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Water for a Healthy Country

Without Water
The economics of supplying water to 5 million more Australians

Policy and Economic Research Unit, CSIRO Land and Water,
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Acknowledgements

This report summarises research undertaken as part of a partnership between the CSIRO Social and Economic Integration Emerging Science Initiative and the Centre of Policy Studies (CoPS) at Monash University. The Partnership seeks to develop expertise in the incorporation of ecological and natural resource information in computable general equilibrium models.

For many years, CoPS has maintained a suite of Computable General Equilibrium models of the Australian Economy and its relationship with the rest of the world. The master database of one of these models – The Enormous Regional Model (TERM) – distinguishes 167 sectors and 58 regions in Australia. As such, it offers a powerful platform to model and predict the economic consequences of changes in many natural resource and environmental conditions and changes in policies that affect the degree of access people have to these resources.

The purpose of this partnership is to build a capability to examine such issues with economic and scientific rigour. One of the major objectives of the Partnership and this report is to provide a backdrop against which the contribution that initiatives like CSIRO's Water for a Healthy Country Flagship Program can be assessed.

Preparation of this report was helped considerably by an informal steering committee of representatives from organisations interested in the development of the TERM model, and by a workshop hosted by the Productivity Commission. In particular, we would like to acknowledge the contributions of Jonathan Pincus, Gavin Dwyer and Deborah Peterson from the Productivity Commission; Claude Piccinin from the Water Services Association of Australia; Mark Eigenraam from the then Victorian Department of Natural Resources & Environment; Michelle Scoccimaro from the Department of Environment; Lindsay White from the MDBC; Fiona Bartlett from the Department of Agriculture Forests and Fisheries; and Alex Smajgl and Scott Maves from CSIRO.

The informal steering committee is seeking opportunities to and is collectively encouraging CoPS to develop TERM. There is collective interest both in adding a dynamic capability to TERM and making it easier to align its regions with catchment areas and other similar boundaries. Australian Research Council funding is assisting in the development of a dynamic capability and, through this CSIRO project, capacity to build new regional boundaries has increased considerably. The work builds upon earlier research commissioned by the Productivity Commission and, also, the Water Services Association of Australia. These developments and extensions of TERM are designed to enable the ongoing evaluation of water supply and management alternatives. The model can also be used to evaluate the impact that new innovations and policy proposals could make.

Invaluable review comments on the content of this report were received from Janaki Alavalapati from the University of Florida and Alan Gregory, Darla Hatton MacDonald, Carol Howe, Jim McColl and Don McFarlane from CSIRO. Important suggestions for improvement were also received from a number of people involved in the water industry and in the management of water in several government departments. Judgements made in this report, remain the responsibility of the authors.

Executive Summary

Overview

The scenarios presented in this report should be used as a means to assist consideration of policy options not as predictions of what will happen. They should be seen as illustrations of what could happen.

The ABS predicts Australia's population will increase by 5 million and reach 25 million people in 2032. This represents a 25% increase in the population of Australia.

With 5 million more people and 15% less water in the Eastern States and South Australia, what will happen to the economy and how will this be reflected in the price of water?

If water is valued at its shadow price – the price that equates supply with demand – the economic model used to produce this report predicts that, with 15% less water in the east and 25% more people, the shadow price of water will change considerably. The answer to this "price" question depends upon some important policy choices. Starting first, with the most restrictive options that are rapidly being superceded:

- If water trading from rural to urban areas is restricted and no major desalination plants, recycling or storm water capture systems are commissioned (and Perth's new desalination plant is not completed), the shadow price of water would rise dramatically – *for our worst affected city, a 10 fold price increase is predicted*;

- but by allowing urban water supply utilities to purchase water from the irrigation industry (as some are already doing) the extent of the increase in the shadow price of water will be much less – *for our worst affected city, a 6 fold price increase is predicted*; and

- by providing access to new sources of water by constructing desalination plants (as Perth is doing and Sydney is planning as a drought security measure) or by finding a way to recycle sewage water or capture and use stormwater at a cost equivalent to desalination changes the story dramatically – *for our worst affected city, only a 3 fold price increase is predicted*.

The above scenarios assume that by 2032, water use efficiency per unit of output in the urban sector will increase by 22% and by 34% in the rural sector. Other changes in water use efficiency and in water supply are possible. More aggressive demand management policies could be introduced.

Increases in water use efficiency – the amount of water each household and business needs – are easily offset by small rainfall declines. In the last quarter of last century, a 14% decline in Perth's rainfall reduced its water supply by three times this amount - by 52%. A small decline in rainfall can make a very big difference to the amount of water available for consumption.

The scenarios used in this report assume a 15% decline in the total amount of water available for consumptive use in the Eastern States and South Australia. This supply decline could be due to adverse climate change or the result of decisions to enhance allocations to the environment.

In summary, expansion of urban-rural water trading and the development of new sources of water offer powerful ways to influence Australia's economy. With 5 million more people living mostly in our big cities, the way Australia allocates and uses water will change significantly. Under the influence of the scenarios selected, the report observes that water policy choices will influence where people choose to live in Australia.

Background

Australia faces difficult management decisions with respect to water in the face of an increasing population and decreased water availability as a result of adverse climate change and/or the need to reallocate water to the environment.

Against this back drop – one of increased population and decreased water availability – this report explores some of the economic implications of:

- using emerging water trading arrangements that allow the transfer of water from rural to urban areas; and
- accessing new sources of water via desalination and/or the construction of sewage recycling and/or storm water capture systems.

The main variable used to assess the options explored is an estimate of the shadow price of water. In essence, the shadow price of water is an estimate of the value of water in the economy. The shadow price is an estimate of the amount of money that households and industry would pay if water managers controlled water use primarily by increasing its supply price. That is, water managers would ration use simply by increasing the supply price until the amount consumed equalled the amount available for use. All users are charged the same price. If you are prepared to pay the price, there are no restrictions on the quantity that may be used.

A Regional Model that connects Australia's Economy with its natural resource base

This report relies upon results generated by a model of the Australian economy developed by Monash University's Centre for Policy Studies in partnership with CSIRO to examine natural resource and environmental management issues. We search for general policy insights not region-specific predictions.

The Computable General Equilibrium (CGE) Model of the Australian economy is known as TERM – The Enormous Regional Model and this report represents our first step towards enhancing Australian capacity to examine regional and national consequences of changing environmental and natural resource conditions. We call this version of the model TERM-Water. TERM-Water can examine these issues for any of 58 regions in Australia.

Water supply and population assumptions

The perspective offered in this report is long term. By 2032, the Australian Bureau of Statistics (ABS) predicts that the population of Australia will be around 25 million people. That is, 5 million more people will live in Australia than reside here today.

This study couples these ABS projections with economic forecasts developed by extrapolating Access Economics projections for 2014-15 to 2032 and superimposing water supply restrictions upon them.

As the prospects of both environmental flow enhancement and/or adverse climate change are real possibilities, we assume a small decline in the volume of water available for use in the Eastern States and South Australia. ABS water accounts suggest that Australia currently uses around 25,000 GL per annum. In the scenarios not involving development of a new water source, total water use is reduced by nearly 3,200 GL.

Consistent with independent estimates by the Water Services Association of Australia (WSAA), we assume that Australia continues to make progress in the adoption of more efficient water technology and in demand management.

a) By 2032, average household and industrial water use efficiency is assumed to have increased by 22% as a result of the installation of more efficient household appliances, increased use of rainwater tanks, changes in garden design and decreases in the amount of water industry needs to produce the same value of output.

b) Efficiency in the irrigation sector is assumed to increase by 34%.

The introduction of water demand management strategies, more aggressive than those already in place, is not explored.

Four Scenarios

To explore the implications of declining water resources and increased population, we explore a set of standardised scenarios for 18 regions. Standardised scenarios make it easier to compare alternatives. Care needs to be taken to ensure one understands which scenario is most consistent with current policies in each region. Some regions have begun urban-rural water trading while others have begun investing in desalination, recycling and storm water capture. The scenarios developed are:

- Scenario 1 – From now until 2032, the only water management possibilities available to Australia are increases in water use efficiency and changes in the supply price of water. Under this scenario, within-regional trading for irrigation purposes in not allowed and no water entitlements may be transferred from rural to urban users. There is no desalination and no recycling of sewage or capture of storm water. *The total quantity of water available for use in the Eastern States and South Australia is reduced by 3,200 GL.*
- Scenario 2 – The introduction of unimpeded water trading among cities and between the rural and urban sectors coupled with the construction of pipelines and associated infrastructure necessary to connect our main cities with *nearby* sources of water. Under this assumption, we incorporate general costs associated with building pipelines based on distances involved but do not make specific costings or assumptions about the feasibility of such infrastructure for different parts of Australia. This scenario is intended to give a general insight into what could be achieved if such water trading was allowed and the pipelines, dams and pumping stations necessary to make it possible are constructed. The cost of building the necessary infrastructure is treated as a fixed cost and deducted from income.
- Scenario 3 and 3A – The provision of a "new" water source to Australia's water constrained cities. The new source modelled is the construction of a desalination plant and associated connections into the supply system but any approach that delivers the same amount of water from a new source at the same cost would have a similar effect on the shadow price of water. Infrastructure costs are amortised and new water is supplied in lumps of either
    - 80GL at a cost of $1.50/kL; or
    - 120 GL per annum at a cost of $1.00/kL.

- Scenario 4 – The regional population growth assumptions we use in scenarios 1, 2 and 3 follow ABS projections that do not take into account changes in relative economic opportunity. Under scenario 4, we use a theory of regional allocation to change relative wages across Australia. As a result, inter-regional migration causes relatively more population growth in Australia's smaller cities. The scenario run is essentially scenario 3 (water trading with access to 80GL of "new" water in each supply constrained city) *plus* inter-regional migration in a manner that favours population growth and the development of smaller cities.

There are many different combinations of the elements involved in developing each of these scenarios and many more that could be developed. Several regions and several States have already amended policies and are making investments to enable them to pursue the options examined in Scenarios 2, 3 and 4.

For each scenario, the predictions generated by TERM-Water are critically dependent upon the ABS population projections for Australia. The ABS stresses that its projections should be regarded as illustrations of what might happen. The population of:

- Sydney is projected to increase from 4.15 million to 4.99 million people (20%);
- Melbourne is projected to increase from 3.49 million to 4.27 million people (22%);
- Brisbane-Moreton is projected to increase from 2.38 million to 3.61 million people (52%);
- Adelaide is projected to increase from 1.11 million to 1.15 million people (4%);
- Perth is projected to increase from 1.40 million to 1.89 million people (35%); and
- the ACT is projected to increase from 0.32 million to 0.34 million people (6%).

The most dramatic projected increase is for the Brisbane-Moreton region where the ABS predicts an additional 1,230,000 people will live. Perth will need to find water for another 490,000 people.

When reading this report, it is important to think long term and imagine an Australia quite different to the one we see today. Moreover, it is important to understand that, in urban centres, relatively small changes in the maximum amount of water available for use can make a very big difference to the shadow price necessary to keep consumption aspirations within the physical capacity of the supply system to deliver.

Scenario 1

Scenario 1 is intended to provide an illustration of what would have happened if those responsible for water management in Australia had not begun to develop the plans and strategies that they are beginning to put in place. No trading is allowed among States or among regions. Urban water utilities are not allowed to enter the rural market within their region and no attempt is made to access "new" sources of water.

If Australia decided not to subsidise water use, not to allow rural-urban water trading, and not to develop new sources of water, scarcity will cause significant changes in the economy. Entitlement and allocation trading among rural water users within any region is unimpeded. In particular, it will force the value of water – its shadow price – to rise. The extent to which this occurs is estimated in TERM-Water by calculating the shadow price of water in the economy. **Under this scenario, there are significant implications for high forecast growth cities such as Perth, Brisbane and Sydney. TERM-Water predicts that these cities will see the real shadow price of water increase by $9.47, $8.51 and $6.20 per kilolitre (kL), respectively.**

Under considerable price pressure, households "save" 362 GL of water.

These estimates are very sensitive to the assumptions made about population growth, the economy, improvements in water use efficiency and changes in water supply. Only a fraction of the change in shadow price arises from increased household demand. Under this scenario, for example, demand growth in Sydney induces a $3.70/kL increase in the shadow price of water, while non-agricultural productivity and import supply growth induces a further increase of $3.81/kL.

If increases in water use efficiency, beyond the 34% we assume, occur in agriculture and 22% in all other industries as well as households, these shadow price increases would be less. Much more recycling at the household and industry level may be possible. Under this scenario no new sources of water as a result of the discovery of new groundwater sources, *the development of major recycling schemes or major storm water capture schemes occur.* Further runs of TERM-Water could be used to examine these possibilities. The impact of adverse climate change coupled with increased environmental allocations could be much more than the 15% we assume.

We stress that this scenario is simplistic. Most water supply authorities are exploring ways to move well beyond this situation and a number already have. This scenario highlights the economic case for serious consideration of and investment in the alternatives. It can also be used as a way to demonstrate the value of decisions recently taken.

Scenario 2 - Urban - rural trading

Allowance of urban-rural trading, coupled with the development of pipes and pumps needed to allow transfer from adjacent agricultural regions, significantly reduces the shadow price increase. In the model, the cost of building the necessary infrastructure is recovered by deducting the fixed cost of building this infrastructure from income. **The volumes of water transferred from rural areas to urban areas are relatively small but have a significant influence on the shadow price. Across the nation, 61 GL is transferred to households and 171 GL to commercial and industrial uses.** Collectively, this represents 1.1% of the 21,800 GL of water in use across Australia. While there are some significant regional impacts, the move from scenario 1 to scenario 2 increases aggregate consumption 1.0%, and GDP 0.6%.

Under this scenario, TERM-Water predicts a reduction in the shadow price increase:

- in Melbourne, from $4.41/kL to $0.37/kL;
- in Brisbane/Moreton, from $8.51/kL to $1.23/kL; and
- in Perth, from $9.47/kL to $4.80/kL.

The technical feasibility and environmental implications of connecting each of the above cities to rural supplies both within their region and with neighbouring regions is not assessed.

TERM-Water results suggest that the introduction of urban-rural water trading, where feasible, or the provision of access to another equivalent water source, has the capacity to change where people live in Australia.

One of the consequences of full urban-rural trading is connection, via the Southern Connected River Murray System, of Adelaide’s and Melbourne’s water supply systems. As a result, the shadow price of water in Adelaide increases to the same shadow price as that for Melbourne – from $0.11/kL to $0.37/kL.

While the expansion of urban-rural water trading produces major benefits for most cities, one could argue, however, that the introduction of urban-rural water trading on its own is not sufficient to solve Perth’s water supply problems. In this city, the shadow price of water still increases by $4.80/kL.

Water Trading plus a "new" water source

In this scenario, we model the implications of using desalination plants to supply an additional "new" source of water. Because of the way that the model calculates the shadow price of water, the resultant estimates can be interpreted as an estimate of the implications of providing access to any "new" source of water at the same cost as a desalination plant. Potential other sources include sewage recycling and storm water capture and storage.

A desalination plant is being built in Perth. Sydney has been actively debating whether or not to build a plant and most recently, has decided to plan for, but not start construction of a plant until dam water supplies fall below 30% of capacity. Desalination is being portrayed as a last resort. Desalination is under consideration elsewhere – particularly in the Brisbane/Moreton region. In practice and once the all cost-effective trading opportunities have been exhausted, most cities can be expected to pursue a combination of sewage recycling, storm water capture and desalination arrangements.

The cost of running large desalination plants is far from clear. In recent times, the cost per kilolitre of water produced has been falling and, as a result of technological improvements, could continue to do so. At the same time, the energy costs associated with running them could rise significantly. Israel's Ashlelon desalination plant is currently producing "new" water at a cost of US$0.53/kL. As plant size increases, production costs per unit decrease significantly.

We model implications for plants capable of supplying 80 GL per annum at a cost of $1.50/kL and capable of supplying 120 GL per annum at a cost of $1.00/kL.

We stress that the scenarios we examine compare predictions for 2032 with the present situation. The question of when and where a new source should be established is not evaluated. Moreover, we make no assessment issues associated with the reliability of alternative new sources. Desalination is highly reliable while many other sources rely upon access to supplies that tend to decline during prolonged dry periods.

With water trading plus the availability of desalinated water, there is a marked decrease in Perth's shadow price of water. People living in Brisbane-Moreton and Sydney also benefit from the installation of a desalination plant or the provision of similar equivalent quantities of water at a similar cost from major investments in recycling or storm water capture. From a 2032 perspective and given current technology, the question seems to be more one of when to build a plant rather than one of whether or not to build. With an 80 GL plant delivering water into the supply pool at a cost of $1.50 per kilolitre, TERM-Water predicts:

- in Sydney, a reduction in the trading alone shadow price increase from $1.48/kL to a trading plus desalination price increase of $1.24/kL;
- in Brisbane/Moreton, a reduction in the trading alone shadow price increase from $1.23/kL to a trading plus desalination price increase of $1.03/kL; and
- in Perth, a reduction in the trading alone shadow price increase from $4.80/kL to a trading plus desalination price increase of $3.11/kL.

If larger 120GL desalination plants are installed and they supply water to cities at the cost of $1.00/kL the shadow price increase is reduced further. In Perth, the shadow price increase is reduced by $0.55/kL from $3.11/kL to $2.56/kL. The construction of another desalination plant or investment in large scale sewage recycling and/or stormwater capture would further reduce the cost of water supply to Perth.

We do not explore the costs of developing a new source without the expansion of urban-rural water trading and supply connection to adjoining regions. We make no attempt to optimise the size of desalination plants, recycling systems or storm water capture systems. Sizes other than 80 GL and 120 GL are likely to be optimal and, in many cases, these volumes will be most appropriately delivered from a combination of these sources.

Other economic scenarios

The ABS population scenarios are based on simple projections of regional growth and do not take into account regional changes in the cost of doing business and living in Australia. It is possible, and indeed likely, that a totally different circumstance will prevail in 2032. The last scenario run is one where, as a result of relatively high population growth rates in Australia's largest cities, people begin to migrate to other parts of Australia.

In TERM-Water we simulate the possibility that people may choose to live in regions different to those projected by the ABS by changing relative wages – wage-driven migration occurs. The net result is that the 2032 population for the Brisbane-Moreton region rises only to 3.51 million rather than the 3.83 million that occurs when there is no wage-driven inter-region migration. With wage-driven migration, population growth is less in Perth and rises only to 1.93 million rather 1.97 million. The population in all other cities increases. Many other scenarios are plausible. Our purpose is to illustrate the sensitivity of water supply issues to population. Water policy decisions have the capacity to influence where people choose to live.

With wage-driven migration, there is a moderate alleviation of the shadow price of water increases in Brisbane/Moreton due to slower population growth. In Perth, the effect is somewhat more substantial, as it applies to a higher shadow price increase and Perth gains less benefit than some other cities from water trading. In all other regions, the effects of wage induced migration on water shadow price increases are minimal.

The more general economic consequences of wage-driven migration are significant and interesting in their own right. Brisbane/Moreton's aggregate consumption falls from 72.2% in scenario 3 to 61.9% in scenario 4. In Perth, the aggregate consumption falls 49.8% to 47.0%. Adelaide's population and employment levels are significantly larger than in other scenarios.

An important issue we can consider in the context of scenario 4 is the risk of investing in development of a new water source in a region where population growth turns out to be smaller than projected. One insight we can obtain from examination of the results for Brisbane/Moreton and a number of other cities is that – dollar for dollar – water trading can play a bigger role in alleviating water scarcities than the development of new sources associated with investment in recycling, desalination and stormwater capture. In cities where all opportunities to access rural water at affordable cost have been exploited, however, desalination possibly combined with recycling and storm water capture appears to have a role to play in meeting future water needs.

In the case of Perth, the water shadow price increases are so large in all scenarios that the issue appears not to be whether to have desalination plants to supplement existing water supplies, but rather the capacity such plants should have. At present the desalination plant proposed for Perth will be the largest in the southern hemisphere and from November 2006 is expected to supply an extra 45 GL of water to the region every year. Desalination plants have the additional advantage that they offer a reliable supply that is independent of the effects of climate change and climatic variability.

Conclusion

The overall conclusion, arising from the above analyses and *if* the combination of the ABS's illustrative population projections and our extrapolation of Access Economics' projections for the economy are feasible, is that the Australian economy could supply water to 25 million people and still enable increases in per capita GDP.

Water policy decisions have the capacity to influence both the nature of regional development and where people live in Australia.

At the national level, more economic progress will be possible if urban-rural trading is introduced. Careful technical and environmental assessment of the feasibility of this option is necessary. The amount of water that will be traded from rural to urban areas is quite small but if expanded it can have a significant impact on the cost of supplying water to urban and industrial water users.

Moreover, in some cities and at some stage in the future, desalination could play an important role in their economic development. The economic attractiveness of desalination is critically dependent upon the cost of this technology.

Desalination coupled with urban-rural water trading is critically important for Perth. While the construction of large recycling and storm water capture initiatives are not examined, if these alternative new water sources can be built at costs similar or less than those associated with desalination then similar benefits could be expected. In practice, a mixture of demand management, sewage recycling, desalination and storm water capture coupled with increased urban-rural trading is likely to be the most efficient strategy.

The benefit of pursuing each of the scenarios examined in this report varies from region to region. As would be expected and with urban-rural trading, growth in aggregate water consumption in urban areas comes at a cost to rural areas but a benefit to the economy as a whole. In some areas, especially when long pipelines are involved, it may not be technically feasible to expand urban-rural trading at reasonable cost. As noted above, from an agricultural perspective, the volumes involved are relatively small. Without the introduction of any new source and with a 15% reduction in supply, if 5 million more people are living in Australia in 2032 and the state of the economy is as predicted these people would like to transfer an additional 240 GL of water from rural Australia.

Shadow price impacts are critically dependent upon the rate of increase in water use efficiency by households and businesses and, also, the rate of establishment of non-traditional (new) sources like sewage recycling, storm water capture and desalination are developed. More research on the relationship between increases in water use efficiency and the shadow price of water is needed.

The model runs in this report assume that by 2032 water use efficiency can be increased by 22% in the urban sector and by 34% in the irrigation sector. Much more research and exploration of these options could be undertaken. Small changes in water use efficiency can liberate significant amounts of water and have a large influence on price.

Finally, apart from an entire range of questions associated with population, immigration and the state of the economy, there is also a need for assessment of the most appropriate sequence for the reforms and investments examined in this report to be introduced.

We compare 2032 with the present under four different scenarios – questions of timing and sequence are left for future reports. Model runs to explore implications for specific industries and for shorter time periods are possible and could be undertaken.

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Abbreviations

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
CGE	Computable General Equilibrium Model
CoPS	Centre of Policy Studies
GDP	Gross Domestic Product
GSP	Gross State Product
GRP	Gross Regional Product
GL	Gigalitre
kL	Kilolitre
ML	Megalitre
NSW	New South Wales
NT	Northern Territory
Qld	Queensland
SA	South Australia
Tas	Tasmania
TERM	The Enormous Regional Model
TERM-Water	The water version of the Enormous Regional Model
WA	Western Australia
Vic	Victoria
Irrig	Irrigation

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1. Introduction

Across Australia, both urban and rural people are expressing increasing concern about the state of Australia's water supplies and the effects that water shortages could have on the environment, on the economy and the way Australians live. Amongst other things, it is possible that water supply for consumption could be reduced either as a result of adverse climate change and/or the need to increase allocations to the environment. Most people also expect the population of Australia to increase.

In response to these, and many other considerations:

- the Council of Australian Governments (COAG 2004) has agreed to a National Water Initiative to encourage, amongst other things, the expansion of trade in water bringing about more profitable use of water;
- Perth has commenced work on the construction of a desalination plant in the southern suburb of Kwinana;
- Sydney has developed plans for a desalination plant that will enable it to commission construction if and when it becomes necessary to invest in this supply source; and
- Virtually all large cities and many regions have begun searching for ways to recycle sewage and capture storm water as a way to enhance the quantity of water available for use.

In parallel with these initiatives, there has been considerable public discussion about the need to improve water use efficiency, to recycle water and to increase opportunities for urban water utilities to buy water entitlements and/or entitlements from the rural sector. Some utilities have already begun to trial development of ways to access "new" sources of water.

The purpose of this paper is to explore some of the economic consequences of changing the way Australia manages water and where the people living in Australia might get water from if the country's population increases by 25%. At the time of writing this report, Australia's population was around 20 million people. As summarised in Figure 1, the ABS projects that the population of Australia will increase by five million more people to reach 25 million in 2032. Moreover, they estimate that the nature and rate of population growth will not be uniform. Most notably, the population of the Brisbane-Moreton region is projected to increase by 53%, Perth by 35%, and Sydney and Melbourne are projected to increase by 20% and 22% respectively. Little growth is projected for Adelaide (4%) and the ACT (6%) (Australian Bureau of Statistics projections 2003).[1] The ABS stresses that these projections should be interpreted as illustrations of what might happen as a result of a continuation of existing rates of migration, the time that people live for and other similar factors.

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[1] On the 7th October 2005, the ABS estimated the Australian population to be 20,408,268. The ABS stresses that these estimates are not intended as predictions or forecasts, but are illustrations of growth and change in the population that would occur if assumptions made about future demographic trends were to prevail over the projection period. They rely upon assessment of past demographic trends. No account is taken of possible changes in non-demographic conditions. Fertility, mortality, population aging and overseas migration are the main variables considered.

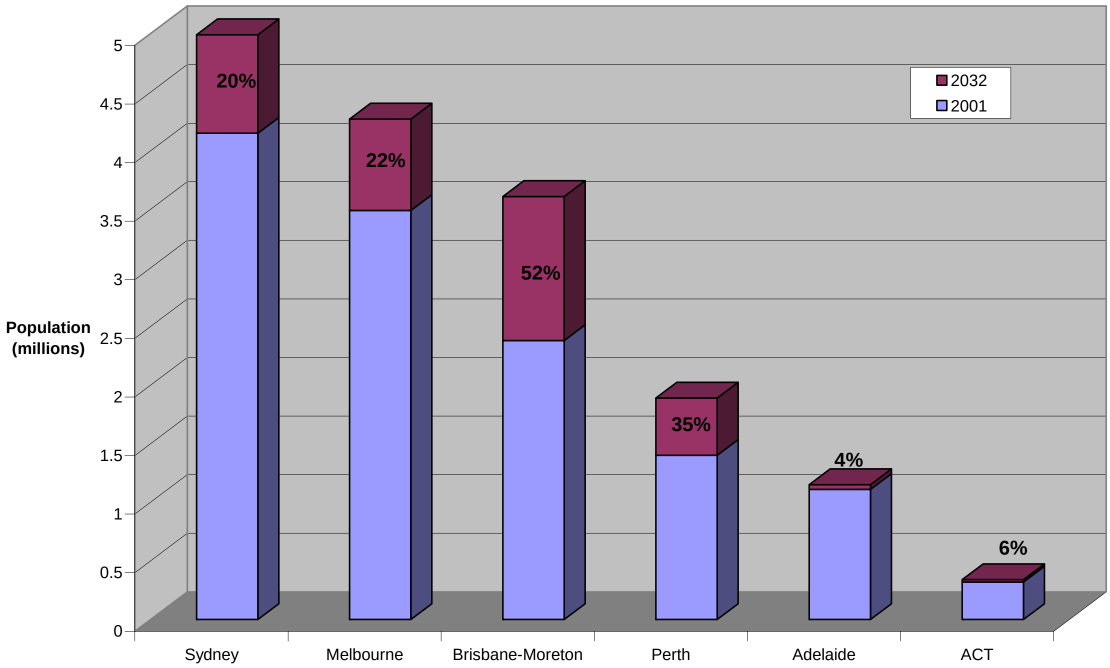

Figure 1 ABS population estimates for 2001 and projection for 2032

We use this 2032 population forecast for all scenarios and impose an arbitrary water supply reduction of 15% in the Eastern States and South Australia. For our purposes, it is not necessary to determine whether or not this reduction is due to adverse climatic variation and/or an increase in allocations to the environment.[2]

We couple the ABS population projection for 2032 with a linear extrapolation of an economic forecast developed by Access Economics for 2014-15 to 2032 and use a computable general equilibrium (CGE) model to assess various water supply scenarios for these population forecasts. The scenarios we explore include:

- An increase in water use efficiency but no changes to current water supply arrangements;[3]
- Development of an infrastructure that facilitates urban-rural water trading involving the transfer of water from agriculture to urban water users facilitated by the removal of all policy restrictions on water trade and the construction of pipes into some of our water constrained cities; and
- The development of a desalination industry in Australia's water constrained cities.

As the purpose of this study is to explore water supply policy and investment options, we include an additional growth scenario favouring population growth and economic development in Australia's smaller cities. We do this in an attempt to avoid becoming embroiled in a debate about the likelihood of different economic development scenarios.

2. Background

For decades, increases in water use efficiency have been achieved through a combination of technological, educational, pricing and regulatory arrangements. Most recently, Radcliffe (2004) reviewed and, subject to the resolution of significant pricing and policy

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2 Implicitly, it is assumed that changes in the environmental health of rivers and aquifers have no influence on the economy.

3 No new sources of water are discovered and no underdeveloped water resources are bought into use.

issues, identified considerable technical opportunities for an increase in the quantity of waste water, sewage water and storm water that is recycled across Australia.

In Australia, water is owned by the state and most opportunities to use water are formalised using licensing arrangements. The nature of the licence – an access entitlement – varies from state to state. Many of the licences issued, especially those issued to irrigators, are tradeable. While most urban entitlements and allocations are not yet tradeable, a number of urban water supply utilities are either considering or have began to purchase water from rural areas. Cities like Adelaide and Perth are already well connected to rural areas and this is enabling them to consider rural areas as a source of water. Perth has purchased on a temporary basis from Harvey Water and SA Water is known to have purchased entitlements to water previously used for dairying in the Lower Murray swamps of South Australia. Other cities would need to install pipelines, pumps etc to make it possible to transfer water from rural to urban areas. The infrastructure necessary to connect Melbourne to the Southern Connected River Murray system via the Goulburn River is comparable with that connecting Adelaide to the River Murray.

In the Murray Darling Basin, water trading began in the early 1980s and has expanded considerably. The legal basis for such trading rests on the issue of an access entitlement that effectively specifies the maximum share of the available water in a supply system that a holder may access within a specific period of time. The actual amount that can be used in any period is known as an allocation. Rather than treating all access entitlement holders equally, some entitlements are assigned a higher priority and, hence, are more reliable than others. The size of an allocation received in any season is a function of this priority. In NSW, less reliable access entitlements are known as general security licences. In rural areas water markets are being expanded rapidly. Entitlement trading and allocation trading are becoming the norm.

Water supply arrangements for urban water users are quite different. For towns along the River Murray in NSW, for example, the entitlement held is partially a function of the town's population. If a town's population increases, the town is allocated more water and this is achieved by reducing allocations to "general security" irrigators. Under the Murray Darling Basin agreement, Metropolitan Adelaide and associated towns in South Australia have a non-tradeable entitlement that must not exceed 650 GL over any five year period which in effect is a guaranteed right to an allocation whose 5 year moving average must not exceed 130 GL per annum.[4]

The recent National Water Initiative at section 64 states that "The Parties agree to implement water pricing and institutional arrangements" to "… facilitate the efficient functioning of water markets, including inter-jurisdictional water markets, and in both rural and urban settings" (COAG 2004).

Another way of contributing solutions to Australia's water scarcity problems is to access non-traditional, "new" sources of water. Other options include the development of untapped groundwater sources, the development of sewage recycling and the capture of storm water. In this report, we use desalination as an example of development of a "new" water source. What matters is the volume of water secured by such an investment and the cost of accessing it.

Desalination of sea water or salty water requires large amounts of energy. The Perth desalination plant will use reverse osmosis to produce fresh water. Here seawater is pumped at very high pressure through membranes. The membrane blocks the larger salt molecules while allowing the smaller water molecules to squeeze though the membrane and trickle down a tube where pure water is collected. Opposition to desalination plants has usually been with respect to the costs involved and the environmental consequences of the greenhouse gases emitted because of the high levels of energy required to either heat or pump the water. The Western Australian government has addressed this latter concern by

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4 GL = 1 Gigalitre which is equivalent to 1,000 megalitres and 1,000,000 kilolitres (kL)

announcing its intent to use wind generated energy to power the desalination plants at Kwinana.

Water trading between and within urban and rural areas as well as the establishment of desalination plants are two possible options to be considered to mitigate the effects of a growing Australian population and reduced water supplies due to climate change. There are however two other important trends evident in Australia that also need to be taken into account. These include the introduction of water saving technologies and wage induced migration.

Water saving technologies are gradually being introduced into agricultural systems, industries and households (such as water saving shower heads and drip irrigation systems). For example, changes in water requirements in cropping may arise from advances in irrigation techniques. In addition, research and development may be directed at reducing water requirements in some crops. The motivation for such research increases as the relative scarcity of water increases and as the potential returns to such research and development increase correspondingly.

It is already evident that patterns of migration of people to certain areas of Australia are changing, induced by the availability of jobs and higher wages in those regions (such as the increasing populations of the Queensland Gold Coast regions and Perth and the static population trends of the Adelaide region). Congestion also has its costs and this could induce people to move to other parts of Australia.

3. Methodology

To explore the economic implications of changing the way Australia manages water access and the effects of water supply on the economy, we use TERM[5] - a computable general equilibrium model developed by the Centre of Policy Studies (COPS) and modified in partnership with CSIRO - to allow the exploration of the effects of changes in water supply and water policy on the economy. We call this version of the model TERM-Water.

Details of TERM-Water are summarised in Appendix 1. The water accounts that we have added to TERM-Water are consistent with the ABS water accounts (ABS 2004).

The approach we take is to keep the analysis simple. In particular, we limit ourselves to one population projection – a 25% increase in the Australian population from its current 20 million[6] to 25 million people. Many other population projections are possible.

The ABS estimates that Australia will reach a population of 25 million people in 2032 (ABS 2003) and provides a set of regional projections that suggest where these people may live. These ABS regional projections are based entirely on demography and do not take into account price-induced influences on regional development and migration.

As summarised above, we make use of four scenarios: to make it easier to understand the policy implications and investment options analysed, a set of standardised scenarios are developed. Care needs to be taken to ensure one understands which scenario fits the status quo in each region. Some regions have begun urban-rural water trading others have begun investing in desalination, recycling and storm water capture. The scenarios developed are:

1. Scenario 1 – From now until 2032, the only water management possibilities available to Australia are increases in water use efficiency and changes in the supply price of water. Under this scenario, no water entitlements may be transferred from rural to urban water users, trading among rural water users within each region is unimpeded but does not occur between regions. There is no desalination, no sewage recycling and no capture of storm water for consumptive use. *The total quantity of water*

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5 The Enormous Regional Model (TERM).

6 On 18 May 2006 at 13:45:48 (Canberra time), the ABS estimated the resident population of Australia is projected to be 20,538,640 people.

available for use in the Eastern States and South Australia is reduced by 3,200 GL. Average household water use efficiency is assumed to have increased by 22%. Efficiency in the irrigation sector is assumed to increase by 34%.[7]

In a number of regions, this would require cities to undo initiatives they have either already committed to or are in the process of carefully evaluating.

2. Scenario 2 – The introduction of unimpeded water trading among cities and between the rural and urban sectors coupled with the construction of pipelines and associated infrastructure necessary to connect our main cities with *nearby* sources of water. Under this assumption, we incorporate general costs associated with building pipelines based on distances involved but do not make specific costings or assumptions about the feasibility of such infrastructure for different parts of Australia. This scenario is intended to give general insight into what could be achieved if such water trading was allowed and the pipelines, dams and pumping stations necessary to make it possible are constructed. The cost of building the necessary infrastructure is treated as a fixed cost and deducted from income.

- Scenario 3 and 3A – The provision of a "new" water source to Australia's water constrained cities. The new source modelled is the construction of desalination plants and associated connections into the supply system but any approach that delivers the same amount of water from a new source at the same cost would have a similar effect on the shadow price of water. Infrastructure costs are amortised and new water is supplied in lumps of either
    - 80GL at a cost of $1.50/kL; or
    - 120 GL per annum at a cost of $1.00/kL.

3. Scenario 4 – Scenario 3 plus wage-driven migration in a manner that favours population growth and the development of smaller cities. The regional population growth assumptions we use in scenarios 1, 2 and 3 follow ABS projections that do not take into account changes in relative economic opportunity. Under scenario 4, we use a theory of regional allocation to change relative wages across Australia. As a result, wage-driven migration causes relatively more population growth in Australia's smaller cities.[8]

Several regions and several States have already amended policies and are making investments to enable them to pursue the options examined in Scenarios 2, 3 and 4.

There are many different combinations of the elements involved in developing each of these scenarios and many more that could be developed. The purpose of this paper is to identify the main effects and the costs of not taking up some of the trading and desalination options under consideration by policy makers.[9]

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[7] These numbers assume that the recent rate of increase in water use efficiency will continue.

[8] The regional labour market structure underpinning TERM-Water does not take into account all the various influences on regional migration. For example, a "headquarters" effect may explain some of the relatively rapid growth in larger cities. Tasmania gives us a current example of migration in the other direction. As changes in relative shadow prices may overwhelm regional projections based only on demography: the Tasmanian economy has grown more rapidly than the national economy since 2003. The housing boom in Sydney and Melbourne in the first few years of the new millennium appears to have fuelled the more recent turn in Tasmania's fortunes. There has been a wave of interstate migration to Tasmania that is inconsistent with ABS projections. Similarly, on the mainland, house price increases in the capital cities and coastal regions have led to some migration to inland regional centres such as Orange (NSW) and Castlemaine (Victoria).

[9] People or organisations interested in the outcomes for other scenarios and assumptions should contact Dr Glyn Wittwer: Glyn.Wittwer@BusEco.monash.edu.au .

As we are concentrating on capital cities and the Murray-Darling Basin, we run TERM-Water using the 18 regions presented in Figure 2 rather than all 57 regions of the model's master database. Details of the regions used are contained in Appendix 2.[10]

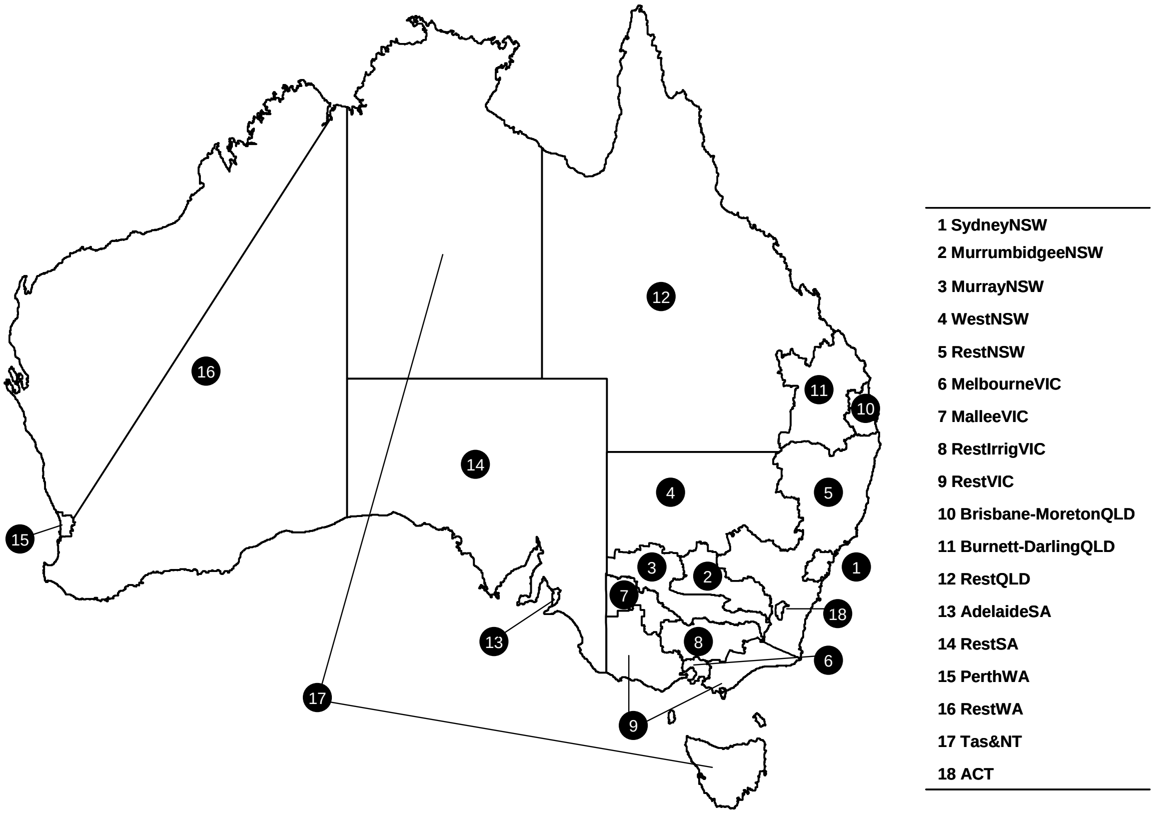

Figure 2 Location of the 18 regions used in this study

TERM –Water is constructed from TERM using closure reversals.[11] When running the TERM-Water model from 2001 to 2032 (in which time the ABS projections suggest that we

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[10] We are in the process of building a general capability to align regions with catchments and regional boundaries defined by people other than the ABS.

[11] TERM-Water, like all other models in the ORANI school of CGE models, has more variables than equations. Moreover, as the model is only able to solve for one variable in each equation, some variables must be exogenous. The number of exogenous variables (X) must equal the total number of variables (V) minus the number of equations (E) (i.e. X=V–E). The choice of endogenous and exogenous variables (i.e. "closure") depends on the nature of the simulation. (For more details on changes in closures, see Dixon and Rimmer (2002, pp.10-17).

When running scenario 1, we use two different closures, a forecast closure and a policy closure. First, we project the model to 2032 by targeting state level macroeconomic variables including real GSP and real GDP, aggregate employment and real aggregate consumption. That is, target variables must be exogenous so that they can be shocked to attain 2032 levels, using the forecast closure. The purpose of the forecast closure is to allow us to impose forecasts from outside the model. In this water-supply and population study, we wish to use key macroeconomic variables as a basis of comparison between scenarios. We can only do this if such variables are endogenous in each simulation. Therefore, we must run simulation 1 again with a closure "reversal" so that key macroeconomic variables are endogenous: this uses the policy closure. In the forecast simulation, we position various supply and demand curves (i.e. they are endogenous) to accommodate the macroeconomic targets. For example, the aggregate consumption forecast implies a certain consumption function shift and state real GSP projections imply a certain all-industry technological change at the state level. When we rerun simulation 1, we shock the state level consumption function shifter rather than state aggregate household consumption. We run all subsequent simulations using the policy closure. That is, in order should expect Australia's population to grow from 19 million to 25 million), we impose state level aggregate consumption, real GDP and aggregate employment assumptions on the model in an initial simulation.

In this water-supply and population study, we wish to compare forecast projections of key macroeconomic variables that are usually exogenous to TERM-Water. This is difficult as one can only compare key variables under different simulations when these variables are endogenous. To overcome this problem, we first ran baseline simulations with the forecast variables exogenous until we found a grouping of economic conditions that are consistent with ABS population and our extension of Access Economics' economic projections to underpin our scenarios. We then reconstructed the model so that the variables necessary to explore water policy issues were endogenous to the model.[12]

For scenarios 2 to 3, we run the model with the same closure reversals. That is, in order to compare scenarios 1 and 2, we allow aggregate household consumption to be endogenous, so that we can compare the changes in aggregate consumption among scenarios and among regions. Similarly, we accommodate the real GDP projection with an all-industry, economy-wide technological shift. This technological shift drives the changes explored in each scenario, so that again, we can compare the real GDP and real GRP estimates in scenarios 2 to 4 to those forecast for scenario 1.

The main variable used to assess the options explored is an estimate of the shadow price of water. The shadow price is an estimate of the amount of money that households and industry would pay if water managers controlled water use primarily by increasing its supply price. That is, water managers would ration use simply by increasing the supply price until the amount consumed equalled the amount available for use. All users are charged the same price. If you are prepared to pay the price, there are no restrictions on the quantity that you may use.

4. Scenario 1: No trading and no desalination

4.1. Water supply

Scenario 1 combines 25% population growth with a decline in water supplies available for consumptive use in the Eastern States and South Australia. Water use efficiency increases as a result of the emergence of investment in water saving technology.

We assume a 15% decline in the amount of water available for consumptive use in agriculture, in industry, in commerce and in households in all regions, other than Western Australia, Tasmania and the Northern Territory. This could be due to climate change or simply because of the emergence of a dry period. It needs to be understood that the quantity of water available for consumptive use declines at a much faster rate than rainfall. Mean rainfall in the last quarter of last century in the Perth region declined by 14% but the quantity of water in water supplies declined by 52% (see Figure 3). A 15% decline in the water supplies available for consumptive use in the Eastern States and South Australia is well within the realm of feasibility.

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to compare scenarios 1 and 2, we allow aggregate household consumption to be endogenous, so that we can compare the changes in aggregate consumption among scenarios and among regions. Similarly, we accommodate the real GSP projection with an all-industry, state-wide technological shift. This technological shift becomes the shock in each scenario, so that again, we can compare the real GSP estimates in scenarios 2 to 4 to the estimate forecast for scenario 1.

[12] For example, the aggregate consumption forecast implies a certain consumption function shift that is influenced by water supply. Such factors are normally exogenous to a CGE model. Having found the appropriate forecast projection, we then reran the scenario with the closure reversals. Among other things, this involves giving a shock to the consumption function shifter rather than to aggregate household consumption.

Because Perth has already experienced a significant decline in water availability, and most recently another decline (see Figure 3) we do not impose any further reduction upon water supply in Western Australia.

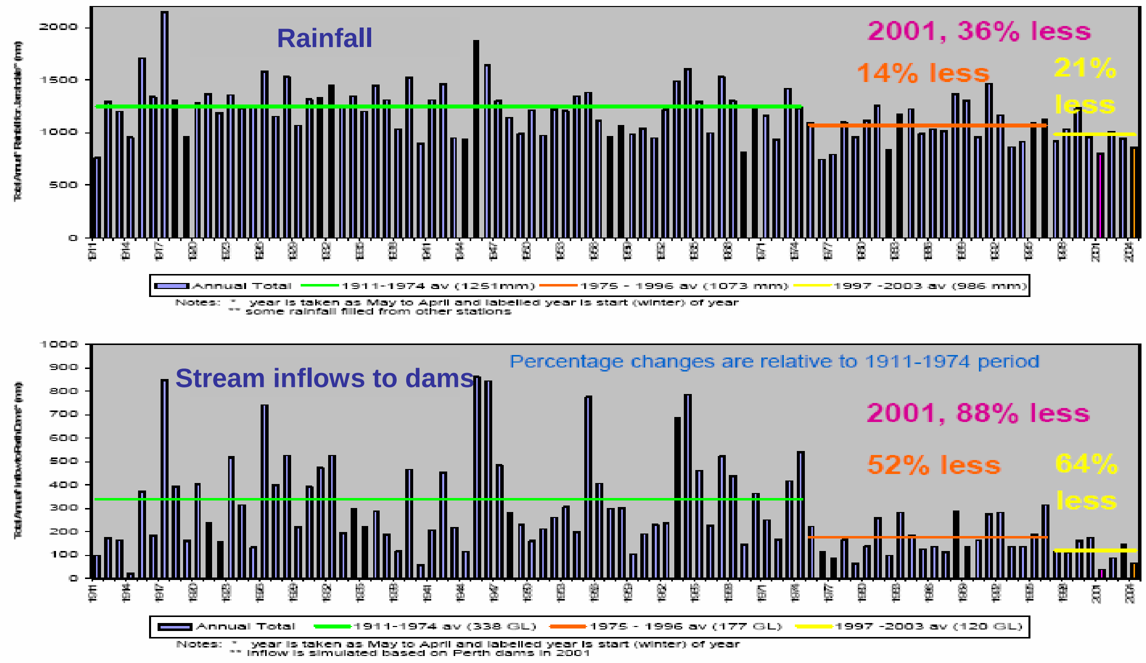

Figure 3 Decline in inflows into Perth's water supply over the last century

Because water supply relative to population is still very high and essentially non-limiting in the Northern Territory and Tasmania we do not impose any reduction in water supply on this state and this territory.

The essential proposition is that water supplies in western and northern Australia and Tasmania remain the same, while in the Eastern States and South Australia they decline by 15%. One way of explaining this scenario is to imagine that Perth's recent climatic experiences are replicated – with less severity - in the Eastern States and South Australia.

4.2. Water Industry

The ABS identifies two different types of water users in Australia:

- System-supplied water users - those that have water supplied to them via pipes or channels; and
- Self-supplying water users - those that collect and/or extract water themselves.

Most urban water users, whether households, commerce or industrial, obtain their water through pipes managed by water utilities. Similarly, many irrigators receive their water through channels and pipes. A number of other water users, particularly those located close to a river or dependent upon an aquifer extract and supply water to themselves. Use of rainwater, collection of run-off in dams and some recycling schemes represent other forms of self supply. In the models we develop, this classification is important as it affects the shadow price of water which drives the responses under the different scenarios tested.

Scenario 1 includes no increase in the transfer of water from rural to urban Australia, no desalination, no wage-driven migration and no development of a "new" water source. Trading among rural water users within any region in the model is unimpeded. All we do is impose ABS regional projections on the database and couple this with conventional economic predictions for the Australian economy. Changes in the demand for water and in the supply of water are managed only by increasing the cost of accessing it. Some improvement in water use efficiency occurs. It is assumed that all the water for consumption is used and that water suppliers supply water to all at its marginal cost.[13] In Scenario 1 for 2032, neither Perth nor Sydney have desalination plants.

4.3. The Economy

In order to examine the consequences of different policy and technological choices, it is necessary to make many assumptions about how the economy is going to change between 2001 and 2032. The core macroeconomic growth assumptions derive from ABS's illustrative regional population projections, and a linear extrapolation of recent economic forecasts for 2014-15 produced by Access Economics (2005). A decomposition of key results from the model allows us to examine how each set of assumptions influence the 2032 scenario 1. Table 1 summarises the results for each of the 18 regions analysed in Scenario 1. It is stressed that this scenario is constrained by ABS regional population projections that do not take into account changes in the prices received and cost structures faced by each industry and labour supply opportunities. As a result, the increase in the aggregate employment in some regions is negative. As stated at the start of this report, many other assumptions are possible. Our fourth scenario explores one of them – wage-driven migration. The model does, however, account for the increase in the number of aged people in the economy.

Table 1 Regional macroeconomic outcomes under the Scenario 1, 2032 relative to 2001 stated as a percentage

Region*	Aggregate consumption (%)	Real GSP and GRP (%)	Aggregate Employment (%)	Population (%)
Sydney	36.2	36.3	12.9	20.2
Murrumbidgee	34.2	34.4	17.8	25.5
Murray NSW	33.8	33.9	19.8	27.6
Western NSW	42.9	43.0	26.3	35.6
Rest NSW	34.9	35.0	16.3	24.2
Melbourne	38.2	38.3	14.3	22.3
Mallee VIC	32.4	32.5	13.9	21.5
Rest Irrig VIC	34.6	34.7	16.2	23.9
Rest VIC	61.4	61.6	43.0	53.6
Brisbane-Moreton	61.1	61.2	40.5	51.5
Burnett-Darling QLD	65.9	66.0	46.9	54.2
Rest QLD	14.1	14.2	-4.9	5.2
Adelaide	10.3	10.4	-6.9	3.8
Rest SA	16.1	16.2	-4.2	6.6
Perth	42.2	42.3	24.1	34.9
Rest WA	61.3	61.5	32.1	43.3
Tas & NT	34.4	34.5	19.5	18.6
ACT	12.4	12.5	-3.3	7.7

*** See Appendix 2 for a more precise definition of these regions.**

13 Excluding the cost of environmental externalities imposed on other people.

4.4. Demand growth

As agriculture is Australia's largest water user, it is particularly important to understand the assumptions made about the nature of water use in this sector. ABARE's farm output index indicates that agricultural output has doubled over the past 25 years (ABARE 2004). This indicates a sector that has experienced rapid and ongoing productivity growth well beyond any expansion in the rate of natural resource utilisation or use of inputs.

Nevertheless, agriculture's share of GDP in Australia has declined from over 20% around 50 years ago to less than 4% now (Maddock and McLean 1987; ABS National Accounts 2005). While the share of GDP has been declining, absolute output from agriculture has been increasing.

Decomposition of Scenario 1 helps us to understand how to interpret the results that TERM-Water is capable of producing. In the case of agriculture, the decline in agricultural terms-of-trade is assumed to continue and this is captured in export demand shifts. As per capita income grows, households spend more on relatively income-elastic service sectors than on food (i.e. real spending on raw food increases, but raw food's share of total household expenditure decreases). Population growth favours relatively non-traded sectors rather than relatively traded sectors, including agriculture.

In the initial year of the database (2001), value-added activity in the crops and livestock sector is $6.3 billion, in dairy $0.7 billion, cotton $0.8 billion and rice $140 million. The crops and livestock sector therefore captures most agricultural activity. The other three sectors – dairy, cotton and rice – are represented separately as these sectors are relatively large water users.

For scenario 1 and since the total water allocated in the 1st column in Table 2 sums to zero, we can interpret movements as changes in *shares* of national water usage as a result of demand growth and population increase. This is the case for all columns other than the 4th, in which the total is the reduction in assumed water allocation, i.e. 3,182 GL. This explains why households, despite growth in aggregate consumption, suffer a small loss in share due to demand growth. Crops and livestock, dairy, and all other water users sectors increase their demand for water slightly more rapidly than households. The "other" sector is dominated by manufacturing, mining and service industries.

Table 2 Change in quantity of water used by sector, Scenario 1 for 2032 relative to 2001, GL

	Demand growth (1)	Taste changes and non-agricultural supply growth (2)	Agricultural tech. change (3)	Reduced water availability (4)	Agricultural water-efficiency gains and leakage reductions (5)	Reduced household water requirements (6)	Total
Crops & Livestock	99	-623	1586	-815	-774	151	-376
Dairy	43	-73	-363	-701	219	112	-763
Cotton	-433	14	-904	-596	785	77	-1057
Rice	-196	30	-380	-448	337	56	-601
Household	-8	69	-91	-142	244	-362	-290
Other	495	583	153	-479	-811	-34	-93
Australia	0	0	0	-3,182	0	0	-3,182

The contribution of demand growth is slightly positive for dairy both in terms of share of water usage (+43 GL, Table 2,1st column) and output (9.8%, Table 3, 1st column) because a relatively high proportion of sales of dairy products is to domestic consumers, whose demand grows over time with income and population. The crops and livestock production is relatively export oriented: the 1st column in Table 2 and Table 3 captures, among other demands, and export price shifts, which tend to be negative. However, overall demand growth is sufficient for both the share of water usage (99 GL) and output (+8.2%) in the crops and livestock sector to be positive. As a result of the collective effects of less water and more people, cotton and rice both suffer in terms of share of water usage (-433 GL and -196 GL respectively, Table 2, 1st column) and output (-11.9% and -11.2% respectively, Table 3, 1st column). As a result of the population increase, demand for dairy, crop and livestock products increase.

We stress that many other scenarios are possible. Our aim is to examine the relative merits of allowing urban-rural water trading and of using desalination to supplement water supplies in Australia's water-constrained cities.

Table 3 Change in value of Output, National, Scenario 1 for 2032 relative to 2001, %

	Demand growth (1)	Taste changes and non-agricultural supply growth (2)	Agricultural tech. change (3)	Reduced water availability (4)	Agricultural water-efficiency gains and leakage reductions (5)	Reduced household water requirements (6)	Total
Crops & Livestock	8.2	-16.5	47.9	-9.1	21.9	1.7	54.1
Dairy	9.8	-5.7	15.3	-16.8	40.9	2.6	46.1
Cotton	-11.9	0.5	-32.7	-17.6	63.2	2.2	3.7
Rice	-11.2	1.4	-23.5	-26.1	61.2	3.4	5.2

4.5. Taste changes and non-agricultural supply growth

As described in Dixon and Rimmer (2002, chapter 2), much structural change in an economy over time concerns productivity changes at the industry level and consumer taste changes at the commodity level. When we examine the supply side for agriculture, a different perspective of prospects for Australian agriculture emerges. As shown in the 3rd columns of Table 2 and Table 3 changes in agricultural technology result in considerable shifts in water use among sectors. These estimates of the supply shifts (technological changes) and demand shifts (taste changes) have been updated using Giesecke (2004). In these tables, water saving technology is kept separate so that we can track changes in the economy induced by changes in water policy and water supply.

Households increase usage shown in the 2nd column of Table 2 which rises (+69 GL), with income growth arising from productivity growth raising demand via the household consumption function.

Primary-factor productivity increases in industries have the effect of raising the shadow price of water. Hence, water becomes more valuable through the non-agricultural productivity effect captured in the 2nd column of Table 2 and Table 3 so that non-agricultural industries (including downstream processors of agricultural products) increase their share of water usage at the expense of other water users. In the case of cotton and rice, productivity growth in downstream sectors has a weakly positive impact on their water shares (+14 GL for cotton, +30 GL for rice, Table 2, 2nd column).

4.6. Agricultural technological change

As already mentioned, despite agriculture contributing a shrinking proportion to GDP, agricultural production has grown relatively rapidly over time, with much of the growth explained by productivity growth. Agricultural technological change, as with non-agricultural technological change, raises the shadow price of water (3rd column, Table 5). The magnitudes are large enough to be quite critical in projecting future urban-rural water needs. This productivity growth favours relatively less water-intensive users at the expense of more water-intensive users. This occurs to the extent that the impact of agricultural productivity growth on some irrigation sector outputs is negative (-32.7% for cotton and -23.5% for rice, Table 3, 3rd column), as primary factors plus water are diverted to crops and livestock. An increase in the shadow price of water draws water away from households (-91 GL). "Other" industries (Table 2, Column 3) use more water, and increase output through this effect. Other industries are largely processing industries that benefit from lower input costs arising from increased agricultural productivity.

4.7. Reduced water availability

We assume a 15% decline in water supply by 2032 relative to 2001 in all regions in mainland Eastern Australia defined to include South Australia (Western Australia, Tasmania and the Northern Territory receive the same amount of water in 2032 as they did in 2001). The 4th column of Table 2 shows that reduced water availability through climate change or increased allocations to the environment has strong negative effects for agriculture and negative for all other users. ABS water accounts suggest that Australia currently uses around 25,000 GL of water per annum.[14] With a 15% decline, total use in the Eastern States and South Australia declines by 3,182 GL. The impact of this reduced water supply on economic output is shown in Table 3. In the period to 2032, growth in the value of cotton and rice output is small.

4.7.1. Agricultural water-efficiency gains and leakage reductions

In Scenario 1, we introduce water use efficiency gains and leakage reductions as a result of investment in technology. The rate chosen is the same as what has been occurring in recent times. We assume that this rate of improvement can be sustained until 2032. The result is a 34% reduction on irrigation water requirements per unit of output,[15] and a 22% reduction in pipeline leakage in the 31 year period.

"Water savings" (the 5th and 6th columns of Table 2 and Table 3) captures the effects of two forms of water savings:

- a reduced water requirement per unit of output as a result of improvements in technology and management; and
- reduced pipeline leakage as a result of investments made.

Some of the effects associated with investments in water saving technology by the rice sector, while impressive, do not quite off-set the loss in supply (-448 GL in (4), +337 GL in (5), Table 2).[16]

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[14] ABS (2000) Water Account for Australia 1993-94 to 1996-97. ABS Publication 4610.0

[15] These estimates of likely rates of improvement in efficiency are derived from Mullen's (2002) review of estimates of productivity growth in Australia. They approximate a 1% per annum improvement in irrigation efficiency.

[16] The shifts in all columns in Table 2 except "reduced water availability" sum to zero as they summarise shifts. Agricultural water efficiency gains and leakage reduction (column 5) causes water to move to relatively water-intensive uses. The agricultural water efficiency gains and leakage reductions column (5) is an approximate mirror image of the reduced water efficiency column (4) but not completely so as the agricultural water efficiency gains and leakage reductions column (5) doesn't include savings by all water users. Reduced water availability (column 4) reduces the share of water used by water-intensive users not just those involved in agriculture.

In Table 2, "Other" industries, includes the water & drains services sector, to which water leakage is allocated as usage. Reductions in leakage reduces the water used by the water and drains sector, explaining much of the drop in "Other" industries water usage (-811 GL, Table 2, 5th column).

From Table 2, we can see that these changes reduce water usage in "Crops and Livestock" and "Other" but a positive effect on the value of output (Table 3) for all industries. That is, improvements in water use efficiency are sufficient to offset the effects of reduced water supply.

4.7.2. Reduced household water requirements

Household appliances have become more water-efficient than they were 20 years ago. Examples include the increasing introduction and encouragement to use water saving shower heads, front load washing machines, dual flush toilets, rain water tanks and water efficient gardens as well as the impact of many years of water restrictions. In Sydney, per capita water consumption has fallen considerably. Average water usage per capita was 412 litres per person per day in 2001-2002, 23 per cent less than in 1980/81 when usage levels peaked at 530 litres per person per day. Sydney Water's customer research has found that customers support water conservation. An example of this awareness and interest is the introduction of regular reporting on the evening TV news of the water levels in Sydney's major dams (Barrett, 2004). In the 31 year period to 2032, we impose a 22% downward shift on household water requirements. This estimate is consistent with independent estimates recently made by the Water Services Association of Australia's estimates (WSAA 2005).[17]

Nevertheless, the 362 GL "saved" by the household sector while the population increases by 5 million people means that more water is available for use in other sectors.

It is stressed that the total amount of water available for use in Australia and in each region could be much less or much more. Scenario 1 estimates do not include any investment in major sewage recycling or stormwater capture systems. If water supply decline of more than 15% occurs in the Eastern States and South Australia then investments of this nature may be necessary just to off-set these effects.

[17] Using a different methodology and using 2030 rather than 2032 as a benchmark, independently WSAA (2005) identifies opportunities to reduce urban water use by 326 GL through improvements in water use efficiency. Coincidently, our estimates for all of Australia are the same.

4.8. Impact on shadow price of water

In Scenario 1, we do not allow any increase in the amount of water transferred from rural to urban Australia. Existing transfer arrangements, like the transfer of water from the River Murray to Adelaide continue, but the volume of transfers is not allowed to increase. Water trading in the agricultural sector is limited to within region trading. Urban water supply utilities are excluded from all markets. Trade for irrigation trade is allowed within each region in Figure 2 but not between regions or among States.

Scenario 1, No urban-rural trading and no new sources of water

From now until 2032, the only water management possibilities available to Australia are increases in water use efficiency and changes in the supply price of water. Under this scenario, no water entitlements may be transferred from rural to urban water users, trading among rural water users within each region is unimpeded but does not occur between regions. There is no desalination, no sewage recycling and no capture of storm water for consumptive use.
The total quantity of water available for use in the Eastern States and South Australia is reduced by 3,200 GL. Average household water use efficiency is assumed to have increased by 22%. Efficiency in the irrigation sector is assumed to increase by 34%.

The first conclusion that arises from a careful examination of the information in the model runs is that the Australian economy would be able to cope with a reduction in water supply and that it could do this by using price mechanisms to equate water demand and supply tensions. This conclusion that Australia could sustain a 3,200 GL reduction in water supply while increasing its population by 25 million derives from assessment of the results summarised in Table 4. An additional five million people (from 2005) – that is a total population of 25 million people – could be achieved by 2032 with a 38% increase in real GDP and a 38% increase in aggregate consumption.

This economic growth and development would result in a number of significant changes to the economy. In particular and under this Scenario 1, the shadow price of water would increase significantly. In TERM-Water changes in the shadow price of water are modelled by supplying water to each industry at its "shadow price." In lay terms, the shadow price is that maximum amount that a profit maximising water user would pay to obtain access to one more unit of water.[18]

[18] In the context of a maximisation problem with a constraint, shadow price of the constrained variable can be defined as "the amount that the objective function would increase by if the constraint were relaxed by one unit."
Source: http://economics.about.com/od/economicsglossary/g/shadowprice.htm

Table 4 Decomposition of national results, Scenario 1 for 2032 relative to 2001, %

	Demand growth (1)	Taste changes and non-agricultural supply growth (2)	Agricultural tech. change (3)	Reduced water availability (4)	Agricultural water-efficiency gains and leakage reductions (5)	Reduced household water requirements (6)	Total
Aggregate consumption	14.7	21.3	1.1	-0.5	0.6	0.1	37.3
Real GDP	15.0	21.2	1.1	-0.5	0.7	0.1	37.6
Aggregate Employment	16.4	0	0	0	0	0	16.4
Population	27.1	0	0	0	0	0	27.1

Table 5 decomposes the changes in patterns of growth necessary to transform the economy so that it can cope with an increase of 5 million people without transferring more water from rural to urban areas and without commencing desalination or making any investments that would similarly increase the quantity of water available for sale to urban water users. In Scenario 1, all water users are required to pay the shadow price for the water they use – there are no non-price related restrictions on the volume of water used over and above those necessary to improve urban water efficiency by 22%. Regional impacts of this approach to water management differ considerably. In particular, all urban regions where the ABS projects rapid growth experience a dramatic major shadow price increase. Those who use water are required to pay for it.

- In Sydney, the shadow price increase is an additional $6.20/kL;
- in Melbourne, the shadow price increase is an additional $4.41/kL;
- in Brisbane/Moreton, the shadow price increase is an additional $8.51/kL; and
- in Perth, the shadow price increase is an additional $9.47/kL.

We stress that these estimates are very sensitive to the assumptions about population growth, the economy and improvements in water use efficiency made in Scenario 1. In Table 5, only a fraction of this potential movement arises from increased household demand. In Sydney, for example, demand growth alone induces a $3.70/kL increase in the shadow price of water, while non-agricultural productivity and import supply growth induces a further increase of $3.81/kL. Similarly, the extent to which water conserving measures are taken by households, has a marked effect on the shadow price, with our present assumption concerning such savings reducing Sydney's shadow price in this scenario by $2.47/kL.

Table 5 Increase/decrease in shadow price of water, Scenario 1 for 2032 relative to 2001, $/kL

	Demand growth (1)	Taste changes and non-agricultural supply growth (2)	Agricultural tech. change (3)	Reduced water availability (4)	Agricultural water-efficiency gains and leakage reductions (5)	Reduced household water requirements (6)	**Total**
Sydney	3.70	3.81	-0.59	2.52	-0.77	-2.47	**6.20**
Murrumbidgee	0.61	-0.17	0.52	0.41	-1.12	-0.05	**0.20**
Murray NSW	0.61	-0.17	0.51	0.41	-1.13	-0.05	**0.18**
Western NSW	0.75	-0.55	0.71	0.22	-1.43	-0.05	**-0.35**
Rest NSW	1.19	0.14	0.33	1.21	-1.27	-0.16	**1.44**
Melbourne	2.55	2.39	-0.22	2.23	-1.39	-1.15	**4.41**
Mallee VIC	1.18	-0.08	0.84	0.78	-1.75	-0.14	**0.83**
Rest Irrig VIC	1.29	-0.02	0.62	0.74	-1.50	-0.15	**0.98**
Rest VIC	1.27	-0.01	0.58	0.72	-1.21	-0.15	**1.20**
Brisbane-Moreton	5.59	3.53	-0.17	1.91	-1.07	-1.28	**8.51**
Burnett-Darling QLD	0.74	-0.11	0.52	0.39	-0.67	-0.07	**0.80**
Rest QLD	0.56	-0.13	0.80	0.65	-1.49	-0.09	**0.30**
Adelaide	0.61	0.31	0.50	1.07	-1.56	-0.82	**0.11**
Rest SA	0.65	-0.07	0.54	0.52	-1.09	-0.09	**0.46**
Perth	6.57	5.82	-0.17	0.40	-1.18	-1.97	**9.47**
Rest WA	4.23	1.44	1.76	0.78	-3.45	-0.53	**4.23**
Tas & NT	2.09	0.16	1.11	0.59	-2.09	-0.37	**1.49**
ACT	2.95	2.55	-0.69	1.16	-0.22	-3.80	**1.95**

Table 6 presents an overview of the resultant increase in the cost of water supplied to households if they are required to pay the marginal opportunity cost of supplying water to them. The highest shadow price increase is that for Perth. The model predicts that – if no urban-rural water trading occurs, no desalination plants are introduced and increases in the efficiency of urban water use is limited to 22% – one would expect the shadow price of water to rise to over $10 per kilolitre. Table 6 provides a benchmark against which the other scenarios can be examined. These data can also be used as a benchmark to assist with the evaluation of other policies under consideration by governments.

Table 6 Current mean urban water shadow price paid by urban water users in 2005 and real shadow price in 2032 under Scenario 1, $/kL

	ABS Population estimate 2001 (1)	ABS Population Projection 2032 (2)	Current Water price* (3)	Estimated increase in water shadow price (4)	2032 Water shadow price in 2005 Dollars
Sydney	4.15	4.99	1.36	6.20	7.56
Melbourne	3.49	4.27	1.17	4.41	5.58
Brisbane-Moreton	2.38	3.61	1.27	8.51	9.78
Adelaide	1.11	1.15	1.30	0.11	1.41
Perth	1.40	1.89	1.12	9.47	10.59
ACT	0.32	0.34	1.11	1.95	3.06

*** Source: WSAA facts 2005. Use charge for first 250 kL includes fixed charges. All adjusted using December 2005 and December 2001 consumer price indices (ABS 2006-02-20). Unless specifically stated, all other estimates in this report are in real 2001prices.**

5. Scenario 2: Water trading allowed among regions

The second scenario examined is one where water is transferred from rural to urban Australia in regions where this is technically possible. In many cases, this would require the construction of extensive pipeline and pumping systems. Our assumption that such systems may be technically possible is influenced by the network of pipelines used to supply water in South Australia and Western Australia.[19] In Scenario 2, Melbourne is connected to the River Murray System. Sydney is connected to the systems to the North and South of it along the Eastern coast of NSW. Brisbane, the Gold Coast and the Moreton Bay region are connected via a pipeline to the Darling Downs.[20] While some consider that such schemes are not possible. We draw attention to the fact that Adelaide is supplied by a 60 km pipeline from Mannum with a 136 GL per annum capacity and also a 48 km pipeline from Murray Bridge and a set of pumps that raise water 418 metres over the Adelaide Hills at a rate of up to 163 GL per annum. Whyalla, Port Pirie and Port Augusta are two 379 km pipelines with a combined capacity of 66 GL per annum.[21] Kalgoorlie is supplied by a 600 km pipeline from Perth.[22] Rather than estimating the cost of establishing a specific scheme, a generalised approach is taken. The fixed cost of establishing connections to adjoining regions via a system of pumps and pipes is estimated and amortised over the life of the asset. In TERM-Water, this amortised cost is then deducted from regional income.

The quantity of water that transfers from one region to another is then determined in a competitive market place. Unrestricted water trading occurs among all rural and urban

[19] It is stressed that we have not done the necessary engineering and environmental assessments to determine the feasibility of doing this. We have simply assumed that connection to the sources being used by agriculture are possible at costs similar to those already in place in other regions.

[20] The cost of constructing the necessary pipelines and pumping stations are annualised.

[21] Source: http://www.sawater.com.au/SAWater/Education/OurWaterSystems/Pipelines.htm, http://www.atlas.sa.gov.au/go/resources/atlas-of-south-australia-1986/environment-resources/water-supply.

[22] Source: http://www.sawater.com.au/SAWater/Education/OurWaterSystems/Pipelines.htm, http://www.atlas.sa.gov.au/go/resources/atlas-of-south-australia-1986/environment-resources/water-supply, http://kernow.curtin.edu.au/www/G&AWS/G&AWS.html.

industries. Even with these extensions to the supply system, in some regions, there is little capacity for urban-rural water trading as the volumes of water available at reasonable cost are minimal. In these regions and under scenario 2 there is little that people can do to alleviate urban water supply price increases. As a general rule, however, there are some agricultural water users in each urban region and "agricultural" water supplies that could be piped from adjacent regions.

Economic benefits are greatest when the opportunity cost of water in an adjacent region is much lower. If, for example, Melbourne can access water from the Murray-Darling Basin then, as shown in our model, the increase in the shadow price of water in Melbourne is less. While those in Melbourne may express interest in such an option, it needs to be appreciated that the result will be an increase in the supply shadow price of water in the River Murray System and as far away as Adelaide and in the Murrumbidgee River System.

Scenario 2 essentially repeats Scenario 1, this time allowing for the market driven transfer of water from rural to urban Australia and unrestricted water trading among regions.

Scenario 2, Full urban-rural trading among regions

The introduction of unimpeded water trading between the rural and urban sectors coupled with the construction of pipelines and associated infrastructure necessary to connect our main cities with nearby sources of water. Under this assumption, we incorporate general costs associated with building pipelines based on distances involved but do not make specific costings or assumptions about the feasibility of such infrastructure for different parts of Australia. This scenario is intended to give general insight into what could be achieved if such water trading was allowed and the pipelines, dams and pumping stations necessary to make it possible are constructed."

Table 7, Table 8 and Table 9 present some of the consequences of allowing urban-rural water trading. Under Scenario 2, shadow price increases for household users are dampened dramatically in Brisbane and Gold Coast (from +$8.51/kL to +$1.23/kL) via water trading with Darling Downs/Wide Bay-Burnett.

As indicated in Table 8, the volumes of water transferred from rural areas to urban areas are relatively small. Across the nation 61 GL is transferred to households and 171 GL to commercial and industrial uses. Collectively, this represents   1.1% of the 21,800 GL of water in use across Australia.

Compared to Scenario 1, significant reductions in the shadow price of water are apparent for Melbourne (from +$4.41/kL to +$0.37/kL), through water trading with the Murray-Darling Basin and for Sydney (from +$6.20/kL to +$1.48/kL), through water trading with the remaining coastal regions of NSW. The fall in Perth, from $9.47/kL to $4.80/kL, is less dramatic in terms of final price but still represents a very important opportunity to halve the price increase predicted for 2032.

One of the consequences of full urban-rural trading is connection, via the Southern Connected River Murray System, of Adelaide's and Melbourne's water supply systems. As a result, the shadow price increase for water in Adelaide rises to the same shadow price increase as that for Melbourne – from $0.11/kL to $0.37/kL.

The introduction of water trading also impacts on the influence of household water requirements to the shadow price of water. Access to rural water means that households, on average, require more water. For Australia's main cities, the effects on the shadow price of water is as follows:

- in Sydney, from -$2.47/kL to -$0.25/kL;
- in Melbourne from -$1.15/kL to -$0.09/kL;
- in Brisbane/Moreton from -$1.28 to -$0.13/kL;
- in Adelaide from -$0.82/kL to -$0.09/kL; and
- in Perth from -$1.97/kL to -$0.73/kL.

Putting issues like the age and condition of infrastructure to one side, these data suggest that households will have a much greater effect on the shadow prices for water in metropolitan areas where water trading with other regions is not possible. This is because regional trading lowers the need for shadow price increases and this means that the incentive to invest in saving technology is less and, hence, fewer household savings are made.

At the macroeconomic level, the expansion of inter-region and inter-sector water trading would appear to be favourable. Table 7 shows that in scenario 2, national aggregate consumption is 1.0% higher in scenario 2 than scenario 1. Real GDP is also found to be slightly higher (0.6%).

Not surprisingly, the regions that suffer the greatest losses in economic activity are the irrigation regions of NSW where rice and cotton currently dominate water usage. Real GRP falls in the Murrumbidgee (-4.6%) and Murray (-5.3%) statistical divisions of NSW, and Western NSW (-11.0%) (combining Far West, North West and Northern NSW statistical divisions).

A region with a substantial economic decline in terms of employment relative to the no water trading scenario is the Wide Bay-Burnett/Darling Downs region in Queensland (-4.3%). The Brisbane/Moreton region's economy gains at the expense of the Wide Bay-Burnett/Darling Downs regional economy.[23]

While these regional losses appear to be large, they arise in the context of economic growth, that is, growth still occurs as a result of water trading but to a lesser extent than without. For example, Western NSW's real GRP is projected to rise by 43% in Scenario 1, compared with 32% in the water-trading scenario 2. This result should also be considered in the context of other impacts which are not modelled here such as the likely benefits to the environment as a result of improvements in technology and the trading of water away from, for example, high salinity impact areas.

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[23] TERM assumes that the money received from the purchase of water entitlements will be re-invested in order to maximise economic activity – even if this means that the money is re-invested outside the region from where the water is sourced.

Table 7 Change in macroeconomic outcomes, water-trading Scenario 2 minus Scenario 1

	Change in aggregate consumption (% - %)	Change in real GDP, GSP and GRP (% - %)	Change in aggregate employment (% - %)
Sydney	-0.2	-0.2	-0.6
Murrumbidgee	-4.5	-4.6	-3.6
Murray NSW	-5.3	-5.3	-4.1
Western NSW	-11.0	-11.0	-10.3
Rest NSW	-1.9	-1.9	-1.3
Melbourne	1.4	1.4	0.4
Mallee VIC	5.6	5.6	3.3
Rest Irrig VIC	5.0	5.1	2.1
Rest VIC	0.2	0.2	0.0
Brisbane-Moreton	11.1	11.2	6.3
Burnett-Darling QLD	-8.4	-8.4	-4.3
Rest QLD	-2.0	-2.0	-1.6
Adelaide	-2.3	-2.3	-1.8
Rest SA	-2.0	-2.0	-1.6
Perth	4.6	4.6	2.4
Rest WA	-4.8	-4.8	-3.1
Tas & NT	-1.3	-1.3	-1.3
ACT	-0.8	-0.8	-0.7
Australia	**1.0**	**0.6**	**0**

Table 8 compares changes in water usage in the water-trading scenario 2 relative to Scenario 1 by user. After all the consequences of full and open water trading have occurred, water is, in effect, traded from the rice and cotton production to urban and other uses. As a result, households and non-agricultural industries use more water in scenario 2. These are expected outcomes, with water moving from relatively water-intensive to relatively fast-growing sectors. While this is the case, it is important to understand that the volumes of water involved in regional transfers are quite small – especially when compared with the overall volumes used. For example, household usage increases by only 61 GL or 4%. Relatively small volumes of water trading have dramatic impacts on regional shadow prices because the demand for water in the household sector is highly inelastic.

Table 8 **Change in water usage, water-trading scenario 2 compared to Scenario 1, GL**

	Demand growth (1)	Taste changes and non-agricultural supply growth (2)	Agricultural tech. change (3)	Reduced water availability (4)	Agricultural water-efficiency gains and leakage reductions (5)	Reduced household water requirements (6)	**Total**
Crops & Livestock	22	-18	-12	56	-55	0	**-7**
Dairy	102	36	44	116	2	-13	**287**
Cotton	-121	-153	-3	-317	131	68	**-395**
Rice	-97	22	-20	16	-57	16	**-120**
Household	29	37	-13	34	2	-28	**61**
Other	64	76	3	94	-23	-43	**171**
Australia	**0**	**0**	**0**	**0**	**0**	**0**	**0**

The main policy conclusion from Scenario 2 is that the introduction of water trading arrangements and the installation of pipes and related infrastructure to enable water transfer among regions will reduce much of the pressure on the shadow price of water across Australia. In cities like Melbourne, water trading will probably be sufficient to address Melbourne's future water needs. In Melbourne, the trading scenario results in a shadow price increase of only $0.37/kL for the city. As would be expected, if Melbourne connects to and draws water from the Murray Darling Basin, the shadow price of water in all cities able to access water from the Southern Connected River Murray System – Adelaide, the ACT and Melbourne – increases.

These predictions are conditional on the assumptions in the scenario. Table 9 shows how the changes in demand, taste changes, technology, supply reduction and efficiency improvement all interact. Generally, water trading makes the shadow price of water less sensitive to urban demand and supply shifts as each city has access to a much larger pool of water. It is wrong to attribute the changes summarised above to any one factor.

Table 9 Decomposition of the increase/decrease in shadow price for water, scenario 2, 2032 relative to 2001, $/kL

	Demand growth (1)	Taste changes and non-agricultural supply growth (2)	Agricultural tech. change (3)	Reduced water availability (4)	Agricultural water-efficiency gains and leakage reductions (5)	Reduced household water requirements (6)	**Total**
Sydney	1.16	0.27	0.22	1.22	-1.14	-0.25	**1.48**
Murrumbidgee	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Murray NSW	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Western NSW	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Rest NSW	1.16	0.27	0.22	1.22	-1.14	-0.25	**1.48**
Melbourne	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Mallee VIC	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Rest Irrig VIC	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Rest VIC	1.32	-0.06	0.58	0.67	-1.39	-0.13	**0.99**
Brisbane-Moreton	0.99	0.05	0.62	0.75	-1.05	-0.13	**1.23**
Burnett-Darling QLD	0.99	0.05	0.62	0.75	-1.05	-0.13	**1.23**
Rest QLD	0.92	-0.13	0.72	0.56	-1.68	-0.09	**0.30**
Adelaide	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Rest SA	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**
Perth	3.94	2.3	1.36	0.82	-2.89	-0.73	**4.80**
Rest WA	3.94	2.3	1.36	0.82	-2.89	-0.73	**4.80**
Tas & NT	1.78	0.02	1.08	0.56	-1.99	-0.31	**1.14**
ACT	0.81	-0.15	0.6	0.37	-1.17	-0.09	**0.37**

6. Scenario 3: Water trading + a "new" water source

Desalination is included in this report as an example of the effect of investments that deliver a "new" source of water. This investment could just as easily be a major sewage recycling system or a major stormwater capture system used to increase the supply of water.

There are several caveats on the role of desalination or an equivalent investment in water recovery. If water-saving technological changes are more rapid than the assumed 34% for rural Australia and the 22% for urban Australia, the number of regions where one might consider investing in the development of a major new source as a relatively low cost means of meeting water needs could fall.[24] Indeed, if inter-regional water trading is implemented across all interconnected water supply systems, the contribution to the economy of increased water use efficiency and reduced leakage in both urban and rural Australia lessens the need

[24] Such changes in requirements would not help in regions where water quality rather than water quantity is the main concern.

to consider desalination. Moreover, small desalination plants are much more expensive to run per kilolitre than large plants. This is not necessarily the case for small scale sewage recycling and storm water capture systems – especially when the water does not have to be delivered at drinking water quality standards.

In passing, we note that, desalination may be a relatively low cost means of filling water supply needs in relatively remote coastal regions. The Eyre Peninsula in South Australia is one example. Such relatively local possibilities for desalination are at a finer level of dis-aggregation in the regional dimension than we model in this study. Small scale desalination plants also offer an important potential source of water for the mining industry.

In recent years, desalination costs have fallen well below $2.00/kL. Quoted real costs per kilolitre range from just under $1.50/kL per kilolitre to a low of $1.00/kL. The desalination system under construction for Perth is expected to deliver water at a cost of $1.16/kL. Construction of a desalination plant for Sydney has been put on hold until water supplies fall below 30% of capacity.[25] Under current expectations and if constructed this plant is expected to deliver water at a cost of around $1.50/kL.[26] Given that desalination is a fuel-intensive process, energy price increases require careful consideration. In the scenarios modelled in this report, relative energy prices are assumed to remain the same. Other scenarios are possible and are regarded as a logical extension for the research described in this report.

As plant size increases production costs per unit decrease significantly. Israel's Ashlelon desalination plant is currently producing "new" water at a cost of US$0.53/kL. Built by VID, a special purpose joint-venture company of IDE Technologies, Vivendi Water and Dankner-Ellern Infrastructure, energy for this plant comes from natural gas. Water is supplied under a 25 year Build Operate and Transfer arrangement. After 25 years, ownership of the plant and all responsibility for ongoing operation transfers to the Government of Israel.[27]

Scenario 3, Trading plus a "new" water source

The construction of desalination plants and development of a desalination industry in Australia's water constrained cities. The plants produce either 80GL or 120 GL per annum. {This scenario can also be interpreted as the construction of recycling or storm water capture systems that make water available at an amortised cost of $1.00 to $1.50 per kilolitre.}

In scenario 3, it is assumed that desalination plants are constructed in Sydney, the Brisbane-Moreton region and Perth. Choosing an appropriate capacity for a desalination plant in a given region is far from trivial. In this scenario, we add desalination plants to the water resources of Sydney, Brisbane-Moreton and Perth. In each case, the plant produces 80 GL per annum at a cost of $1.50/kL.

As unit production costs appear to decrease with size we also run Scenario 3A with a plant producing 120 GL per annum at a cost of $1.50/kL.

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[25] Metropolitan Water Plan February 2006 http://www.waterforlife.nsw.gov.au/publications/index.shtml

[26] Sydney Water's Desalination planning study reports that "the preliminary design undertaken has shown that water could be produced and delivered into the water distribution system for a cost in the order of $1.44/kL. Depending upon the greenhouse reduction strategy chosen this cost could increase (potentially in the order of $0.10/kL)". It also reports that "the recent plant at Perth is quoted at $1.16/kL. The difference is attributable to the nature of Sydney's coastline and required intake and discharge structures." (Sydney Water 2005)

[27] http://www.water-technology.net/projects/israel/

In scenarios 3 and 3A, we do not attempt to choose a desalination plant size that is optimal for a given region. The entire plant capacity is produced every year. No attempt is made to determine the optimal size of a plant. In each case desalination reduces the shadow price for water after the introduction of full trading significantly. The results for an 80 GL plant are presented in Table 14 and Table 17, and can be summarised as follows:

- in Sydney, the shadow price increase declines from $1.48/kL in scenario 2 to $1.24/kL which would result in a total “2032 price” of $2.60/kL;[28]
- in Brisbane/Moreton, the shadow price increase declines from $1.23/kL to $1.03/kL which would result in a total “2032 price” of $2.33/kL;
- in Perth, the shadow price increase declines $4.80/kL to $3.11 which would result in a total “2032 price” of $4.23/kL.

As would be expected and as summarised in Table 14, a larger capacity 120GL plant with lower unit costs set at $1.00/kL – scenario 3A – reduces the shadow price increase compared with the Scenario 3 to:

- $1.16/kL in Sydney resulting in a total “2032 price” of $2.52/kL;
- $0.96/kL in Brisbane/Moreton resulting in a total “2032 price” of $2.26/kL; and
- $2.56/kL in Perth resulting in a total “2032 price” of $3.68/kL.

Perth has the most acute water shortages of any city prior to desalination. Therefore, desalination does more to alleviate growing water needs in Perth than other cities. Lower desalination costs in turn have a greater impact on Perth than elsewhere. The construction of another desalination plant or investment in large scale sewage recycling and/or stormwater capture would further reduce the cost of water supply to Perth.

In this report, TERM-Water simulates what would happen in an average year. The issue of how a water supplies and prices should be managed and how much higher shadow prices would be during a drought is not examined. When considering this issue, proponents for desalination point out that this source of new water can be accessed independently of climatic conditions. In contrast, during prolonged dry periods less water is available for storm water capture and some recycling systems.

7. Scenario 4: Water trading + desalination + wage-driven migration

ABS projections predict relatively high population growth rates for Brisbane-Moreton and Perth. One possible consequence of this growth is that people begin to migrate to other parts of Australia. In scenario 4, we reduce the interregional growth rate differences among cities by reducing real wage growth differentials among regions.

Scenario 4, trading, desalination plus wage-driven migration

Scenario 3 plus wage-driven migration in a manner that favours population growth and the development of smaller cities. The regional population growth assumptions we use in scenarios 1, 2 and 3 follow ABS projections that do not take into account changes in relative economic opportunity. Under scenario 4, we use a theory of regional allocation to change relative wages across Australia. As a result, wage-driven migration causes relatively more population growth in Australia’s smaller cities.

The regional population implications of this alternative scenario on population distribution in Australia are summarised in Table 10.

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28 Assumes that the current price charged is the shadow price.

Table 10 Overview of changes in population as a result of wage-driven migration

	Population in 2001 (1)	Scenario 3 Projection for 2032 (2)	Scenario 4 Projection for 2032 (3)
Sydney	4.15 million	4.94 million	4.97 million
Melbourne	3.49 million	4.27 million	4.30 million
Brisbane-Moreton	2.38 million	3.83 million	3.51 million
Adelaide	1.11 million	1.13 million	1.20 million
Perth	1.40 million	1.97 million	1.93 million
ACT	0.32 million	0.34 million	0.35 million

The economic consequences of this wage-driven interregional migration can be appreciated by comparing the columns for each in Table 11. There is a moderate alleviation of the water shadow price increase in Brisbane/Moreton due to slower population growth. In Perth, the effect is somewhat more substantial, as it applies to a higher shadow price increase, as the water trading we have also assumed in each scenario plays a smaller role in reducing water shadow price increases than in Brisbane/Moreton. In all other regions, the effects of wage induced migration on water shadow prices are minimal.

The more general economic consequences of wage-driven migration are significant and interesting in their own right. Brisbane/Moreton's aggregate consumption increase falls from 72.2% in scenario 3 to 61.9% in scenario 4. In Perth, the increase in aggregate consumption declines from 49.8% under scenario 3 to 47.0% under scenario 4. The increase in aggregate consumption in Adelaide doubles from 7.6% in Scenario 3 to 15.2% in Scenario 4.

An important issue we can consider in the context of scenario 4 is the risk of investing in desalination in a region in which population growth turns out to be smaller than projected. One insight we can obtain from comparing the row for Brisbane/Moreton in Table 14 is that water trading plays a bigger role in alleviating water scarcities than desalination. However, the water shadow price increase is still large enough with water trading that desalination appears to have a role to play in meeting future water needs. In the case of Perth, the water shadow price increases are so large in all scenarios that the issue appears not to be whether to have desalination plants to supplement existing water supplies, but rather the capacity such plants should have. At present the desalination plant proposed for Perth will be the largest in the southern hemisphere and supply an extra 45 GL of water to the region every year.

Table 11 Changes as a result of wage-driven migration, scenario 4 compared to scenario 3

	Change in shadow price water $/KL from 2001		Change in Aggregate consumption from 2001 as %		Change in employment from 2001 as %	
	Scenario 3	**Scenario 4**	**Scenario 3**	**Scenario 4**	**Scenario 3**	**Scenario 4**
	(1)	(2)	(3)	(4)	(5)	(6)
Sydney	1.24	1.24	35.80	36.30	12.00	12.50
Murrumbidgee	0.33	0.34	29.60	30.00	14.00	14.40
Murray NSW	0.33	0.34	28.40	28.80	15.50	16.10
Western NSW	0.33	0.34	31.80	31.80	15.80	15.90
Rest NSW	1.24	1.24	33.10	33.80	14.90	15.50
Melbourne	0.33	0.34	39.10	39.90	14.40	15.00
Mallee VIC	0.33	0.34	37.40	37.80	16.70	17.30
Rest Irrig VIC	0.33	0.34	39.10	39.70	17.90	18.60
Rest VIC	0.93	0.87	61.40	54.80	42.70	35.80
Brisbane-Moreton	1.03	0.90	72.20	61.90	46.70	37.90
Burnett-Darling QLD	1.03	0.90	59.00	52.10	43.10	35.60
Rest QLD	0.25	0.39	11.70	18.20	-6.80	-1.20
Adelaide	0.33	0.34	7.60	15.20	-9.00	-2.70
Rest SA	0.33	0.34	13.60	19.80	-6.20	-0.20
Perth	3.11	2.72	49.80	47.00	28.60	26.20
Rest WA	3.11	2.72	61.40	59.50	32.00	29.90
Tas & NT	1.06	1.03	32.70	32.60	17.90	17.80
ACT	0.33	0.34	11.30	15.60	-4.30	-0.40
Australia			39.50	39.10	16.40	16.40

8. Aggregated results and conclusions

Table 12 to Table 16 provide the data necessary to enable comparison of all the scenarios presented. People and industries use water and respond to changes in opportunities in complex but predictable ways that TERM-Water attempts to capture. In scenario 1, we accept the ABS's illustrative regional population projections. Changes in population projections produced in the other scenarios show how much each region's population is exposed to the way it manages and develops its water economy. Industries adjust and people migrate in response to changing conditions in all regions – not just what happens in their own region. This is most evident when one looks at the results for Scenario 3 and 3A. The effect of Perth, Sydney and Brisbane-Moreton investing in "new" water sources extends well beyond their city limits. One of the most noticeable effects is that it reduces the extent of water trade from rural areas.

Table 12 Overview of changes in population under each scenario (millions of people)

	Population in 2001	2032 Population Scenario 1	Scenario 2	Scenario 3	Scenario 3a	Scenario 4
Sydney	4.15	4.99	4.96	4.94	4.94	4.97
Melbourne	3.49	4.27	4.29	4.27	4.26	4.30
Brisbane-Moreton	2.38	3.61	3.83	3.83	3.83	3.51
Adelaide	1.11	1.15	1.13	1.13	1.13	1.20
Perth	1.40	1.89	1.93	1.97	1.99	1.93
ACT	0.32	0.34	0.34	0.34	0.34	0.35

Table 13 summarises changes in water use. Water trading reallocates water to household and "other" sectors. "Other" is largely manufacturing, industrial and mining uses. An increase in population means that consumption in the other sector grows by decreasing use in agriculture.

Desalination means that less water has to be given up by all sectors. All scenarios are heavily dependent assumptions based upon the distribution of people across Australia and the economy as a whole. It needs to be recalled that we reduce water supplies in Eastern States and South Australia by 3,200 GL (15%).

Table 13 Change in water usage by sector, all scenarios 2032 relative to 2001, GL

		Trade	Trade + desal. @ $1.50/kL	Trade + desal. @ $1.00/kL	Trade plus desalination at $1.50 plus wage-driven migration
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 3A**	**Scenario 4**
	(1)	(2)	(3)	(4)	(5)
Crops & Livestock	-376	-356	-268	-227	-268
Dairy	-763	-477	-462	-455	-470
Cotton	-1057	-1493	-1445	-1421	-1429
Rice	-601	-708	-690	-681	-689
Household	-290	-246	-235	-226	-232
Other	-93	98	158	188	145
National	**-3182**	**-3182**	**-2942**	**-2822**	**-2942**

Perhaps the most notable observation is the effect of each scenario on the shadow price for water (Table 14). Urban-rural water trading increases the shadow price of water in most rural areas but decreases it in areas that contain large cities.

Table 14 Increase/decrease in shadow price of water, all scenarios 2032 relative to 2001, $/kL*

	Trade	Trade + desal. @ $1.50/kL	Trade + desal. @ $1.00/kL	Trade plus desalination at $1.50 plus wage-driven migration
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 3A**	**Scenario 4**
	(1)	(2)	(3)	(4)	(5)
Sydney	6.2	1.48	1.24	1.16	1.24
Murrumbidgee	0.2	0.37	0.33	0.31	0.34
Murray NSW	0.18	0.37	0.33	0.31	0.34
Western NSW	-0.35	0.37	0.33	0.31	0.34
Rest NSW	1.44	1.48	1.24	1.16	1.24
Melbourne	4.41	0.37	0.33	0.31	0.34
Mallee VIC	0.83	0.37	0.33	0.31	0.34
Rest Irrig VIC	0.98	0.37	0.33	0.31	0.34
Rest VIC	1.2	0.99	0.93	0.9	0.87
Brisbane-Moreton	8.51	1.23	1.03	0.96	0.9
Burnett-Darling QLD	0.8	1.23	1.03	0.96	0.9
Rest QLD	0.3	0.3	0.25	0.22	0.39
Adelaide	0.11	0.37	0.33	0.31	0.34
Rest SA	0.46	0.37	0.33	0.31	0.34
Perth	9.47	4.8	3.11	2.56	2.72
Rest WA	4.23	4.8	3.11	2.56	2.72
Tas & NT	1.49	1.14	1.06	1.02	1.03
ACT	1.95	0.37	0.33	0.31	0.34

***** Note: In Scenario 3 and 3A, desalination plants are commissioned only in Sydney, Perth and Brisbane-Moreton.

Aggregate consumption estimates (Table 15) are lowest for Scenario 1 which indicates the inefficiency and nation-wide consequences of this option. Several regions have already moved past the policies that underpin Scenario 1. Other regions are in the process of evaluating the consequences of accessing rural water and/or building desalination plants or recycling water on a large scale. The increase in aggregate consumption as a result of more efficient water use varies from region to region. This inefficiency, however, does result in more rural as distinct from urban employment (Table 16).

Table 15 Increase in aggregate consumption, all scenarios 2032 relative to 2001, %[a)]

	Scenario 1	Trade Scenario 2	Trade + desal. @ $1.50/kL Scenario 3	Trade + desal. @ $1.00/kL Scenario 3A	Trade plus desalination at $1.50 plus wage-driven migration Scenario 4
	(1)	(2)	(3)	(4)	(5)
Sydney	36.2	35.2	35.8	35.7	36.3
Murrumbidgee	34.2	29.4	29.6	29.6	30.0
Murray NSW	33.8	28.3	28.4	28.4	28.8
Western NSW	42.9	31.7	31.8	31.8	31.8
Rest NSW	34.9	33.3	33.1	33.2	33.8
Melbourne	38.2	39.2	39.1	38.9	39.9
Mallee VIC	32.4	37.4	37.4	37.2	37.8
Rest Irrig VIC	34.6	39.2	39.1	38.9	39.7
Rest VIC	61.4	61.5	61.4	61.3	54.8
Brisbane-Moreton	61.1	72.2	72.2	72.3	61.9
Burnett-Darling QLD	65.9	59.3	59.0	59.7	52.1
Rest QLD	14.1	11.8	11.7	11.6	18.2
Adelaide	10.3	7.7	7.6	7.5	15.2
Rest SA	16.1	13.6	13.6	13.4	19.8
Perth	42.2	49.7	49.8	50.8	47.0
Rest WA	61.3	61.6	61.4	63.2	59.5
Tas & NT	34.4	32.8	32.7	32.6	32.6
ACT	12.4	11.4	11.3	11.2	15.6
Australia	**38.4**	**39.4**	**39.5**	**39.6**	**39.1**

a) The model structure does not allow the emergence of differential rates of unemployment as a result of changes in water use and, hence, at the national level employment is constant under all scenarios.

Table 16 Change in employment, all scenarios 2032 relative to 2001, %

	Scenario 1	Trade **Scenario 2**	Trade + desal. @ $1.50/kL **Scenario 3**	Trade + desal. @ $1.00/kL **Scenario 3A**	Trade plus desalination at $1.50 plus wage-driven migration **Scenario 4**
	(1)	(2)	(3)	(4)	(5)
Sydney	12.9	-0.6	12.0	12.0	12.5
Murrumbidgee	17.8	-3.6	14.0	13.9	14.4
Murray NSW	19.8	-4.1	15.5	15.5	16.1
Western NSW	26.3	-10.3	15.8	15.8	15.9
Rest NSW	16.3	-1.3	14.9	14.8	15.5
Melbourne	14.3	0.4	14.4	14.2	15.0
Mallee VIC	13.9	3.3	16.7	16.6	17.3
Rest Irrig VIC	16.2	2.1	17.9	17.8	18.6
Rest VIC	43.0	0.0	42.7	42.6	35.8
Brisbane-Moreton	40.5	6.3	46.7	46.7	37.9
Burnett-Darling QLD	46.9	-4.3	43.1	43.4	35.6
Rest QLD	-4.9	-1.6	-6.8	-6.9	-1.2
Adelaide	-6.9	-1.8	-9.0	-9.2	-2.7
Rest SA	-4.2	-1.6	-6.2	-6.3	-0.2
Perth	24.1	2.4	28.6	29.3	26.2
Rest WA	32.1	-3.1	32.0	33.1	29.9
Tas & NT	19.5	-1.3	17.9	17.8	17.8
ACT	-3.3	-0.7	-4.3	-4.4	-0.4
Australia	**16.4**	**16.4**	**16.4**	**16.4**	**16.4**

Using the ABS consumer price index, Table 17 converts the shadow price estimates in this report to real 2005 prices and adds these estimates to the current mean price of water. Under all scenarios, and as a result of access to the Connected Southern River Murray System, shadow price increases for Adelaide, Melbourne and Canberra are small relative to those for Perth, Sydney and Brisbane. To aid comparison, these estimates are then presented in relative terms in Table 18.

Table 17 Estimated mean urban shadow price of water in 2032 under different scenarios, $/kL and in Dec 2005 dollars
Except where explicitly stated, all other shadow price estimates in this report are presented as increases in the real price rather than an absolute price

	Current Water price*	**Scenario 1** (1)	Trade **Scenario 2** (2)	Trade + desal. @ $1.50/kL **Scenario 3** (3)	Trade + desal. @ $1.00/kL **Scenario 3A** (4)	Trade plus desalination at $1.50 plus wage-driven migration **Scenario 4** (5)
Sydney	1.36	8.09	2.97	2.71	2.62	2.71
Melbourne	1.17	5.96	1.57	1.53	1.51	1.54
Brisbane-Moreton	1.27	10.51	2.61	2.39	2.31	2.25
Adelaide	1.30	1.42	1.70	1.66	1.64	1.67
Perth	1.12	11.40	6.33	4.50	3.90	4.07
ACT	1.11	3.23	1.51	1.47	1.45	1.48

Source: WSAA facts 2005. Use charge for first 250 kL includes fixed charges. All estimates adjusted using December 2005 and December 2001 consumer price indices (ABS 2006-02-20).

Table 18 Relative change in estimated mean urban shadow price of water in 2032 under different scenarios, current price = 100%

	Current Water price*	**Scenario 1** (1)	Trade **Scenario 2** (2)	Trade + desal. @ $1.50/kL **Scenario 3** (3)	Trade + desal. @ $1.00/kL **Scenario 3A** (4)	Trade plus desalination at $1.50 plus inter regional migration **Scenario 4** (5)
Sydney	100%	595%	218%	199%	193%	199%
Melbourne	100%	509%	134%	131%	129%	132%
Brisbane-Moreton	100%	827%	205%	188%	182%	177%
Adelaide	100%	109%	131%	128%	126%	128%
Perth	100%	1018%	565%	401%	348%	364%
Sydney	100%	595%	218%	199%	193%	199%

9. Conclusions

9.1. Implications for Australia as a whole

Overall for Australia, the implications of the different scenarios are as follows:

- changes in water policy and investment in infrastructure can lead to rather large changes in the shadow price of water in each region, positive and negative;
- Sydney, Melbourne, Brisbane/Moreton and Perth face rather large shadow price increases unless they embrace urban-rural trading and/or desalination (shadow price increases in these cities range from $4.41/kL to $9.47/kL).

Since the demand for water in urban areas is relatively inelastic, relatively small trade volumes will have quite a significant impact on shadow prices. In many cases, the volumes of water involved are quite small. Across the nation, the amount of water shifted from rural to urban areas under all scenarios is around 1.1% of all the surface and ground water that our scenarios assume is available for consumption across Australia in 2032.

While we have neither attempted to assess the technical feasibility nor the environmental implications of connecting urban and rural supply systems, the option has important implications for all regions involved. For example, if Melbourne decides to buy water from the Southern Connected River Murray system, this action would affect shadow prices of water used for irrigation in the River Murray system, in Adelaide and in the Murrumbidgee.

It should also be noted from the results of the model that the impacts of technological change on water usage and subsequent shadow prices can be significant. For example, it was noted that greater water-efficiency gains in irrigation than we have modelled reduces the number of urban centres where the development of “new” water sources appears to be a favourable option.

An important question that has yet to be modelled is the question of when it is optimal to introduce the policy changes and investments in infrastructure explored in this report. One could, for example, run TERM-water with projections for 2010, 2020 as well as for 2032.

It is stressed that many other scenarios could be run both for Australia as a whole and for specific regions. One could also include analysis of changes in the stock of water available as a result of the discovery of new groundwater sources, increased recycling and under different climatic scenarios. The TERM-Water platform is both rich and full of potential.

9.2. An agricultural perspective

From an agricultural perspective, the introduction of water trading has mixed consequences. When 2032 is compared with 2001, water intensive industries reliant on access to low cost water sources such as cotton and rice face greater reductions in water usage with the introduction of trading as more of the water they use moves to cities. Overall, water trading potentially diverts economic activity away from irrigation regions and the associated industries. As a result, the shadow price of water in these regions increases. Development of new water sources and actions that increase urban and industrial water use efficiency will tend to reduce the extent to which a 25% increase in Australia’s population causes water transfers from rural to urban areas.

9.3. An urban water perspective

Water trading also has significant impacts on and advantages for urban regions. The shadow price of water in 2032 is significantly reduced for most regions by the introduction of trading and even more with trading combined with desalinated water being available. For example, water shadow prices in Melbourne are greatly reduced under all alternative scenarios compared to the Scenario 1. To a lesser extent, water trading is a reasonable solution for Brisbane/Moreton (and, if technically feasible, Sydney) although shadow prices do still increase significantly compared to what they are at present. Water trading, however, is not by itself able to resolve the water supply challenges faced by Perth. Nevertheless, water trading does halve the shadow price increase that Perth in 2032, with nearly 500,000 more people, are predicted to face. If one is interested in keeping the cost of water down, access to a new water source, like desalination, has a key role to play. Similarly, it may be reasonable to conclude that to take advantage of greater water shadow price decreases, the development of new water sources for Sydney and the Brisbane/Moreton may be necessary. The economic answer to the question of whether or not one goes with desalination, sewage recycling, storm water capture or some other source depends upon relative costs and reliability issues.

10. References

ABARE (2004), *Australian Commodity Statistics*, Canberra.

ABS (Australian Bureau of Statistics) (1998), *Western Australian Year Book*, Catalogue no. 1300.5. ABS, Perth.

ABS (Australian Bureau of Statistics) (1999), *Queensland Year Book*, Catalogue no. 1300.3. ABS, Canberra.

ABS (Australian Bureau of Statistics) (2000), *Household Expenditure Survey, 1998-99*, Catalogue no. 6530.0. ABS, Canberra.

ABS (Australian Bureau of Statistics) (2002b), *Australian Grape and Wine Industry*, Catalogue no. 1329.0. ABS, Canberra.

ABS (Australian Bureau of Statistics) 2002a (and previous issues), *Australian National Accounts: State Accounts*, Catalogue 5220.0. ABS, Canberra.

ABS (Australian Bureau of Statistics) (2004), *Water Account, Australia*, Catalogue no. 4610.0. ABS, Canberra.

ABS (Australian Bureau of Statistics) (2003), Population Projections, Australia Catalogue no. 3222.0.

ABS (Australian Bureau of Statistics) (2006), Consumer price Index, Australia, Dec 20052, Catalogue 6401.0 ABS, Canberra.

Access Economics (2005), *Business Outlook*, Access Economics Report, Canberra.

Adams, P., Horridge, M., Madden, J. and Wittwer, G. (2002a), "Drought, regions and the Australian economy between 2001-02 and 2004-05", *Australian Bulletin of Labour*, 28(4): 231-246.

Adams, P., Horridge, M., Wittwer, G. (2002b), *MMRF-Green: A dynamic multi-regional applied general equilibrium model of the Australian economy, based on the MMR and MONASH models*, Prepared for the Regional GE Modelling Course, 25-29 November.http://monash.edu.au/policy/elecpapr/g-140.htm.

Barrett, G. (2004), "Water conservation: The role of price and regulation in residential water consumption", Economic Papers, 23(3): 271-85, September.

Council of Australian Governments (COAG) (1994), "Report of the Working Group on Water Resources Policy: Communiqué." February, Canberra.

Council of Australian Governments (COAG) (2004a), Intergovernmental Agreement, Communiqué, June, Canberra.

Council of Australian Governments (COAG) (2004b), Intergovernmental Agreement on addressing water over-allocation and achieving environmental objectives in the Murray-Darling Basin, between the Commonwealth of Australia and the Governments of New South Wales, Victoria, South Australia and the Australian Capital Territory, June, Canberra.

Dixon P. and Rimmer, M. (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy: A Practical Guide and Documentation of MONASH,* Contributions to Economic Analysis 256, North-Holland Publishing Company, Amsterdam.

Dixon, P., Parmenter, B., Sutton, J. and D. Vincent (1982), *ORANI: A Multisectoral Model of the Australian Economy,* Contributions to Economic Analysis 142, North-Holland Publishing Company, Amsterdam.

Dixon, P., Schreider, S. and Wittwer, G. (2005), "Combining engineering-based water models with a CGE model", chapter 2 in *Quantitative Tools for Microeconomic Policy Analysis*, Productivity Commission Conference Proceedings, 17-18 November 2004, Canberra.

Giesecke, J. (2004), "The extent and consequences of recent structural changes in the Australian economy, 1997-2002: results from historical/decomposition simulations with

MONASH", General Working paper no. G-151, Centre of Policy Studies, Monash University. *http://www.monash.edu.au/policy/ftp/workpapr/g-151.pdf*

Horridge, M, Madden, J. and Wittwer, G. (2005), "Using a highly disaggregated multi-regional single-country model to analyse the impacts of the 2002-03 drought on Australia", *Journal of Policy Modelling* 27(3):285-308, May.

Maddock, R. and McLean, I. (1987), "The Australian economy in the very long run", chapter 1 in *The Australian economy in the long run,* Cambridge University Press: Cambridge.

Mullen, J. (2002), Farm management in the 21st Century, Agribusiness Review 10: Paper 5.

Pearson, K., (1988), "Automating the Computation of Solutions of large Economic Models", *Economic Modelling*, 7(4): 385-395, October.

Productivity Commission (2005), Review of National Competition Policy Reforms. Report No. 33, Canberra.

Productivity Commission (2005), Trends in Australian Agriculture, Research Paper, Canberra.

Radcliffe, J. (2004), Water recycling in Australia. Australian Academy of Technological Sciences and Engineering, Melbourne.

Sydney Water (2005), Planning for Desalination. Sydney Water, Sydney. http://www.sydneywater.com.au/EnsuringTheFuture/Desalination/DesalinationPlanning.cfm

Water Corporation (2003), Securing our water future: A State water strategy for Western Australia, Perth.

Water Services Association of Australia (WSAA) (2005) Testing the water: Urban water in our growing cities: The risks, challenges, innovation and planning. WSAA Position Paper No. 01.

Wittwer, G. (2003), "An outline of TERM and modifications to include water usage in the Murray-Darling Basin", Report prepared for Productivity Commission, Department of Treasury and Finance, Victoria, Department of Primary Industries, Victoria and CSIRO, http://monash.edu.au/policy/archivep.htm TPGW0050/.

Appendix One - Details of TERM-Water

What is TERM?

TERM (**T**he **E**normous **R**egional **M**odel) paper is a unique multi-regional computable general equilibrium (CGE) model devised by Mark Horridge at the Centre of Policy Studies (CoPS). Its first major application was for a study of the 2002-03 drought (Adams *et al.* 2002a, 2000b; Horridge *et al.* 2005).

CoPS has been at the forefront of CGE model development since the late 1970s, when Peter Dixon led the development of the ORANI model (Dixon *et al.* 1982). Through the use of linearised equations and multi-step solution algorithms, Dixon's team was able to solve models accurately with over 100 sectors in the late 1970s, when computational resources were much scarcer than they are now. Early versions of ORANI included regional detail: national results for quantity variables were broken down by region using techniques borrowed from input-output analysis. From 8 to 100 regions could easily be distinguished. Region-specific demand shocks could be simulated, but, since price variables were not given a regional dimension, there was little scope for region-specific supply shocks. On the other hand, the "top-down" approach did not need much extra data or computer power.

The GEMPACK software developed by Ken Pearson (1988) and colleagues in the mid-1980s simplified the specification of new models, while cheaper, more powerful computers allowed the development of computer-intensive multi-regional and dynamic models. On the demand side, these advances have been driven by the appetite of policy-makers for sectoral, temporal, and in the present study, water usage in analyses of the effects of policy or external shocks.

A second generation of regional CGE models adapted ORANI by adding two regional subscripts (source and destination) to most variables and equations. In this "bottom-up" type of multi-regional CGE model, national results are driven by (i.e. are additions of) regional results. The best-known example of this type of regional model is the Monash Multiregional Forecasting model, MMRF (Adams *et al.* 2002a, 2002b). TERM represents a quantum leap on previous multi-regional models, including the Monash Multiregional Forecasting Model devised at CoPS in the 1990s.

In summary, TERM has the following features:

- It can solve with more regions than was previously computationally possible, because it runs with various commodity sourcing assumptions that minimize computer memory requirements.
- TERM has a variable aggregation facility from the master database so that the dimensions of the project-specific database reflect the focus of the particular project.
- The model includes details of port of entry/exit of merchandise, and allows margins services (i.e., retail and wholesale trade, various transport modes) to be sourced from regions other than of domestic origin or destination of a regionally traded commodity. For example, a trucking company based in Canberra can move goods between Melbourne and Sydney, a detail not available in earlier multi-regional CGE models.

A number of versions of TERM now exist:

- The present study uses a version of TERM that includes water accounts, covering all industries and households in the database of the present application.
- A recursive dynamic variable aggregation of TERM has been developed by Glyn Wittwer at the Centre of Policy Studies.
- Versions of TERM have been developed for Indonesia, Japan, Korea and Brazil by Mark Horridge working with various international colleagues and Ph.D. candidates. China is the next country on the list.

How the master database of TERM was constructed

The ABS does not publish regional input-output tables. In addition, regional trade matrices of data are not available for Australia. However, ABS collects regional statistics that make it possible to estimate regional input-output tables at the statistical division level. Mark Horridge of the Centre of Policy Studies has devised a strategy used in a series of computing programs for TERM to estimate its database from very limited regional data. The key features of this strategy are:

a) The process starts with a national input-output table and certain regional data. The *minimum* requirements for regional data are very modest: the distribution between regions of industry outputs and of final demand aggregates. Additional regional detail, such as region-specific technologies or consumption preferences may be added selectively, when available. In TERM, ABS household expenditure survey data are used to distinguish the consumption patterns of different states, and to distinguish between capital city and rest of state expenditure patterns. For example, housing accounts for a larger share of household consumption expenditure in Sydney than other regions.

b) The database is constructed at the highest possible level of detail: 167 sectors and 58 regions. Aggregation (for computational tractability) takes place at the end of the process, not at the beginning. Perhaps surprisingly, the high level of dis-aggregation is often helpful in estimating missing data. When aggregated, the model database displays a richness of structure that belies the simple mechanical rules that were used to construct its disaggregated parent. For example, even though we normally assume that a given disaggregated sector has the same input-output coefficients wherever it is located, aggregated sectors display regional differences in technology. Thus, sectoral detail partly compensates for missing regional data.

The national input-output database

The TERM data process starts from the 1997 Australian input-output tables, distinguishing 107 sectors. Our first step was to convert these tables to the file format of ORANI-G, a standard single-country CGE model. Next, working at the national level, we expanded the 107 sectors to 167. In choosing to split sectors, we hoped to avoid quirks of classification that have caused problems in the past (such as the lumping together of ginned cotton and services to agriculture) and also to split up sectors which showed regional differences in composition. For example, we split up electricity generation according to the fuel used (which differs among Australian regions) and added considerable agricultural detail. In particular, “other agriculture” has been split to represent the major irrigation sectors of the economy.

The main source for the sectoral split was unpublished Australian Bureau of Statistics (ABS) commodity cards data. Such data provide a split of sales for approximately 1,000 commodities to 107 industries, plus final users.

Estimates of the regional distribution of output and final demands

The next step was to obtain, for each industry and final demander, an estimate of each statistical division’s share of national activity. To develop a full input-output table for each region, we required estimates of industry shares (i.e. each region’s share of national activity for a given industry), industry investment shares, household expenditure shares, international export and import shares, and government consumption shares.

The main data sources for the industry split were:

- unpublished AgStats data from ABS, which details agricultural quantities and values at the statistical division level;
- employment data by industry by statistical division prepared by our colleague Tony Meagher from ABS census data and surveys;

- published ABS manufacturing census data (state level); and
- state yearbooks (for mining, ABS 1998; ABS 1999 and, for grapes and wine, ABS 2002a).

Published ABS data (Tables 4 and 5, ABS 2000) provide sufficient commodity dis-aggregation for the task of splitting regional consumption aggregates into commodity shares. Such data also provide a split between capital city regions and other regions within each state.

In compiling international trade data by region, we first gathered trade data by port of exit or entry. For this task, we used both unpublished ABS trade data available for each state and territory plus the annual reports of various ports authorities. Queensland Transport's annual downloadable publication *Trade Statistics for Queensland Ports* gives enough data to estimate exports by port of exit with reasonable accuracy for that state. For other states, port activity is less complex; most manufacturing trade passes through capital city ports, and regional ports specialize in mineral and grain shipments.

State accounts data provide aggregated Commonwealth and state government spending in each region (ABS 2002b). Employment numbers by statistical division for government administration and defence provide a useful split for these large public expenditure items. For other commodities, population shares by statistical division were used to calculate the distribution of Commonwealth and state government spending across regions.

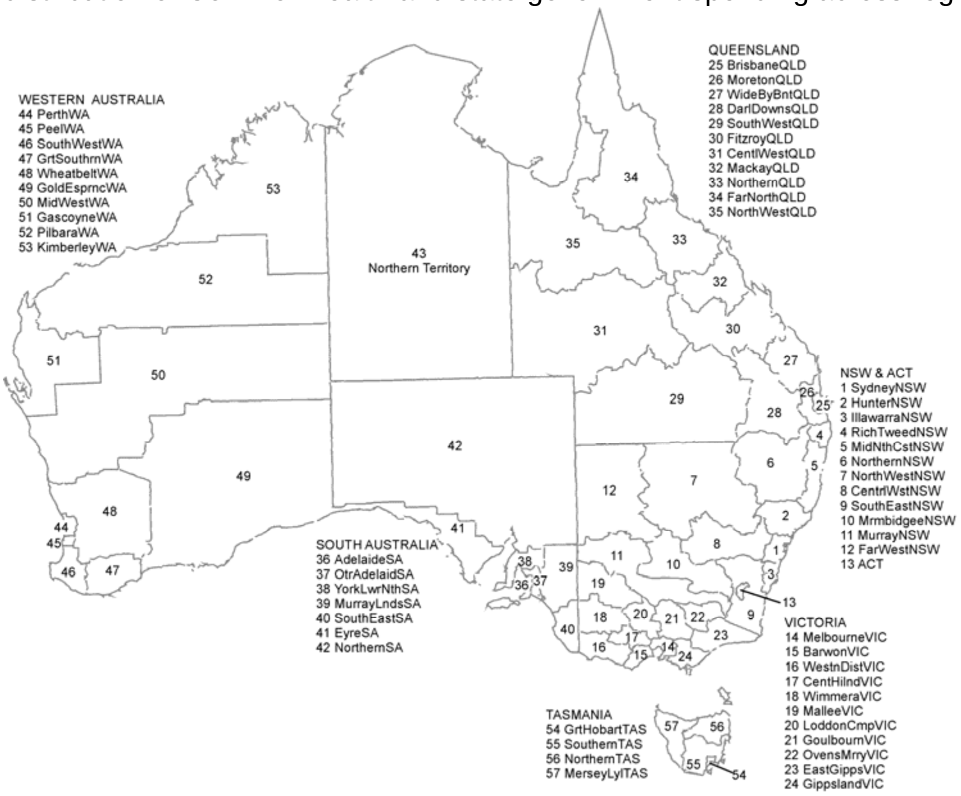

Figure A1.1: Statistical divisions in Australia

The inter-regional TRADE matrix

The next stage was to construct the TRADE matrix of inter-regional sources and destinations. For each commodity either domestic or imported, TRADE contains a 58x58 sub-matrix, where rows correspond to region of origin and columns correspond to region of use. Diagonal elements show production which is locally consumed. We already know both the row totals (supply by commodity and region) and the column totals (demand by commodity and region) of these sub-matrices. For Australia, hardly any detailed data on inter-regional state trade are available. We used the gravity formula (trade volumes follow an inverse power of distance) to construct trade matrices consistent with pre-determined row and column totals.

In defence of this procedure, two points should be noted:

- Wherever production (or, more rarely, consumption) of a particular commodity is concentrated in one or a few regions, the gravity hypothesis is called upon to do very little work. Because our sectoral classification was so detailed, this situation occurred frequently.
- Outside of the state capitals, most Australian regions are rural, importing services and manufactured goods from the capital cities, and exporting primary products through a nearby port. For a given rural region, one big city is nearly always much closer than any others, and the port of exit for primary products is also well defined. These facts of Australian geography again reduce the weight borne by the gravity hypothesis.

All these estimates are made with the fully-disaggregated database. In many cases, zero trade flows can be known *a priori*. For example, ABS data indicate that rice is grown in only four of the 58 statistical divisions. At a maximum dis-aggregation, the load born by gravity assumptions is minimized.

Aggregation

Even though TERM is computationally efficient, it would be slow to solve if a full 167-sector, 58-region database were used. The next stage in the data procedure is to aggregate the data to a more manageable size. The aggregation choice is application-specific. In urban-rural water trading scenarios, we wish to concentrate on irrigation sectors and other major water users, as discussed under the next sub-heading. The sectoral aggregation was most detailed in the agricultural and agriculture-related sectors, where a number of sectors were more finely disaggregated than in the published ABS input-output tables, while manufacturing and service industries were grouped broadly. In the regional dimension, the aggregation concentrates on the Murray-Darling Basin and mainland capital cities. Brisbane and Moreton (Gold Coast) were grouped together in one region, because their projected population growth rates are relatively similar. However, the Darling Downs and Wide Bay-Burnett statistical divisions adjacent to the Brisbane-Gold Coast region were aggregated to a separate region from the rest of Queensland. This is because we wished to differentiate water used by sugar cane growers in northern Queensland from that used by farmers in the Darling Downs/Wide Bay-Burnett region. Water from northern Queensland is not readily tradable with the urban south-Eastern corner of Queensland, while that in regions adjacent to the urban corner potentially is tradable with the urban region.

Adding water accounts to TERM

The ABS (catalogue no. 4610.0) now devises water accounts by sector and region. The first set of accounts adapted for use in TERM applied to 1996-97 and earlier years. Since then, a set of accounts have been devised for 2000-01. One significant improvement in the accounts for 2000-01 is that they contain estimates of water usage by the dairy industry in each state. To add water accounts to TERM, we first must update TERM from 1996-97 to 2000-01. This is done by first running a project-specific aggregation of TERM in dynamic mode, taking on board macroeconomic changes, taste and technology changes by sector and observed export volume change. Indeed, similar shocks ascribed to the dynamic version of the model are subsequently used in our simulation to project the water accounts version of TERM from 2001 to 2032.

The next task is to add water accounts to the updated input-output structure of the TERM database. We ascribe water usage to the regions of our specific aggregation, based on state level water usages. That is, each region’s water used will be equal to its share of state activity for that sector multiplied by state level sectoral water usage. From the outset, it is worth noting the limitations of this exercise:

- We do not distinguish crops & (non-dairy) livestock water usage in the Murray-Darling basin (i.e., irrigated) from usage in other regions, which are not irrigated. Therefore, the regional estimates of water usage by sector could change had we access to data on water usage at a finer level of regional dis-aggregation.

- We have no data distinguishing water usage in broad-acre cropping from other activities in the crops & livestock sector.

In noting these limitations, CoPS is aiming to improve the data concerning rural water usage. This is an ongoing process. Among the many issues of projecting water demands to 2032, updated water accounts in the future may help us to track changes in unit water requirements by users. The ABS has warned that the editions of the water accounts produced so far are not comparable for users other than households, as the conceptual basis on which these accounts are based is evolving.

The theory of water usage in TERM

The theory of TERM with water accounts is elaborated in Wittwer (2003). The theory applied in this application is that water usage by industry is proportional to industry output, net of water-saving technological change. Household demands for water are treated in the same way as demands for other commodities. That is, the household demand theory is based on a linear expenditure system. Water's own-price elasticity of demand is around -0.5, while the expenditure elasticity is around 1.0. The expenditure elasticity implies that for each 1.0% increase in household income at constant prices, the volume of water demanded by households increases by 1%. Hence, demand for water grows as household income grows, placing upward price on urban water prices.

Future water modelling work with TERM

There are several directions in which future water modelling could proceed. CSIRO's support and involvement is integral to this task.

- Introducing a theory of hydrology to the model. This is explained in Dixon et al. (2005).
- Moving to recursive dynamics. At present, we assume the simplest form of dynamics in moving from 2001 to 2032, by using the smooth growth assumption. Recursive dynamics would include inter-temporal linkages between capital stocks, investment and depreciation. In the context of water, hydrological detail would provide inter-temporal links between regional rainfall, annual water usage, environmental flows and reservoir stocks.

More elaborate links between water flows and environment outcomes may form part of the research program further down the track.

Those interested in using the model can download it from http://monash.edu.au/policy/archivep.htm.

Appendix Two - Regions and Sectors

Table A2.1 Definitions of regions used in the model

Region	ABS Statistical Divisions (Numbers refer to the regions indicated in Figure A2 below
Sydney	1
Murrumbidgee NSW	10
Murray NSW	11
Western NSW	12 + 7
Rest NSW	2 + 3 + 4 + 5 + 6 + 8 + 9
Melbourne	14
Mallee VIC	19
Rest Irrig VIC	20 + 21 + 22
Rest VIC	15 + 16 + 17 + 18 + 23 + 24
Brisbane-Moreton	25 + 26
Burnett-Darling QLD	27 + 28
Rest QLD	29 + 30 + 31 + 32 + 33 + 34 + 35
Adelaide	36
Rest SA	37 + 38 + 39 + 40 + 41 + 42
Perth	44
Rest WA	45 + 46 + 47 + 48 + 49 + 50 + 51 + 52 + 53
Tas & NT	54 + 55 + 56 + 57 + 43
ACT	13

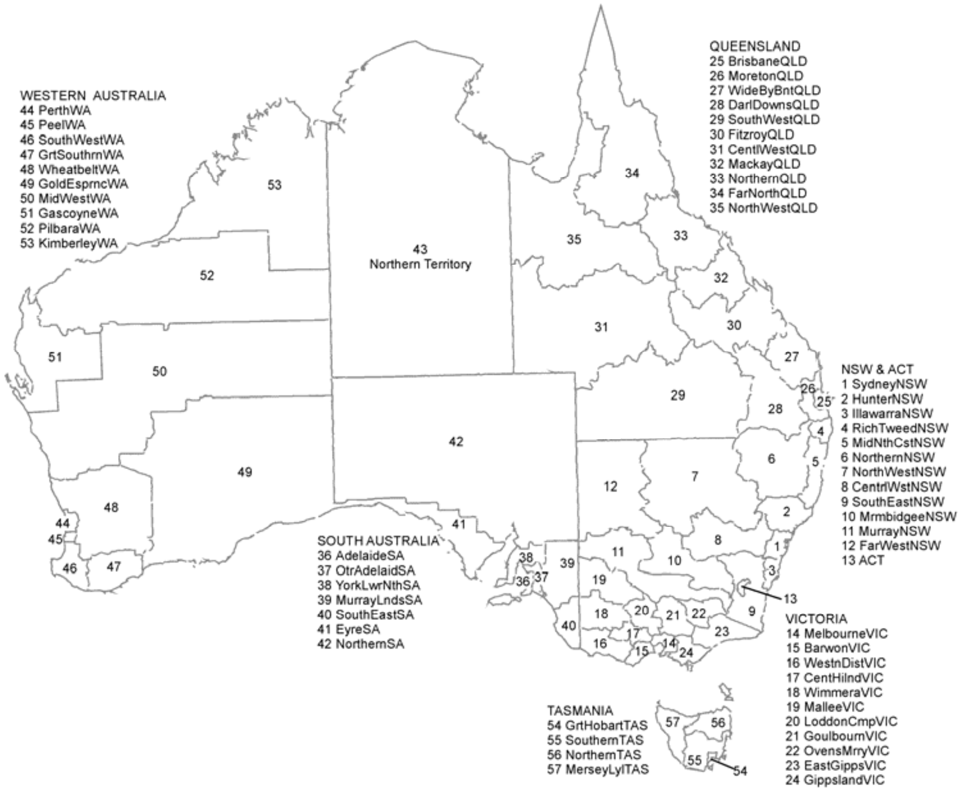

Figure A2 Location of ABS Statistical Divisions in Australia

Table A2.2 Definitions of sectors used in the model

Sector	Definition
Crops & Livestock	All Crops including wheat and all livestock except dairy cattle
Dairy	All dairy cattle
Cotton	All cotton production but not cotton processing
Rice	All rice production but not rice processing
Household	All households
Other	All other industries including manufacturing and processing