%. In contrast to this, adverse impacts on yields in the dryland agricultural areas lying between the 350mm and 600mmm isohyets seem less certain (Kingwell, 2007). It is tacitly understood that in the highest rainfall areas of this region that there may have been benefits from changes seen so far, certainly when combined with the benefits of modern crop varieties and drill seeding.

In terms of farm incomes, and associated levels of regional economic activity, a counter-veiling factor will be that the generally depressed physical productivity in cereals and beef production *globally* would tend to increase the prices received by producers.

Kingwell's (2007) suggestion that climate change is likely to *increase demands on farm water storage* is highly relevant in this region. This would imply that the downward effect on farm production and productivity would be to some degree offset by an upward trend in unit water use. In the wheat belt, this use is generally un-licensed.

4.5.2 The South West

The South West climatic region includes Preston, Vasse, and Blackwood Demand regions, which contain a large area of intensive production of beef, milk, horticultural products and grapes, on both rain fed and irrigated land.

To the extent that water availability for irrigation in temperate Australia is likely to be correlated with rainfall trends, there would be likely to be increasing incentive for irrigators to improve irrigation efficiency, and this would tend to offset declines in bulk water supply availability to irrigation areas. Direct water requirements for irrigation of pasture are also likely to increase as a result of increased temperature and evaporation, and this would reinforce the incentive to achieve irrigation system improvements. It is also likely that water will become more freely traded in future, with more examples of transfers from agricultural production into higher-value uses, or from low-marginal value uses such as pasture irrigation into higher-marginal value uses such as horticulture. (Resource Economics Unit, 2007).

4.5.3 Kimberley Region

The Kimberley Climate Region covers the West and East Kimberley Demand Regions. By far the largest water use is in the Ord River Scheme in the East Kimberley, where sugar cane is the prime crop. The region also supports an extensive pastoral industry producing beef. The region has experienced increased monsoonal activity in recent decades and some associated cooling. This circumstance may be influenced by Asian aerosols and may also be a manifestation of regional rainfall variability. Climate scenarios for global warming are ambivalent for rainfall in this region, but whilst the Asian aerosols persist the mid-term probabilities favour the status quo. In the longer term, the effects of global warming will be a more dominant influence on outcomes for this region and warming is expected. However, the long term rainfall projections show no clear trends at this stage of investigation.

According to ABARE (2007) sugar output in Brazil is expected to expand under a climate change scenario, *relative to the reference case*, given a projected increasing comparative advantage for Brazilian sugar production. Sugar production in India and ASEAN countries (particularly Thailand) is projected to be most adversely affected by climate change. Given the generally more favourable observed rainfall and temperature trends and projections for at least the next few decades in the Kimberley it appears unlikely that water availability will be an issue for the sugar cane industry in the Kimberley regions. However, the international competitiveness of Australian sugar, including that from the Kimberley will remain an issue. More work is needed on potential market share of Kimberley sugar industry given the projected declines in productivity in Indian and ASEAN countries.

5. MINERALS AND ENERGY INDUSTRIES

We are not aware of any assessment of climate change impacts on international trade in the minerals and energy sectors that might affect growth prospects for these industries in Western Australia. Much has been written about the carbon-intensity of China's and India's rapid build-up of infrastructure, and how clean coal technology might help to abate future carbon emissions from the steel industry in those countries. However, there is little to suggest that the rates of economic growth and infrastructure investment in those countries will be slowed as a result of climate initiatives. Thus, no-one has argued that demand for Western Australian minerals or energy from the ferrous and non-ferrous metals industries of China, India and other countries will be affected in the foreseeable future.

Based on Stern (2006), ABARE assumed that in developed and developing countries economic activity will decline by 5 per cent and 10 per cent respectively by 2050, *relative to what would otherwise be the case*, as a result of potential changes in climate.

To put this in the context of the current study, arbitrarily-chosen growth rates with and without a 10 per cent reduction are due to climate change. The last column shows the reduction in growth factor over 22 years (the time period for the current study) for a 10 per cent reduction in the annual average growth rate. It is seen that for all initial growth rates the climate-adjusted growth factor for Year 22 is 4.5 per cent less than the original factor. Thus, as a broad indication, the maximum rate of impact considered in ABARE (2007) would suggest, *ceteris paribus*, an average 4.5 per cent *downward* variation in primary industry output and *ergo* water demand estimates at year 2030 as a result of economic activities responding to depressed global markets.

Table 5:Illustrative growth rates with and without climate change

Initial Growth Rate (%/Yr)	Growth Factor by End Year (50 Years)	Growth factor after a 10% reduction (50 Years)	Revised Growth Rate (%/Yr)	Change in Growth Factor by Year 22
1.0	1.64	1.48	0.79	-4.5%
2.0	2.69	2.42	1.79	-4.5%
3.0	4.38	3.94	2.78	-4.5%
4.0	7.11	6.40	3.78	-4.5%

Under a climate-dependent scenario such factors could be used to replace the growth rates assumed for the mining sector in the 1st MONASH-TERM run, with lower growth rates. Economic impacts on other sectors within the WA economy would then be generated through the economic model.

6. UNIT WATER USE

This Section summarises indicative conclusions about potential changes in the amount of water likely to be demanded per unit of activity in each user group. These changes can be used to modify the water use coefficients within the Water Demand Scenario Modelling Tool for climate-dependent projections.

6.1 Units of Activity

We do not discuss here the absolute unit rates of use in the Base Year. These are set out in Technical Paper No 4. The units that have been used within the Water Demand Scenario Modelling study are as follows:

❑ Irrigated agriculture	Areas irrigated, value added, employment
❑ Dryland agriculture	Value added, employment, number of livestock
❑ Fishing, Forestry	Value added, employment
❑ Mining	Value added, employment
❑ Manufacturing and Processing Industry	Value added, employment
❑ Service Industries	Value added, employment
❑ Civic uses	Value added, employment
❑ Households	Population

6.2 Principal Climate Change Factors

Rising temperatures and diminution of rainfall inputs will push water demands higher in most regions. These changes in-turn will increase demand for efficiencies and substitutions in regional water use. The net effect on unit water demand will vary between classes of use. This area of demand adjustment is a primary input in use of the demand tool. There is not much available basis for predictive modeling and a sensitivity approach may be needed.

Regulatory measures will develop further to add structural pressure to market forcing of water efficiencies. Examples would be changes to urban form and appliance design or even prohibition of some usage. The Demand Tool will allow the Department to explore alternative regulatory scenarios.

The principal climate change factors that may affect future unit water use are as follows:

- Rainfall (declining in most regions, possibly increasing in the Kimberley). This is generally likely to increase unit water demands.
- Rising temperatures and evapotranspiration (ET): while they are to be expected everywhere, these are likely to be particularly severe in the Murchison, Pilbara and Kimberley regions. The effect seems likely to increase unit water demands.
- Drought conditions of increasing frequency. The effect is likely to be to increase demands for surface water storage capacity

It is not considered likely that cyclones will increase in frequency, though they may increase in intensity. They have not been considered as a major influence on water demand. Similarly flooding has not been viewed as a major influence on water demand.

6.3 Summary of Unit Demand Influences

Our preliminary assessments of potential climate-induced shifts in *unit demand* for water, in each climate region, are given in Annex A. The potential effects may be summarised as follows:

❑ Irrigated agriculture	Unit demands generally increase in response to higher temperatures and ET, and in response to declining rainfall in

	areas where irrigation is supplementary.
❑ Dryland agriculture	Unit demands for stock water purposes increase
❑ Fishing	Possible small effects from rising temperature and ET in processing activities
❑ Forestry	No change in unit demands
❑ Mining	Small increases in unit demands for wash down, dust suppression etc
❑ Manufacturing and Processing Industry	Significant increase where water is used for cooling. Small increases for water-intensive process activities.
❑ Service Industries	Some indoor cooling/humidifying processes e.g. sprays, may have higher unit use; landscaped areas will have increased irrigation demand, wash down, dust suppression uses in construction or transport could require higher unit use.
❑ Civic uses	Ovals, golf courses, bowling greens, parks, gardens etc may require higher unit rates of irrigation unless layout or irrigation systems are modified
❑ Households	Garden irrigation requirements could increase unless counteracted by water conservation practices; there could be small increases in in-house use for showers etc in homes that lack air conditioning.

7. GREENHOUSE POLICY-INDUCED CHANGES

7.1 Overview

Carbon Trading is a market based mechanism for helping mitigate the increase of CO_2 in the atmosphere. Carbon trading markets are developed that bring buyers and sellers of carbon credits together with standardised rules of trade. Any entity, typically a business, that emits CO_2 to the atmosphere may have an interest or may be required by law to balance their emissions through mechanism of C sequestration. Similarly, business entities that reduce their carbon emissions may be able to sell their reductions to other emitters. Entities that manage forest or agricultural land might sell carbon credits based on the *accumulation* of carbon in their forest trees or agricultural soils.

7.2 Agriculture

In Australia, the agriculture sector accounted for just under 60 per cent of total methane emissions, 84 per cent of total nitrous oxide emissions and 17 per cent of overall greenhouse gas emissions in 2005. Adaptive responses in the agricultural industries will therefore be important for maintaining productivity growth and international competitiveness in response to climate change impacts and new policy environments. The agriculture sector may generate offsets through a range of agricultural management practices, including stubble retention, grazing management and conservation or minimum tillage practices, in order to build up carbon stocks in agricultural soils (M Keogh, 2007). There are still large gaps in scientific and technical knowledge of soil carbon. For example, the capacity of Australian soils to sequester carbon for an extended period is still unknown. A robust soil carbon accounting methodology will need to be developed before the development of an appropriate system for recognising carbon stored in soils is considered.

The implications for trends in agricultural water use with respect to carbon trading follow principally from constraints that might be placed on agricultural activity to limit greenhouse emissions. Modelling in WA has suggested that, because of their methane production, ruminants would soon leave the optimum solution for farm plans under carbon constraints (Kingwell, 2007). This would impact on the demand for stock water.

7.3 Forestry

Reduced land clearing and expansion of forestry areas are important for reducing growth in Australia's greenhouse gas emissions and increasing terrestrial carbon sequestration. There is evidence to suggest that the marginal cost of abatement through carbon sequestration, particularly in forestry, may be comparable to other abatement options such as fuel switching or energy efficiency (Stavins and Richards 2005). This sector therefore has a considerable opportunity for early involvement as a provider of offsets.

Changes of land use from agriculture to forestry may, however, lead to higher use of water. For example, it has been estimated that a change in land use from pine plantations to native *Banksia sp* woodlands would produce a net increase of 200mm/yr in recharge to the superficial aquifer. The use of groundwater by plantation forests is an unlicensed use.

Carbon offsets may be generated by expanding forestry areas (new forests plus regrowth of old forests), revegetating farmland (regeneration of native trees and shrubs) and protecting existing native trees and shrubs. About 70 per cent of forest plantations are located on private and leasehold land in Australia, and while plantations make up only around 1 per cent of the forest estate, plantations expanded by an average of 70 000 hectares a year nationally between 1995 and 2005 (BRS 2007). Present arrangements for recognising the carbon sequestered in above ground sinks such as forest plantations require the carbon stock to be maintained for a period of a hundred years (GGAS 2007). However, assuming no change in existing policy measures, the sequestration of carbon in the forestry sector is expected to decrease to about 39 Mt CO_2-eq by 2020 (table 2), a reduction of 25 per cent compared with 2005 (AGO 2006b).

The cost of achieving a given carbon offset, particularly in the forestry sector, is likely to be influenced by a range of factors. These include biophysical factors, such as tree species, forestry practices, geographic location, and carbon yield patterns. Other factors that could influence the efficiency of carbon sequestration in the forestry sector include the opportunity cost of land, availability of water, forest management practices, the disposal of forest products and related biomass, and the policy instruments used to achieve carbon sequestration. The amount of carbon that can be sequestered in forests is influenced by region and tree species. In Australia, forestry sequestration potentials range from about 23.6 tonnes of carbon dioxide per hectare a year in tall, dense eucalypt forests that are less than ten years old to about 0.7 tonnes of carbon dioxide per hectare a year in mature, medium density forests (NGGIC 2006).

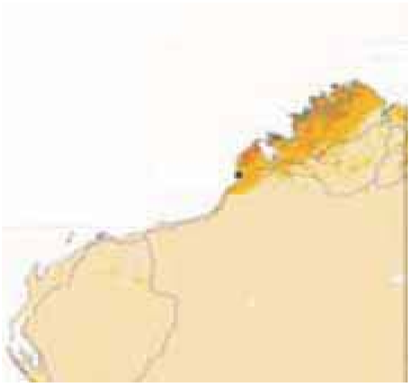
ABARE has produced a map of areas in Australia that are prospective for increased carbon sequestration from forestry. The Western Australian sections of that map are reproduced below as Figure 3. It is seen that the area deemed to be the most prospective (but still obtaining only a

“Medium” rating) is in the Vasse and Blackwood Demand Regions, with “Medium-Low” or “Low” ratings elsewhere in the South West and in the Kimberley.

Figure 3: Carbon sequestration potential for forestry in WA
(after ABARE, 2007)

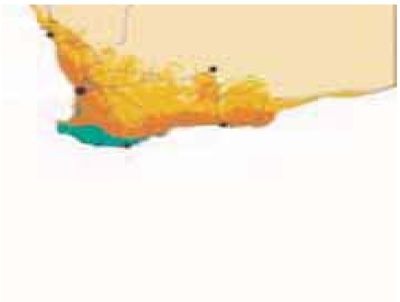
Legend:

(a) Northern Half



	High
	Medium High
	Medium
	Medium Low
	Low
	No Data/Not Applicable

(b) Southern Half



7.4 WA Treasury Modelling

The Western Australian Department of Treasury and Finance has undertaken a preliminary analysis of the potential impacts on the Western Australian economy of an emissions reduction strategy (Layman, 2008). Model scenarios were developed for reductions in Western Australian emissions of between 35% (Scenario 1) and 45% (Scenario 2) relative to the levels projected for the year 2030. The reductions would broadly keep the level of emissions at 2003 levels *(which appears to imply that it relates more to a global A1B type compromise scenario rather than to aspirations for avoiding dangerous change through a B1 type scenario).*

These imposed reductions in emissions would lead to a reduction of 1.3% to 1.4% in WA Gross State Product in the year 2030. Impacts on individual industry sectors, shown in Table 6, would be much more marked.

Table 6: Potential impacts on WA industries of alternative scenarios for reductions in emissions

Industry	**Change Relative to Projected Level in 2030 (%)**	
	Scenario 1	Scenario 2
Agriculture	-4	-6
Forestry	143	351
Mining	1	1
Coal	-2	-45
Gas	3	6
Manufacturing	0	-2
Electricity	-14	-14
Other Utilities	0	-2
Transport	-3	-3
Construction	-2	-2
Services	-1	-1

Source: Layman (2008)

Both scenarios indicate a major expansion of Forestry for production of carbon offsets. There is also a significant impact on Electricity production under both scenarios. The more ambitious emissions reduction scenario requires a substantial reduction in output of the Coal industry and a significant increase in the output of Gas. There are relatively small impacts on other sectors. Net gains are projected for output from the Mining sector. Conversely, Manufacturing, Utilities, Transport, Construction and Services all decline from between 1% to 3% relative to the base case. It is important to remember that these projected changes are estimated for alternative emissions reduction strategies. They do not take account of wider climate change impacts: e.g. on international markets for WA products resulting from global GDP effects.

8. GROWTH SCENARIOS AND UNIT WATER USE UNDER EXPECTED CLIMATE CHANGE

The following table prescribes a set of assumptions that could be used in compiling a climate-sensitive projection of water demand in WA, using the Water Demand Scenario Modeling Tool, and drawing on the literature review and our interpretation of the implications for individual usage sectors with each of the 19 Demand regions.

Table 7: Compilation of a climate-sensitive MONASH-TERM run to the year 2030

SECTOR		Suggested adjustments to value added growth rates	Suggested adjustments to unit water use coefficients
Agriculture Forestry & Fishing			
1	Grain & Livestock	Steady decline relative to initial growth rates in all wheat belt regions with the sharpest declines being in Midlands and Greenough (productivity forced)	Steadily increasing
2	Beef Cattle	Unchanged growth rates to 2020, with decline thereafter in Peel, Preston, Vasse and Blackwood plus all wheat belt regions. Unchanged growth rates in the Kimberleys (Productivity forced)	Steadily increasing
3	Dairy Cattle	Growth to 2020, decline thereafter notably in Preston	Steadily increasing
4	Pigs	Change generated by model	Steadily increasing
5	Poultry	Change generated by model	Steadily increasing
6	Cotton	Change generated by model	Steadily increasing
7	Grapes	Change generated by model	Steadily increasing
8	Vegetables	Change generated by model	Steadily increasing
9	Other Horticulture	Change generated by model	Steadily increasing
10	Sugar Cane	Could go either way: a pessimistic case would be for negative growth after 2020	Steadily increasing
11	Other Agriculture & Services	Change generated by model	Steadily increasing
12	Forestry	Increased growth in Vasse and Blackwood (Incentives forced)	Static
13	Fishing	No change (may be some productivity forced decline through effects of ocean warming and acidification)	Static

Mining and Energy			
14	Coal	Possible shutting down of the industry (policy forced)	Static
15	Oil Gas	No change	Static
16	Iron Ores	4.5% reduction in 2030 (Changed export growth rates)	Static
17	Other Metal Ores	4.5% reduction in 2030 (Changed export growth rates)	Static
18	Other Mining	4.5% reduction in 2030 (Changed export growth rates)	Static

Manufacturing			
19	Meat Products	Change generated by model	Small increases
20	Dairy Products	Change generated by model	Small increases
21	Fruit & Vegetables	Change generated by model	Small increases
22	Other Food & Tobacco	Change generated by model	Small increases
23	Beverages	Change generated by model	Small increases
24	Textiles, Clothing & Footwear	Change generated by model	Small increases
25	Sawmill Products	Change generated by model	Small increases
26	Other Wood Products	Change generated by model	Small increases
27	Pulp, Paper & Printing	Change generated by model	Small increases
28	Petroleum & Coal Products	Change generated by model	Small increases
29	Chemicals	Change generated by model	Moderate increase for cooling demand
30	Non-Metalic Mineral Products	Reduce output by 4.5% in 2030	Small increases
31	Iron & Steel	Change generated by model	Moderate increase (cooling demand)
32	Basic Non-ferrous Metal products	Reduce output by 4.5% in 2030	Moderate increase (cooling demand)
33	Metal Products	Change generated by model	Small increases
34	Transport Equipment	Change generated by model	Small increases
35	Photographic & Electronic Equipment	Change generated by model	Small increases
36	Other Equipment	Change generated by model	Small increases
37	Other Manufacturing	Change generated by model	Small increases

Service Industries			
38	Electricity & Gas	Change generated by model	Moderate increase for cooling demand)
39	Water, Sewerage & Drainage	Change generated by model	Moderate increase for system evaporative losses, primarily in irrigation systems
40	Construction	Change generated by model	Static
41	Wholesale Trade	Change generated by model	Static
42	Retail Trade	Change generated by model	Static
43	Mechanical & Other Repairs	Change generated by model	Static
44	Hotels, Restaurants & Cafes	Change generated by model	Moderate increase for landscaping demands
45	Transport & Communication	Change generated by model	Static
46	Finance, Business & Property Services	Change generated by model	Static
47	Ownership of Dwellings	Change generated by model	Sector is not used
48	Government Administration & Defence	Change generated by model	Static
49	Education	Change generated by model	Moderate increase for landscaping demands
50	Health	Change generated by model	Static
51	Welfare Services	Change generated by model	Static
52	Entertainment & Leisure (incl civic uses)	Change generated by model	Moderate increase for landscaping demands (large increase if there is no change to landscaping)
53	Personal & other Services	Change generated by model	Static

Additional categories			
54	Population (Household usage from public supply)	Change generated by model	Increased unit water use coefficient in the absence of successful water conservation initiatives
55	Licensed Domestic and Stock Water	Linked to growth rates in relevant agricultural industries	Increase unit water use coefficients (defensive water harvesting to counteract climate change impacts on productivity in all except the Kimberley regions
56	Environmental Allocation	No change (will be entered directly following the current review of allocation limits)	
57	Use Not Specified in WRL	No change (treated as a function of growth across all other sectors).	
58	Licensed Rural Domestic Usage		Increase unit water use coefficients (defensive water harvesting to counteract climate change impacts on productivity in all except the Kimberley regions)
59	Unlicensed Use		Increased use in both metropolitan and rural areas (defensive water harvesting to counteract climate change impacts

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ANNEX A: DETAILED ASSESSMENT OF POTENTIAL CLIMATE CHANGE IMPACTS BY USER SECTOR AND CLIMATE REGION

Important Note: The usage quantities given in this Annex were those available at an early stage in the study, and have been changed in the Final Report. However, they have been left in this document in order to give a broad impression of scale against each assessment.

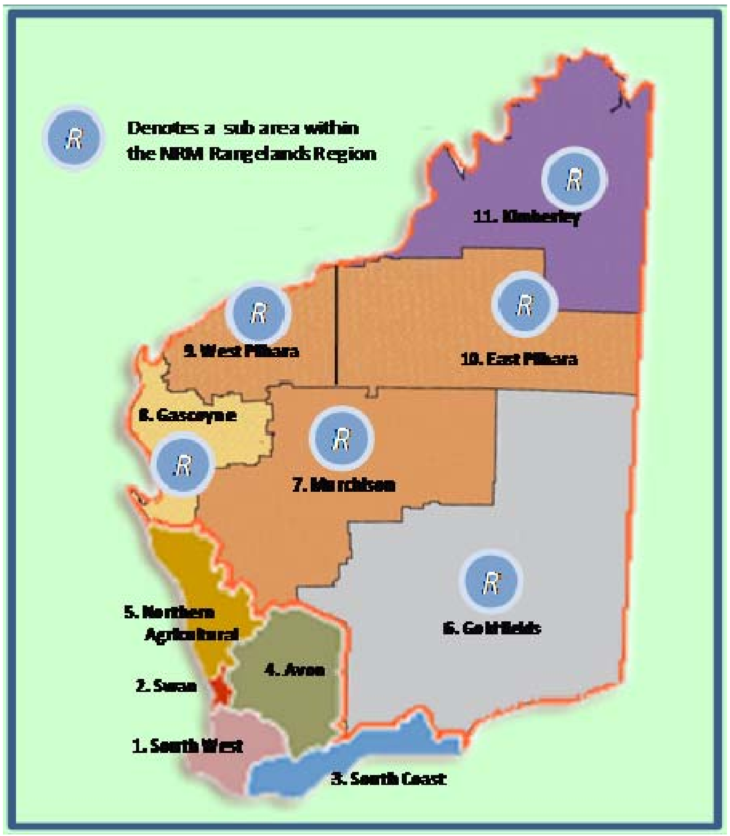
For background see -
Climate Change Scenarios affecting the Water Supply/Demand Balance in Western Australia (Draft)
Part 1 – Report and State Overview
Part 2 – Regional Scenarios

THE REGIONS

The map below shows regions as defined for development of hydroclimatic scenarios (Sadler ed., 2008). These boundaries allow simple correspondence to the more geographically detailed Demand Regions of this study.

Boundary Definition:

The regional boundaries used for this report are hybrid boundaries, with the Natural Resources Management Regions as their prime source.



Northern Agricultural, Avon, Swan, South West and South Coast regions are NRM regions.

The other regions are sub-divisions of the NRM Rangelands Region.

The Rangelands Region sub-division has followed boundaries used in defining the DoW Demand Regions. However, the East and West Pilbara separation has been moved eastwards to roughly differentiate the Pilbara rivers from the desert zone.

Two prime means by which climate change is seen to affect future (and present) water demand in WA are :

- Effect of climate on unit consumption
- Structural effects such as
    - changes in growth driven by climate induced changes in the global economy (global GDP),
    - changes in comparative economic competitiveness and opportunity consequent on climate change
    - changes in regional economic and social infrastructure driven by climate
    - changes in productive feasibility (eg crop or farming style) caused by crossing of climate thresholds

The draft worksheets below have made some first pass judgements on how these might develop over the next two decades for seven component sub-divisions of the total regional water demand in WA.

The nature of these potential impacts, together with judgements on their likely scale and the confidence underlying these judgements are presented for each of the 11 regions in the Demand Worksheets. Also tabulated is the current annual use in GL for each component of use in each region.

The magnitude of annual use in the 7 components and 11 regions varies greatly and clearly the greatest potential water impact will come from significant changes at the higher end of use.

The most readily identified impacts are changes in unit demand (Effect 1.) and (Effect 2. i) implicit change in regional growth responding to changes in Global GDP(potentially projected via the Monash Model). Other structural changes (2. ii, 2. iii, 2. iv) are more difficult to identify and poorly researched at this stage of climate change knowledge.

Of these potential changes recognised in the work sheets the following tables present a simple analysis enabling a first judgement of the potential scale of impact on each component of use for each region and some appreciation of the confidence of that assessment. The analysis considers both (1.) unit consumption impacts and (2.) Structural impacts.

Because the State is warming and (except perhaps for the Kimberley) drying, the effects on (1.) unit consumption are almost always expected as an increase (of differing scales from low to high). The presently identified structural change potentialities are mostly 2.(i) GDP driven and are generally for some lowering through reduction of business as usual growth.

The following summary tables serve three purposes:

- They present a means for quick inspection of the regions and use components which are most likely to affect the State's water balance

- They present a quick inspection assessment of the components of climate driven demand most warranting further investigation

- They provide a side-by-side view of the first-pass judgements for various demand components across the regions and thereby show up possible inconsistencies for quality checking and review.

Climate Change Impacts on Unit Demand - 3. Industrial

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	127	L	2	H	6
1	South West	16	M	4	H	6
6	Goldfields	4	L	2	M	4
4	Avon	3	L	2	H	6
5	North Agricultural	3	L	2	H	6
9	West Pilbara	3	M	4	H	6
3	South Coast	2	VL	1	H	6
11	Kimberley	2	L	2	M	4
8	Gascoyne	1	L	2	M	4
10	East Pilbara	1	M	4	H	6
7	Murchison	0	I?	0	VH?	7

Climate Change Impacts on Structural Demand - 3. Industrial

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	127	L	2	H	6
1	South West	16	Z	0	H	6
6	Goldfields	4	L	2	M	4
4	Avon	3	L	2	M	4
5	North Agricultural	3	L	2	M	4
9	West Pilbara	3	L	2	M	4
11	Kimberley	2	L	2	M	4
3	South Coast	2	VL	1	H	6
8	Gascoyne	1	L	2	M	4
10	East Pilbara	1	L	2	M	4
7	Murchison	0	I?	0	VH?	7

Climate Change Impacts on Unit Demand - 4. Mining

Region	Name	Use GL	Scale of Impact		Confidence	
6	Goldfields	210	LM	3	M	4
10	East Pilbara	177	MH	5	MH	5
7	Murchison	90	LM	3	M	4
9	West Pilbara	89	LM	3	M	4
1	South West	63	L	2	H	6
5	North Agricultural	48	M	4	M	4
11	Kimberley	24	L	2	M	4
3	South Coast	14	VL	1	H	6
4	Avon	13	Z	0	M	4
2	Swan	5	L	2	H	6
8	Gascoyne	3	LM	3	M	4

Climate Change Impacts on Structural Demand - 4. Mining

Region	Name	Use GL	Scale of Impact		Confidence	
6	Goldfields	210	M	4	M	4
10	East Pilbara	177	L	2	M	4
7	Murchison	90	M	4	M	4
9	West Pilbara	89	M	4	M	4
1	South West	63	L	2	H	6
5	North Agricultural	48	L	2	M	4
11	Kimberley	24	L	2	M	4
3	South Coast	14	VL	1	H	6
4	Avon	13	L	2	M	4
2	Swan	5	L	2	H	6
8	Gascoyne	3	L	2	M	4

Climate Change Impacts on Unit Demand - 1. Irrigation

Region	Name	Use GL	Scale of Impact		Confidence	
11	Kimberley	356	L	2	LM	3
1	South West	228	M	4	H	6
5	North Agricultural	152	MH?	5	H	6
2	Swan	93	M	4	H	6
8	Gascoyne	19	MH	5	M	4
3	South Coast	6	L	2	MH	5
7	Murchison	3	M	4	H	6
4	Avon	0	Z	0	H	6
6	Goldfields	0	Z	0	H	6
9	West Pilbara	0	Z	0	VH	7
10	East Pilbara	0	I	0	VH	7

Climate Change Impacts on Structural Demand - 1. Irrigation

Region	Name	Use GL	Scale of Impact		Confidence	
11	Kimberley	356	MH	5	L	2
1	South West	228	M	4	M	4
5	North Agricultural	152	L	2	M	4
2	Swan	93	L	2	H	6
8	Gascoyne	19	L	2	M	4
3	South Coast	6	L	2	MH	5
7	Murchison	3	M	4	H	6
4	Avon	0	Z	0	H	6
6	Goldfields	0	Z	0	H	6
9	West Pilbara	0	Z	0	VH	7
10	East Pilbara	0	I	0	VH	7

Climate Change Impacts on Unit Demand - 2. Town Supply

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	233	M	4	H	6
1	South West	55	M	4	M	4
5	North Agricultural	13	L	2	M	4
3	South Coast	8	L	2	M	4
4	Avon	8	L	2	M	4
8	Gascoyne	5	L	2	M	4
11	Kimberley	5	L	2	M	4
6	Goldfields	4	L	2	M	4
9	West Pilbara	4	MH	5	MH	5
10	East Pilbara	3	L	2	MH	5
7	Murchison	1	L	2	M	4

Climate Change Impacts on Structural Demand - 2. Town Supply

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	233	M	4	H	6
1	South West	55	M	4	H	6
5	North Agricultural	13	M	4	M	4
4	Avon	8	M	4	M	4
3	South Coast	8	L	2	MH	5
8	Gascoyne	5	L	2	M	4
11	Kimberley	5	L	2	M	4
9	West Pilbara	4	M	4	M	4
6	Goldfields	4	LM	3	M	4
10	East Pilbara	3	M	4	M	4
7	Murchison	1	L	2	M	4

Climate Change Impacts on Unit Demand - 5. Commercial

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	176	M	4	H	6
1	South West	16	M	4	H	6
5	North Agricultural	10	L	2	M	4
6	Goldfields	10	LM	3	M	4
11	Kimberley	8	L	2	M	4
4	Avon	7	L	2	M	4
9	West Pilbara	6	M	4	M	4
10	East Pilbara	6	M	4	M	4
8	Gascoyne	5	M	4	M	4
3	South Coast	4	VL	1	H	6
7	Murchison	1	LM	3	M	4

Climate Change Impacts on Structural Demand - 5. Commercial

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	176	L	2	H	6
1	South West	16	L	2	H	6
6	Goldfields	10	M	4	M	4
5	North Agricultural	10	L	2	M	4
11	Kimberley	8	L	2	M	4
4	Avon	7	L	2	M	4
9	West Pilbara	6	M	4	M	4
10	East Pilbara	6	M	4	M	4
8	Gascoyne	5	M	4	M	4
3	South Coast	4	VL	1	H	6
7	Murchison	1	M	4	M	4

Climate Change Impacts on Unit Demand - 6. Self Supply & Civic

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	252	MH	5	H	6
1	South West	23	M	4	H	6
11	Kimberley	17	L	2	M	4
4	Avon	15	M	4	M	4
5	North Agricultural	15	M	4	M	4
3	South Coast	10	VL	1	H	6
8	Gascoyne	4	L	2	MH	5
7	Murchison	3	L	2	MH	5
9	West Pilbara	3	L	2	M	4
10	East Pilbara	3	L	2	M	4
6	Goldfields	2	L	2	MH	5

Climate Change Impacts on Structural Demand - 6. Self Supply & Civic

Region	Name	Use GL	Scale of Impact		Confidence	
2	Swan	252	M	4	H	6
1	South West	23	LM	3	M	4
11	Kimberley	17	L	2	M	4
5	North Agricultural	15	H	6	L	2
4	Avon	15	M	4	H	6
3	South Coast	10	VL	1	LM	3
8	Gascoyne	4	L	2	M	4
9	West Pilbara	3	M	4	M	4
7	Murchison	3	L	2	MH	5
10	East Pilbara	3	L	2	M	4
6	Goldfields	2	L	2	MH	5

Climate Change Impacts on Unit Demand -7. Env Provs/ Releases

Region	Name	Use GL	Scale of Impact	Confidence
11	Kimberley	?		
2	Swan	4		
1	South West	0		
3	South Coast	0		
4	Avon	0		
5	North Agricultural	0		
6	Goldfields	0		
7	Murchison	0		
8	Gascoyne	0		
9	West Pilbara	0		
10	East Pilbara	0		

Climate Change Impacts on Structural Demand -7. Env Provs/ Releases

Region	Name	Use GL	Scale of Impact		Confidence	
11	Kimberley	?				
2	Swan	4	H	6	H	6
1	South West	0				
3	South Coast	0				
4	Avon	0				
5	North Agricultural	0				
6	Goldfields	0				
7	Murchison	0				
8	Gascoyne	0				
9	West Pilbara	0				
10	East Pilbara	0				

1. South West Region

1. South West Region - Climate Change driven trends in Water Demand				
Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	228	*Unit Demand ex Climate Change:* depends (i) on the future crop mix: e.g. grapes lower water use, vegetables higher than existing pasture-based activities (covered by MONASH projections); (ii) reductions in irrigation water supply system losses due to channel replacement in the Collie Irrigation District. Future growth of irrigation water use may be constrained by water availability, but not land availability.	Moderate	High
		Unit Demand With Climate Change: all uses (including channel delivery systems) will have increasing unit demands due to higher temperatures and ET	Moderate	High
		Ex-Climate Structural Change: Steady tendency for change of land use from pasture irrigation to higher-value crops. Market pressure for transfer of water to urban/industrial uses with or without improved irrigation efficiency.	Moderate to High	High
		With Climate Structural Change: International competitiveness of the beef and dairy industries likely to decline. If water remains available for irrigation it will help to sustain these industries despite climate change, as productivity loss will then be less than that in dryland areas.	Moderate	Moderate
		The area is prospective for forestry initiatives in response to carbon credit incentives, and this could increase evapotranspirational demands on groundwater (currently unlicensed water use), depending on the pre-existing land use	Moderate	Moderate to High
Town Water Supply	55	*Unit Demand ex Climate Change:* assume constant per capita water use	Zero	Moderate
		Unit Demand with Climate Change: moderate increase as a result of increasing temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: continuing tendency for higher residential densities	Low to moderate	High
		With Climate Structural Change: there will be some reinforcement of trends in housing styles	Moderate	High
Industrial Demand	16	*Unit Demand ex Climate Change* : there will continuing attempts to make industrial processes more water efficient.	Low	High

		Unit Demand with Climate Change: a small increase due to increased cooling requirements	Moderate	High
		Ex-Climate Structural Change: growth as projected by MONASH model	Moderate	High
		With Climate Structural Change: no change	Zero	High
Mining Demand work site and process	63	*Unit Demand ex Climate Change*: no change	Zero	High
		Unit Demand with Climate Change: not very sensitive	Low	High
		Ex-Climate Structural Change: minor change: coal mining at Collie continues to grow; mineral sands mining continues to grow	Moderate	Moderate
		With Climate Structural Change: not very sensitive. It is not clear whether a possible slow-down in global economic growth will translate into slower growth prospects for mining in this region.	Low	High
Commercial Demand	16	*Unit Demand ex Climate Change:* efficiency drivers will dominate	Moderate	High
		Unit Demand with Climate Change: small climate effect	Moderate	High
		Ex-Climate Structural Change: continued growth of service industries in the region	High	High
		With Climate Structural Change: No major effect	Low	High
Self Supply Demand Including Civic	23	*Unit Demand ex Climate Change* : big efficiency drive (e.g. sporting facilities, parks and gardens, other landscaping)	Moderate to High	High
		Unit Demand with Climate Change: increasing temperature and ET will increase the water demands of turfs	Moderate	High
		Ex-Climate Structural Change: leisure activities are income-elastic and grow in response to regional economic growth	High	High
		With Climate Structural Change: possible switch away from outdoor to indoor activities	Low to moderate	Moderate

2. Swan Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	93	*Unit Demand ex Climate Change:* assume constant, as potential gains in irrigation efficiency are moderate for the current crop mix.		
		Unit Demand With Climate Change: all uses will have increasing unit demands due to higher temperatures and ET.	Moderate	High
		Ex-Climate Structural Change: MONASH model suggests substantial growth in water demand for vegetables and other horticulture, and lower for grapes. However, the growth of irrigation water use will be constrained by the availability of and land and water. There will be market pressure for transfer of land and water to urban/industrial or environmental uses with or without improved irrigation efficiency.	High	High
		With Climate Structural Change: None of the current irrigation activities seems likely to be much affected by international shifts in comparative advantage. However, the need to maintain environmental values in the face of changed temperatures and ET will further constrain allocation limits for irrigation use.	Low	High
Town Water Supply Demand including mine towns and camps	233	*Unit Demand ex Climate Change:* the Water Corporation has a target of keeping per capita use at 155kl/head, versus 170kl/head.	Moderate	Moderate
		Unit Demand with Climate Change: some increase as a result of increasing temperatures and ET	Moderate	High
		Ex-Climate Structural Change: there will be a continuing tendency for smaller block sizes in Perth. Housing styles will continue to change, with less ex-house water use but greater in-house use.	Low to Moderate	High
		With Climate Structural Change: there will be some reinforcement of trends in housing styles.	Moderate	High
Industrial Demand	127	*Unit Demand ex Climate Change* : there will continuing attempts to make industrial processes more water efficient.	Low	High
		Unit Demand with Climate Change: a small increase due to increased cooling requirements	Low	High
		Ex-Climate Structural Change: continued growth of the sector due to both heavy industry (coastal strip), food processing and servicing functions	Moderate	High

		With Climate Structural Change: small incremental effect	Low	High
Mining Demand work site and process	5	*Unit Demand ex Climate Change*: no change	Low	High
		Unit Demand with Climate Change: not very sensitive	Low	High
		Ex-Climate Structural Change: minor change	Low	High
		With Climate Structural Change: not very sensitive. It is not clear whether a possible slow-down in global economic growth will translate into slower growth prospects for mining in this region.	Low	High
Commercial Demand	176	*Unit Demand ex Climate Change:* efficiency drivers will dominate	Low	High
		Unit Demand with Climate Change: increasing temperatures and ET will push up irrigation use in this sector, especially in the area landscaped areas around offices, tertiary education facilities etc. Counteracting this, there will be a major efficiency drive.	Moderate	High
		Ex-Climate Structural Change: continued growth of service industries in the region	Moderate	High
		With Climate Structural Change: No major water demand impacts.	Low	High
Self Supply Demand Including Civic	252	*Unit Demand ex Climate Change* : major growth sector, counteracted by big efficiency drive (e.g. household bore usage, sporting facilities, parks and gardens, other landscaping)	Moderate to High	High
		Unit Demand with Climate Change: increasing temperature and ET will increase the water demands of household bores, parks, playing fields, gardens etc.	Moderate to High	High
		Ex-Climate Structural Change: leisure activities are income-elastic and grow strongly in response to regional demographic and economic growth	Moderate to high	High
		With Climate Structural Change: possible switch away from outdoor to indoor activities	Moderate	High
Environmental Provisions/ Releases	4	*Unit Demand ex Climate Change* :There will be a substantial increase in environmental water allocations in response to past rates of daw down of superficial aquifers	High	High
		With Climate Structural Change: There will be a significant increase in environmental allocations, or constraints imposed on licensed usage under new Statutory Water Management Plans	High	High

3. South Coast Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	6	*Unit Demand ex Climate Change:* little change	Low	Moderate to High
		Unit Demand With Climate Change: minimal impact	Low	Moderate to High
		Ex-Climate Structural Change: minimal change	Low	Moderate to High
		With Climate Structural Change: potential increase in plantation forestry schemes	Low	Moderate to High
Town Water Supply Demand including mine towns and camps	8	*Unit Demand ex Climate Change:* assume constant per capita water use	Zero	Moderate to High
		Unit Demand with Climate Change: minor increase as a result of slightly increasing temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: there will be less of a tendency for smaller block sizes than will occur in Perth.	Low	Moderate
		With Climate Structural Change: little effect	Low	Moderate to High
Industrial Demand	2	*Unit Demand ex Climate Change* : little change	Very Low	High
		Unit Demand with Climate Change: no effect	Very Low	High
		Ex-Climate Structural Change: minor	Very Low	High
		With Climate Structural Change: Minimal effect	Very Low	High
Mining Demand work site and process	14	*Unit Demand ex Climate Change* : little change	Zero	High
		Unit Demand with Climate Change: not very sensitive	Very Low	High

		Ex-Climate Structural Change: Some small initiatives may come to fruition	Very Low	High
		With Climate Structural Change: No discernible effect	Very Low	High
Commercial Demand	4	*Unit Demand ex Climate Change* : assume zero change	Zero	High
		Unit Demand with Climate Change: no effect	Very Low	High
		Ex-Climate Structural Change: Steady growth	Very Low	High
		With Climate Structural Change: no effect	Very Low	High
Self Supply Demand Including Civic	10	*Unit Demand ex Climate Change* : assume zero change	Zero	High
		Unit Demand with Climate Change: little effect	Very Low	High
		Ex-Climate Structural Change: growth in irrigation and pasture activities	Very Low	Low to Moderate
		With Climate Structural Change: little effect	Very Low	Low to Moderate

4. Avon Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	0	*Unit Demand ex Climate Change:*	Not Significant	Not Significant
		Unit Demand With Climate Change:	Not Significant	Not Significant
		Ex-Climate Structural Change:	Not Significant	Not Significant
		With Climate Structural Change	Not Significant	Not Significant
Town Water Supply Demand including mine towns and camps	8	*Unit Demand ex Climate Change:* static	Zero	Moderate
		Unit Demand with Climate Change: increase as a result of increasing temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: MONASH model predicts moderate population growth.	Low	Moderate
		With Climate Structural Change: accelerated decline in rural towns in the eastern part of the region, resulting from climate-induced reductions in farm output and productivity	Moderate	Moderate
Industrial Demand	3	*Unit Demand ex Climate Change* : static	Not significant	High
		Unit Demand with Climate Change: small increase for cooling purposes	Low	High
		Ex-Climate Structural Change: moderate growth of industrial activity	Low	Moderate
		With Climate Structural Change: there could be a small negative impact due to flow-on effects from climate impacts on the farm sector.	Low	Moderate
Mining Demand work site and process	13	*Unit Demand ex Climate Change*: static	Low	Moderate
		Unit Demand with Climate Change: not significant	Zero	Moderate

		Ex-Climate Structural Change: moderate growth expected in MONASH projections	Moderate	Moderate
		With Climate Structural Change: small negative effect on growth rate due to reduced growth in global GDP	Low	Moderate
Commercial Demand	7	*Unit Demand ex Climate Change:* static		Moderate
		Unit Demand with Climate Change: minor increase as a result of slightly increasing temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: Moderate growth envisaged	Moderate	Moderate
		With Climate Structural Change: accelerated decline in some rural towns resulting from climate impacts on the farm sector	Moderate	Moderate
Self Supply Demand Including Civic	15	*Unit Demand ex Climate Change* :usage for rural domestic and stock assume static	Moderate	Moderate
		Unit Demand with Climate Change: increase due to increased temperature and ET.	Moderate	Moderate
		Ex-Climate Structural Change: MONASH projects steady growth in the agricultural sector for this region which has been translated into continuing growth of self-supply in rural areas.	Moderate	High
		With Climate Structural Change: Analysts project significant negative productivity and output impacts from climate change for this region. However, this could translate into increased water use as farmers attempt to defend their profitability.	High	Low

5. Northern Agricultural Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	152	*Unit Demand ex Climate Change:* assume static	Zero	Moderate
		Unit Demand With Climate Change: increased demand due to higher temperatures and ET	Substantial effect	High
		Ex-Climate Structural Change: product mix generally stable	Substantial growth	Moderate to High
		With Climate Structural Change: no discernible effect on mix of irrigated products	Low	Moderate
Town Water Supply Demand including mine towns and camps	13	*Unit Demand ex Climate Change:* static	Zero	Moderate
		Unit Demand with Climate Change: increase as a result of increasing temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: MONASH model predicts moderate population growth.	Low	Moderate
		With Climate Structural Change: accelerated decline in rural towns in the eastern part of the region, resulting from climate-induced reductions in farm output and productivity	Moderate	Moderate
Industrial Demand	3	*Unit Demand ex Climate Change* : static	Not significant	High
		Unit Demand with Climate Change: small increase for cooling purposes	Low	High
		Ex-Climate Structural Change: moderate growth of industrial activity	Low	Moderate
		With Climate Structural Change: there could be a small negative impact due to flow-on effects from climate impacts on the farm sector.	Low	Moderate

Mining Demand work site and process	48	*Unit Demand ex Climate Change*: assume static	Zero	Moderate
		Unit Demand with Climate Change: minor impact	Moderate	Moderate
		Ex-Climate Structural Change: there are a number of mining projects that could be developed in this region, that could increase usage beyond the existing healthy growth rate	Low	Moderate
		With Climate Structural Change: small negative effect on growth rate due to reduced growth in global GDP	Low	Moderate
Commercial Demand	10	*Unit Demand ex Climate Change:* static	Zero	Moderate
		Unit Demand with Climate Change: minor increase as a result of slightly increasing temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: Moderate growth envisaged	Moderate	Moderate
		With Climate Structural Change: accelerated decline in some rural towns resulting from climate impacts on the farm sector	Moderate	Moderate
Self Supply Demand Including Civic	15	*Unit Demand ex Climate Change* :usage for rural domestic and stock assume static	Moderate	Moderate
		Unit Demand with Climate Change: increase due to increased temperature and ET.	Moderate	Moderate
		Ex-Climate Structural Change: MONASH projects steady growth in the agricultural sector for this region which has been translated into continuing growth of self-supply in rural areas.	Moderate	High
		With Climate Structural Change: Analysts project significant negative productivity and output impacts from climate change for this region. However, this could translate into increased water use as farmers attempt to defend their profitability.	High	Low

6. Goldfields Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	0	*Unit Demand ex Climate Change:*	Zero	High
		Unit Demand With Climate Change:	Zero	High
		Ex-Climate Structural Change:	Zero	High
		With Climate Structural Change:	Zero	High
Town Water Supply Demand including mine towns and camps	4	*Unit Demand ex Climate Change:* Assume static	Low	Moderate
		Unit Demand with Climate Change:	Low	Moderate
		Ex-Climate Structural Change: Steady but moderate growth in the mining sector leading to continued growth in demand		
		With Climate Structural Change: Possibility of a small reduction in growth rate in response to slower growth in global GDP and the mining sector		
Industrial Demand	4	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Slight increase for cooling purposes	Low	Moderate
		Ex-Climate Structural Change: No major changes assumed	Low	Moderate
		With Climate Structural Change: Possibility of slightly slower growth	Low	Moderate
Mining Demand	210	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate

work site and process		*Unit Demand with Climate Change*: Higher unit demand for wash-down etc purposes due to raised temperatures and ET	Low to Moderate	Moderate
		Ex-Climate Structural Change: Steady but moderate growth of the mining sector in this region	Significant	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Moderate	Moderate
Commercial Demand	10	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for irrigation purposes on commercial sites due to raised temperatures and ET	Low to Moderate	Moderate
		Ex-Climate Structural Change: Steady but moderate growth of the mining sector in this region will boost growth in the sector	Significant	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in flow-on effect of mining due to reductions in global GDP	Moderate	Moderate
Self Supply Demand Including Civic	2	*Unit Demand ex Climate Change* : Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for domestic and stock and some irrigation purposes due to raised temperatures and ET	Low	Moderate to High
		Ex-Climate Structural Change: Relatively static.	Zero	Moderate
		With Climate Structural Change: Probable reduction in demand for domestic and stock purposes	Low	Moderate to High

7. Murchison Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	3	*Unit Demand ex Climate Change:* Assume static	Zero	High
		Unit Demand With Climate Change: Increased due to higher temperatures and ET	Moderate	High
		Ex-Climate Structural Change: Moderate growth	Moderate	High
		With Climate Structural Change: Growth rate reduced	Moderate	High
Town Water Supply Demand including mine towns and camps	1	*Unit Demand ex Climate Change:* Assume static	Low	Moderate
		Unit Demand with Climate Change: Increased due to higher temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: Steady but moderate growth in the mining sector will lead to continued growth in demand		
		With Climate Structural Change: Possibility of a small reduction in growth rate in response to slower growth in global GDP and the mining sector		
Industrial Demand	0	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Slight increase for cooling purposes	Low	Moderate
		Ex-Climate Structural Change: No major changes assumed	Low	Moderate
		With Climate Structural Change: Possibility of slightly slower growth	Low	Moderate
Mining Demand	90	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate

work site and process		*Unit Demand with Climate Change*: Higher unit demand for wash-down etc purposes due to raised temperatures and ET	Low to Moderate	Moderate
		Ex-Climate Structural Change: Steady but moderate growth of the mining sector in this region	Significant	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Moderate	Moderate
Commercial Demand	1	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for irrigation purposes on commercial sites due to raised temperatures and ET	Low to Moderate	Moderate
		Ex-Climate Structural Change: Steady but moderate growth of the mining sector in this region will boost growth in the sector	Significant	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in flow-on effect of mining due to reductions in global GDP	Moderate	Moderate
Self Supply Demand Including Civic	3	*Unit Demand ex Climate Change* : Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for domestic and stock and some irrigation purposes due to raised temperatures and ET	Low	Moderate to High
		Ex-Climate Structural Change: Relatively static.	Zero	Moderate
		With Climate Structural Change: Probable reduction in demand for domestic and stock purposes	Low	Moderate to High

8. Gascoyne Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	19	*Unit Demand ex Climate Change:* Assume static	Zero	High
		Unit Demand With Climate Change: Increased due to higher temperatures and ET	Moderate to High	Moderate
		Ex-Climate Structural Change: Moderate growth	Moderate	High
		With Climate Structural Change: Little effect	Low	Moderate
Town Water Supply Demand including mine towns and camps	5	*Unit Demand ex Climate Change:* Assume static	Zero	High
		Unit Demand with Climate Change: Increased due to higher temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: Steady but moderate growth	Low	Moderate
		With Climate Structural Change: Little effect	Low	Moderate
Industrial Demand	1	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Slight increase for cooling purposes	Low	Moderate
		Unit Demand ex Climate Change: Assume static	Zero	High
		Unit Demand With Climate Change: Increased due to higher temperatures and ET	Low	Moderate
Mining Demand	*3*	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate

work site and process		*Unit Demand with Climate Change*: Higher unit demand for wash-down etc purposes due to raised temperatures and ET	Low to Moderate	Moderate
		Ex-Climate Structural Change: Steady but moderate growth of the mining sector in this region	Low	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Low	Moderate
Commercial Demand	5	*Unit Demand ex Climate Change*: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for irrigation purposes on commercial sites due to raised temperatures and ET	Moderate	Moderate
		Ex-Climate Structural Change: Steady but moderate growth	Moderate	Moderate
		With Climate Structural Change: Little effect	Moderate	Moderate
Self Supply Demand Including Civic	4	*Unit Demand ex Climate Change* : Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for domestic and stock and some irrigation purposes due to raised temperatures and ET	Low	Moderate to High
		Ex-Climate Structural Change: Steady but moderate growth	Low	Moderate
		With Climate Structural Change: Little effect	Low	Moderate

9. West Pilbara Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	0	Unit Demand ex Climate Change:	Not significant	
		Unit Demand With Climate Change:	Not significant	
		Ex-Climate Structural Change:	Not significant	
		With Climate Structural Change:	Not significant	
Town Water Supply Demand including mine towns and camps	4	Unit Demand ex Climate Change:	Zero	Moderate
		Unit Demand with Climate Change:	Moderate to High	Moderate to High
		Ex-Climate Structural Change: Assumed that the gas-related economy of this region will grow substantially	Moderate	Moderate
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Moderate	Moderate
Industrial Demand	3	Unit Demand ex Climate Change: Assume static	Moderate	Moderate
		Unit Demand with Climate Change: Higher temperatures and ET will increase cooling requirements	Moderate	Higfh
		Ex-Climate Structural Change: Little change in economic structure is projected. However, there is always the possibility that large energy-related major projects will diversify the economic base in the region. If they proceed they would rely on sea water desalination for their water supplies.	Moderate	Moderate

		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Low	Moderate
Mining Demand work site and process including gas facilities	*89*	*Unit Demand ex Climate Change:* Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher temperatures and ET will increase cooling and wash-down requirements	Low to Moderate	Moderate
		Ex-Climate Structural Change: Substantial growth of the gas industry	Moderate to High	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Moderate	Moderate
Commercial Demand	6	Unit Demand ex Climate Change: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for irrigation purposes on commercial sites due to raised temperatures and ET	Moderate	Moderate
		Ex-Climate Structural Change: Sector grows as flow-on from the mining and energy sector	Moderate	Moderate
		With Climate Structural Change: Little effect	Moderate	Moderate
Self Supply Demand Including Civic	3	Unit Demand ex Climate Change: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for domestic and stock purposes due to raised temperatures and ET	Low	Moderate
		Ex-Climate Structural Change: Sector grows as flow-on from the mining and energy sector	Moderate	Moderate
		With Climate Structural Change: Little effect	Moderate	Moderate

10. East Pilbara Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	0	Unit Demand ex Climate Change:	Not significant	
		Unit Demand With Climate Change:	Not significant	
		Ex-Climate Structural Change:	Not significant	
		With Climate Structural Change:	Not significant	
Town Water Supply Demand including mine towns and camps	3	Unit Demand ex Climate Change:	Zero	Moderate
		Unit Demand with Climate Change: Substantial increases in temperature will increase unit demands	Low	Moderate to High
		Ex-Climate Structural Change: Assumed that the iron ore-related economy of this region will grow substantially, with flow-on to town water requirements	Moderate	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Moderate	Moderate
Industrial Demand	1	Unit Demand ex Climate Change: Assume static	Moderate	Moderate
		Unit Demand with Climate Change: Higher temperatures and ET will increase cooling requirements	Moderate	High
		Ex-Climate Structural Change: Little change	Low	Moderate
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Low	Moderate

Mining Demand work site and process	177	*Unit Demand ex Climate Change:* Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher temperatures and ET will increase wash-down requirements	Moderate to High	Moderate to High
		Ex-Climate Structural Change: Substantial growth of the iron ore	Moderate to High	Moderate to High
		With Climate Structural Change: Possibility of a slight reduction in growth rate due to reductions in global GDP	Moderate	Moderate
Commercial Demand	6	Unit Demand ex Climate Change: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for irrigation purposes on commercial sites due to substantially raised temperatures and ET	Moderate	Moderate
		Ex-Climate Structural Change: Sector grows as flow-on from the mining and energy sector	Moderate	Moderate
		With Climate Structural Change: Little effect	Moderate	Moderate
Self Supply Demand Including Civic	3	Unit Demand ex Climate Change: Assume static	Zero	Moderate
		Unit Demand with Climate Change: Higher unit demand for domestic and stock purposes due to raised temperatures and ET.	Low	Moderate
		Ex-Climate Structural Change: Sector grows as flow-on from the mining and energy sector	Moderate	Moderate
		With Climate Structural Change: Effect could be negative for water requirement	Low	Moderate

11. Kimberley Region

Impacted Demand Component	Current Use (GL)	Nature of Impact	Potential Scale	Confidence
Irrigation Demand	356	**Unit Demand ex Climate Change:** Assume static	Zero	
		Unit Demand With Climate Change: Potentially reduced with higher rainfall, but depends on seasonality	Low	
		Ex-Climate Structural Change: Assumed that the sugar industry will continue to grow at a moderate rate.	Moderate to High	Low to Moderate
		With Climate Structural Change: Continuing changes in international comparative advantage in favour of Brazil are expected to result from climate change, but India's and ASEAN countries' production is expected to decline. Implications for Kimberley production still not clear.	Moderate to High	Low to Moderate
Town Water Supply Demand including mine towns and camps	5	**Unit Demand ex Climate Change:** Assume static	Zero	
		Unit Demand with Climate Change: Little effect	Low	Moderate
		Ex-Climate Structural Change: Growth of towns continues	Low	Moderate
		With Climate Structural Change: Little effect, except if tourism is adversely affected by increasing monsoonal activity.	Low	Moderate
Industrial Demand	2	**Unit Demand ex Climate Change:** Assume static	Low	Moderate
		Unit Demand with Climate Change: Little effect	Low	Moderate
		Ex-Climate Structural Change: Minor growth	Low	Moderate
		With Climate Structural Change: Little effect	Low	Moderate

Mining Demand work site and process	24	**Unit Demand ex Climate Change:** Assume static	Zero	Moderate
		Unit Demand with Climate Change: Little effect	Low	Moderate
		Ex-Climate Structural Change: Minor growth	Low	Moderate
		With Climate Structural Change: Little effect	Low	Moderate
Commercial Demand	8	**Unit Demand ex Climate Change:** Assume static	Zero	Moderate
		Unit Demand with Climate Change: Little effect	Low	Moderate
		Ex-Climate Structural Change: Minor growth	Low	Moderate
		With Climate Structural Change: Little effect	Low	Moderate
Self Supply Demand Including Civic	17	**Unit Demand ex Climate Change** : Assume static	Zero	Moderate
		Unit Demand with Climate Change: Little effect	Low	Moderate
		Ex-Climate Structural Change: Same pattern continues	Low	Moderate
		With Climate Structural Change: Little effect	Low	Moderate