



Chapter 6

The future of water

**From
Future Dilemmas: Options to 2050 for
Australia's population, technology,
resources and environment**



Report to the Department of
Immigration and Multicultural
and Indigenous Affairs

By CSIRO Sustainable
Ecosystems

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October 2002

Working paper series 02/01

CSIRO Resource Futures Working Paper 02/01
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Published by
CSIRO Sustainable Ecosystems
GPO Box 284
CANBERRA ACT 2601
Phone: +61-2-6242-1600
Fax: +61-2-6242-1555
This report is available online at
<http://www.cse.csiro.au/futuredilemmas>

ISBN 0 95808453 X

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Chapter 6

The future of water

ABSTRACT

Water, like energy, is essential to the nation's economic productivity, its lifestyle characteristics and the maintenance of biodiversity values and ecosystem services. In economic terms however, its undervaluation has resulted in a number of unintended environmental consequences in southern Australia with irrigation salinity and high water tables in irrigation areas, as well as degraded river systems. By 2050 the water requirement for urban Australia could vary from 5,000 to 8,000 gegalitres per year depending on the population scenario. By contrast, the base case scenario simulated a total managed water usage expanding from a contemporary level of 24,000 gegalitres per year to more than 40,000 gegalitres per year by 2050. This is due to a major expansion of irrigated agriculture in northern Australia as constraints on the availability and quality of water are experienced in the south. This expansion is not without its risks, and it is possible that the southern experience could be repeated in the north. The water requirements for industry, mining and domestic use represent about 20% of the total and while there is a population effect due to the scenarios, it could be met by transfer of water from agriculture. It is assumed that the integrity of key urban water catchment areas will be improved and that with appropriate regulation and technology innovations, high quality water supplies will be maintained for domestic use. The Australian water system appears to have many similarities to water systems in developing countries and it is critical that the transition is made to equitable and just water allocation between competing uses. In international trade terms it could be to Australia's advantage to quantify the embodied water content of the goods and services it imports and exports. Australia exports an estimated 4,000 gegalitres of embodied water more than it imports. This is about the same amount used each year by urban Australia. If we receive relatively poor trade prices for these products, then the nation accepts a double loss as funds are sought to repair the integrity of its inland river systems. It is possible that technical and management innovations could reduce the overall requirements from the managed water resource, and allow the delivery of similar water services for less water.

AUSTRALIA AND WATER

Water, like energy, clean air and soil organic matter, makes an essential contribution to the maintenance of economic productivity, social well being and lifestyle and the maintenance of nature and ecosystem services. There is a very close connection between water and energy. We use energy to help clean and transport the fresh water we need, and we use water to help us produce the energy we need (Gleick, 1994, 2001). Services provided by the water system remain under-valued with charges being made on the repairs and maintenance of built water infrastructure, rather than on the repairs and maintenance of the whole water system including the catchments, rivers, wetlands and estuaries.

This chapter reports on the amount of water required for the maintenance of national productivity as defined by the assumptions in the base case scenario. In particular it investigates:

- Analytical approaches that integrate the physical aspects of the water system with economic and other measures including process analysis, water accounting, embodied water analysis and water vapour flows;
- The water required by manufacturing, mining and urban areas to 2050;
- The water required by agriculture including a major expansion in northern Australia;

- Issues that relate to trade in 'virtual water', the water embodied in goods and services that countries import and export;
- The particular population dependent issues for water in Australia, and how they link to the tertiary population issues of trade.

WATER METHODOLOGIES

Process analysis

The process analysis approach used in the modelling framework ties the water requirements to the size, type and location of infrastructure in the case of houses and commercial buildings and to a wide number of specific manufacturing processes, whether they are basic materials such as paper and textiles, or more elaborately transformed items of a manufactured nature (Table 6.1). As houses are required, manufactured items made or agricultural crops grown, the water requirements are totalled and compared to the water available in that location. If there is a tension between requirement and available supply in a region then decisions must be made to resolve it by adjusting the requirement or shifting the activity to another water region. This process has been undertaken in the simulations reported in this chapter, and a major expansion of irrigated agriculture made in northern Australia.

Table 6.1. Examples of water applied in different processes in the modelling framework.

Good, process or service in model	Water required and units of measure	Comments and caveats
Domestic housing	4,700 litres per square metre per year	Varies throughout Australia with a range of 3,000 to 10,000 litres per square metre
Commercial buildings	2,700 litres per square metre per year	Varies throughout Australia with a range of 1,600 to 4,700 litres per square metre
Manufacture of office machines and space conditioning	19,600 litres per tonne produced	General figures applied across the full industrial cycle to give correct outputs for industrial sectors
Manufacture of motor cars and heavy machinery	47,600 litres per tonne produced	General figures applied across the full industrial cycle to give correct outputs for industrial sectors
Manufacture of paper	23,400 litres per tonne produced	New processes and water recycling will reduce this value
Manufacture of textiles	13,100 litres per tonne produced	New processes and water recycling will reduce this value
Dairy cows	1 megalitre (10 ⁶ L) per dairy cow	Data represent the irrigation requirement of pasture but are applied to cow numbers over whole herd and milk cycle
Fruit and vegetables	3-6 megalitres (10 ⁶ L) per hectare	Varies depending on location and nature of the crop

Water accounting

The water accounts maintained by national statistical agencies are central to understanding where water is used, for what purpose, and to show the developing trends. A simplified account is

portrayed in Table 6.2, which shows that Australia's water usage increased by 7,400 gigalitres per year or 14 Sydney Harbours over the 12-year period from 1985 to 1997. Most of the change was in agriculture followed by a combination of all manufacturing and commercial interests. The latest set of water accounts (Australian Bureau of Statistics 2000-a) breaks the water usage down to 38 economic sectors, displayed by state for the years 1994-1997. It also includes a number of summary indicators that compare economic productivity and labour generation per unit of water used. These data are central to the modelling work reported in this chapter as well as the water embodiment analysis reported in the next section.

Table 6.2. Water account for managed water resource in 1970, 1985 and 1997.

Aggregate sector	Water use 1965-1970 (Department of Minerals and Energy 1975) (GL/year)	Water use 1977 (Newton et al., 2001) (GL/year)	Water use 1985 (Department of Primary Industries and Energy 1987) (GL/year)	Water use 1997 (Australian Bureau of Statistics 2000) (GL/year)	Water use 1996/97 (National Land and Water Resources Audit; Commonwealth of Australia 2001) (GL/year)
Agriculture	4,688	14,596	10,200	15,520	17,935
Domestic	1,330	1,780	1,790	1,828	4,754
Industry, commercial and mining	n/a	890	1,200	3,067	
Other	n/a	534	100	1,770	1,369
Total	6,018	17,800	14,600	22,185	24,058

Water embodiment

The concept of water embodiment of economic output parallels the use of the concept used for energy analysis applications in Chapter 5. The analytical procedure combines the economic input-output tables with the detailed water accounts provided by the *Water Account for Australia* (Australian Bureau of Statistics, 2000). The results are presented in Tables 6.3 to 6.6 for selected sub-sectors of the agricultural, mining, manufacturing and service sectors along with the energy and labour embodiments for those sectors. The selected data for the agricultural sector shows a wide range, with more than 7,000 litres required per dollar of output for rice compared to 245 litres for wheat and other grains (Table 6.3). Sugar cane, milk and seed cotton are roughly comparable in the range of 1,220 to 1,600 litres per dollar of output. These data represent only the input of the managed water resource and do not include the green water or soil water that comes from rainfall. The data are not intended to portray a water theory of value but, with labour and energy requirements being roughly equivalent, they can help indicate priorities for water policy development.

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Table 6.3. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected agricultural sectors (After Lenzen 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10 ⁶) of primary energy per dollar of output	Minutes of required labour per dollar of output
Rice in the husk	7,458	11.6	1.8
Wheat and grains	245	11.6	1.8
Beef cattle	812	11.6	1.9
Dairy cattle and whole milk	1,470	14.3	1.8
Sugar cane	1,239	15.3	1.9
Seed cotton	1,600	15.3	1.9
Vegetable and fruit growing	379	15.3	1.9

In the case of mining, the selected industries have roughly similar requirements for energy and labour, but bauxite uses more water than the others (Table 6.4). Water is integral to the bauxite process and its preparation for conversion to alumina. Even small values for some minerals may be critical since large tonnages of ore are processed. In addition, many ore bodies are in water poor areas. Therefore water may have to be piped over long distances or, if obtained locally, it may represent a large proportion of the yearly water flow.

Table 6.4. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected mining sectors (After Lenzen, 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10 ⁶) of primary energy per dollar of output	Minutes of required labour per dollar of output
Black coal	22	16.8	1.4
Crude oil	13	16.8	1.4
Iron ores	23	15.2	1.4
Bauxite	366	15.9	1.7
Gold and lead	15	15.9	1.7

Greater differences in water and energy requirements emerge between the manufacturing sectors (Table 6.5). Both pulp/paper and aluminium require 50 litres of water per dollar of output generated while basic chemicals and aluminium require 40-50 megajoules of primary energy per dollar of output. Compared to the mining sector, the manufacturing sector has slightly higher requirements for labour and generally uses more water and energy.

Table 6.5. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected industrial sectors (After Lenzen, 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10 ⁶) of primary energy per dollar of output	Minutes of required labour per dollar of output
Pulp, paper and paperboard	51	30.2	1.9
Basic chemicals	36	52.7	1.9
Pharmaceutical goods, insecticides and agricultural chemicals	24	10.2	2.0
Cement lime concrete and mortar	15	26.2	1.8
Alumina, Aluminium alloys and aluminium recovery	52	41.1	1.6

The services sector generally requires less water and energy and slightly more labour. The exceptions are accommodation and restaurants, and community services which have higher water and energy requirements on par with the average of the whole economy. However, both these sectors also have a higher labour requirement, which might compensate in social terms.

Table 6.6. Embodiment of water, primary energy and labour in each 1994-95 Australian dollar for the selected service sectors (After Lenzen, 1999; Lenzen and Foran, 2001).

Sector	Litres of water per dollar of output	Megajoules (Joules*10 ⁶) of primary energy per dollar of output	Minutes of required labour per dollar of output
Accommodation, cafes and restaurants	75	9.6	2.4
Banking	9	4.5	1.8
Education	7	3.7	2.5
Health	7	3.2	2.1
Community services	27	12.4	3.2

From the water embodiment data, a detailed picture of the extent water (and labour and energy) are required to help in the production of economic output begins to emerge. In a relative sense, the services sector has lower requirements and the mining sector is equivalent to the average of the whole economy. The manufacturing sector has some processes that require more water requirements such as aluminium and pulp/paper but these are relatively low compared to the high water requirements of the agricultural sector. Depending on one's values, these data can be interpreted in a number of ways. Food is central to the maintenance and enjoyment of life, so it could be argued that

the water requirements of agriculture are justified. If the food was imported from elsewhere, then water flow from another country would be required and Australia would be the cause rather than the recipient of the tertiary population influence of trade. Alternatively it could be argued that consumers, both domestic and in other countries, pay the full cost of the water services embodied in each kilogram or dollar's worth of food. Developing this argument, both domestically and in export trade terms, and then using it to make strategic decisions, is a key foundation to understanding any transition towards the concept of a more resilient national water system.

Water vapour flows

As the emergy concept is used to integrate the full life cycle of energy and environmental services (see Chapter 5 for a discussion of emergy), so does the concept of water vapour flows attempt a similar integration for the continental water cycle of Australia (Rockstrom et al., 1999; Gordon et al., 2000). The concept links the ideas of blue water (rivers, dams and underground aquifers), green water (water in the root zone available for plant growth) and white water (water transpired by soil and plant surfaces plus some evaporation from water surfaces). It was developed by Falkenmark (1997, 1999) and others in order to focus global and continental water policy on areas other than blue water flows alone. In these terms, blue water conceptually represents the tip of the iceberg. It may be worth concentrating on green and white water as small changes in those areas may reap bigger rewards for the whole water sector.

Table 6.7. Components of water vapour flow and liquid water flow in gegalitres per year (10^9 litres) in pre-European and contemporary times.

Category of flow	Amount of flow in gegalitres per year	Comments
Total precipitation	3,314,000 to 3,390,000	Range of published estimates that obviously vary significantly from year to year
Total water vapour flow in 1780 (pre-European settlement)	3,436,000	Estimate is based on known transpiration rates of vegetation applied to the continental map of pre-European vegetation distribution
Total water vapour flow in 1980 (post development)	3,097,000	Decrease is due to removal of perennial deep-rooted vegetation and replacement by annual cropping systems and grass-legume pastures
Difference between 1780 and 1980	339,000	Difficult to determine how the (now) liquid water flows are apportioned between systems but some would go to stream flow, some would re-fill groundwater aquifers and the rest would contribute to the emerging dryland salinity problem.
Continental runoff	362,000 to 397,000	Range of estimates in published literature
Total managed water use in 1995-96	22,000	Could expand to 40,000 gegalitres by 2050 under base case assumptions
Crop and animal agriculture use on 1995-96	15,500	Could expand to 32,000 gegalitres by 2050 under base case assumptions

The net outcome of land clearing in the wheat sheep zone and higher rainfall pasture zone, after 200 years, is a decrease in yearly flows of Australian white water (evapo-transpiration) of 339,000 gigalitres per year (Table 6.7). This becomes part of the green water (soil water) but it is unclear how it is then partitioned between the different parts of the hydrological system at a continental level. Some may be added to surface runoff, some may replenish underground aquifers and a significant portion contributes to a slow-moving underground flow that is the root cause of dryland salinity on Australian farms. This decrease in continental evapo-transpiration represents the volume contained in 600 Sydney Harbours and is a yearly event (or non-event). It is 15 times the volume of the managed water flows of 22,000 gigalitres per year, and is approximately equal to the entire yearly runoff from the continent.

Capturing this unintended water flow could provide productive returns for crop and animal agriculture as well as avoid the knock-on effects of dryland salinity and the land loss that will result with the continuance of marginal approaches. Chapter 4 presents some options for exploring these issues. The challenge presented by the water vapour flows approach is to capture a green water flow that is 15 times the size of the current managed blue water flow. If this is possible over the next century, it might be possible that additional blue water resources are not required and that additional blue water could be returned to the environment.

ISSUES FROM THE DIMA WORKSHOP SERIES

In preparation for the design and testing of the population scenarios with ASFF, a workshop series was conducted in 1999 (Conroy et al., 2000), to critically review the structure of the analytical framework and the implementation of the scenarios. Six important issues for the scenario implementation responses in this chapter are described below.

- The timescale and partitioning of flows and stocks were examined particularly with reference to Australia's highly variable rainfall regime, and the passage of surface water to soil water and aquifer water. The water calculator in ASFF does not yet bring together the entire stock and flow of Australia's water resources at a continental level. One simplification is to treat the surface flows and soil water both as flows, but to treat the aquifers as stocks, as these are the resources at risk of depletion. The time for a particular unit of water to pass through a system, is in terms of decades for aquifers, three months for soil water and five years for large water supply dams. In implementing the population scenarios, these issues were dealt with in two ways. Firstly, the water requirements for cities and agriculture were checked against the yearly flow rates for the river basins that surrounded them. In the case of agriculture, the new development was located in northern Australia where large underdeveloped water resources were still available. Secondly, most effort was devoted to ensuring that water requirements for key physical processes adequately reflected regional realities and expert opinion about future technological trends. The enumeration and balancing of the entire Australian water system was deferred to another round of model development.
- The need to decrease managed water use and increase environmental flows was an important topic of discussion at workshops. One suggestion was to classify the environment as a user in its own right (equivalent to mining or industry) and to allocate water on the specific requirements for each river basin. The scenarios do not take account of the environmental requirement for water flows. In real life, the environmental flows for, e.g. bird and fish breeding are needed at a specific time of year, temperature and so on, that lie outside the scope and timestep of the modelling approach. Nevertheless, all water requirements were checked to ensure that over allocation of surface water resources did not occur. The northern

Australian development represents a partial approach to the reconciliation of increasing and competing demands.

- Workshop participants regarded the effect of global climate change on Australia's water resources as an important issue. The recent release of updated climate change scenarios for Australia (CSIRO, 2001-a) reinforces the outlook for rainfall declines of 20% in the south-west corner of Western Australia by 2030 and up to 60% by 2070. The outlook for northern Australia, by contrast, is for increasing rainfall. The implications of climate change are acknowledged in the discussion of population scenarios but not actively included as part of the analysis. The sub-scenarios developed in this chapter show the likely water requirement when the same goods and services are delivered for 30% less water, which is technically feasible in most cases. An increased water requirement, due to increased temperature (when rainfall might also decline) is therefore possible, up to 30%. The view of the industry is that climate change is important, but less so (perhaps a longer timeframe) than the challenge of infrastructure renewal and augmentation facing both urban and agricultural water sectors (Dunlop and Foran, 2001).
- Water quality rather than quantity is the key water issue in Australia and should be the prime focus of futures modelling work. Water quality is not modelled in this version of ASFF but is the subject of detailed modelling exercises for areas such as the Murray Darling Basin. Like environmental flows, water quality is influenced by many local issues that cannot be represented in a nationally scaled model. At a larger scale however, the amount of land used for cropping, the amount of irrigation, and demand from domestic and industrial users, all contribute to the water quality equation. In general, the larger the allocation of managed water use, the higher the pressure that exists on water quality indicators, although treatment technologies have a part to play. Although water quality scenarios are not simulated in this chapter, water quality (through reference to the reports from The National Land and Water Audit) is one of the crosscutting issues of environmental quality presented in Chapter 7.
- The problem of inconsistencies in the water statistics available at local, state and national levels is an ongoing one that is important for the type of modelling being undertaken in this study. Two comprehensive water accounts were available at a national level for 1985 and the period 1994 to 1997, which were used as the grounding for the model. Subsequent revisions of the water account by the National Land and Water Audit (Commonwealth of Australia, 2001) have increased estimates of national water use from 22,000 to 24,000 gegalitres per year due to new information from Queensland irrigation statistics. Another water project working parallel to this population study (Dunlop, 2001) has undertaken a comprehensive analysis of all water uses at a statistical division level which reveals a wide range of anomalies and gaps in information. The population scenarios implemented here concur with the best national information available. In addition, the full process accounting of most water using sectors in the physical economy used in the ASFF approach is proposed as a robust and defensible approach (in addition to survey and reporting) to underpin national physical accounting for all sectors.
- A number of potential land uses such as reforesting large areas of farmland to help deal with dryland salinity, could potentially dry up the overland flows from many catchments that contribute to river flow and thereby water available for irrigation use. The scenarios were implemented on the basis of three premises. The first is that the social and policy drivers behind the widescale reafforestation of farmland would probably be attempting to deal with irrigation salinity as well as dryland salinity, i.e. they would not attempt to solve one issue while ignoring another one that was closely linked to integrative issues such as water quality.

Thus implementation of the scenarios for land and water use must be logical and mutually compatible. The second is that the science underpinning these broadscale issues (eg Vertessy, 2001) provides qualitative input to scenario implementation, which will be used in subsequent redevelopments of the water calculator. Thirdly in an annual sense, much of Australia's irrigation water is derived from limited areas of higher altitude catchments and from non-normal rainfall events. Prior to European settlement, rivers still flooded or ran dry, but today's management infrastructure (weirs and dams) has modified the dynamics and ensured that water is supplied on a year-round basis. In a general sense therefore, the water scenarios have a good basis for ensuring that water is available in spite of radical land-use changes.

SCENARIO ASSUMPTIONS

Since water is critical for most transactions in the physical economy, enough water was allocated to enable the full set of physical transactions detailed in the starting scenario. General assumptions made in the implementation of the scenario are tied to each tonne of ore processed, each square metre of domestic housing built, and each hectare of irrigated land by crop. The important assumptions were as follows:

- That water use, along with energy use, would continue to expand as it underpinned economic growth and development, although this challenges national perceptions about water quality and quantity. Two lines of argument support this scenario driver. Water experts such as Thomas (quoted in Dunlop and Foran, 2001) note that most studies report expanded water use of about 2-3% per annum over the last 30 years, closely linked to economic growth. The recent revision of water use in the National Land and Water Audit (Commonwealth of Australia, 2001) puts the growth rate at nearly 4% over the last decade between water accounts. This represents a doubling time of approximately 20 years. The scenarios conservatively implement the doubling over 50 years, to 2050, taking account of proposals to implement better technologies and institutional arrangements.

The second line of argument is derived from detailed analyses of the water content (embodied water) of personal consumption (Lenzen and Foran, 2001; Lenzen et al., 2002; Figure 6.1). The data relationships presented in the left hand graph show that as personal consumption (expressed in dollars per capita) rises, so does the total water content of that expenditure. For example, the average per capita expenditure of A\$20,000 across nearly 2,000 Sydney households had a water content of 1,000 kilolitres (or one megalitre). Doubling personal consumption to A\$40,000 per capita gave a water content of 1,700 kilolitres (or 1.7 megalitres). Thus, there is a reducing water content as per capita consumption rises, but the data relationship does not suggest any saturation or levelling out until reasonably high consumption levels. These data include direct consumption (showers, clothes washing and gardens) as well as the indirect (food, milk products, beverages, industrial production). It could be argued that as per capita consumption rises, then so too does the sophistication of house fittings (furnishings and swimming pools), the frequency of restaurant meals and the incidence of travel. All these sectors use water, which is allocated back to the consumer through this analytical approach.

Under the current structure and function of the Australian economy, it is anticipated that consumer expenditure will double in real terms over the next 50 years simulated in these population scenarios. Economic modelling over the whole economy, aimed at estimating the interactions between population ageing, national savings policies and household expenditure in the long run (Guest and McDonald, 2001) supports this view. In historic terms, over the period 1950-1996, per capita consumption in constant dollar terms grew at a little more than 3% per annum (Hamilton and Saddler 1997) giving a doubling time of about 24 years. Given both the

future orientated modelling and the historic precedent, a doubling of personal consumption (if not a quadrupling) in real terms is feasible over the next 50 years. A doubling of the water embodied in that consumption through the full life cycle of all products and services is also feasible.

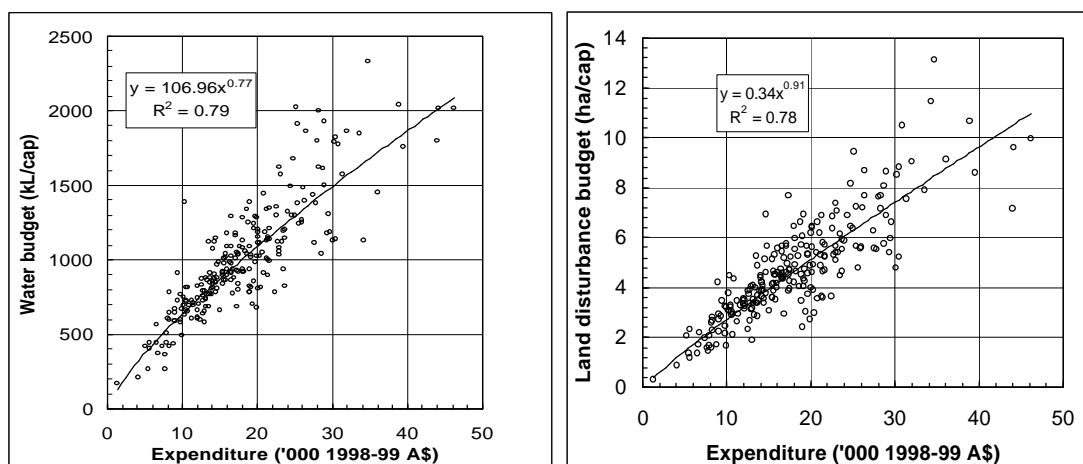


Figure 6.1. The water (gigalitres per capita) and land disturbance (hectares per capita) embodied in personal consumption expenditure in the household expenditure survey for Sydney 1998. (Data from Lenzen and Foran 2001; Lenzen et al., 2002).

- That additional irrigated agriculture would follow available water resources. Irrigated agriculture in northern Australia would need to expand to meet the physical production expectations of the base case scenario. The future commodity expectations were derived from a collaborative study by the CSIRO Resource Futures Program and The Centre for International Economics undertaken for the Land and Water Resources Research and Development Corporation (LWRRDC, 1997).
- The move to northern Australia was the result of a tension resolution exercise within the modelling framework when it was found that future productivity assumptions in the base case to 2050 could not be met by the water resources of established irrigation areas. While the problems of river quality and water salinity were not modelled, they were used as corroborative evidence to support the opening of new areas in the north. All new irrigated requirement for cotton, sugar, rice and some horticulture and vegetables were located in northern Australia from the year 2000.
- That domestic, commercial and general urban requirements would be met by a mixture of re-allocation and pricing, pipelines, inter-basin transfers and recycling technologies over the timescale of the simulation.
- That best practice technologies would allow a 30% reduction in water requirements for the same delivery of product, service or lifestyle and that this would be implemented in a sub-scenario rather than embedded in the base case.

The most recent water resources data contained in *Water and the Australian Economy* (Australian Academy of Technological Sciences and Engineering, 1999) and *Water Account for Australia* (Australian Bureau of Statistics, 2000) were used as the basis for current consumption levels by different sectors. The *1985 Review of Australia's Water Resources and Water Use* (DPIE, 1987) was used to determine water availability in different river catchments and groundwater provinces.

Data on water requirements for crops, industrial and food processing, mineral refining and urban usage were obtained from a wide range of sources, many of them conflicting. The calibration

procedure in the model was used to aggregate and balance a wide range of information and to reflect current estimates contained in the national water account.

SCENARIO RESULTS

Secondary industry

The water requirements of secondary industry increase from 800 gigalitres per year currently to 1,400 gigalitres per year by 2050 (Figure 6.2). The major requirements are for thermal electricity, food processing and non-vehicle manufacture. Differences due to population occur; the 0.67%pa scenario requires 300 gigalitres per year more than the base case in 2050, and the zero scenario uses 50 gigalitres per year less than the base case. Many opportunities exist for reducing the industrial water requirement in all scenarios by treatment and recycling of water, as well as by developing new processes which have a much lower requirement per unit of good or service delivered. By 2050 the water requirement for secondary industry represents 3% of the national total (see Figures 6.8 and 6.9) and while it could equal 25% of the urban requirement at that stage, many adaptations and management options are available to ensure that industry receives its required allocation. An important feature of industrial water, once it has been used, is the route taken for its disposal and its concentration of nutrients, heavy metals, organic chemicals and its waste heat content. It is assumed that continued improvement in industrial processes and a strong regulatory framework implemented by state environmental protection agencies will result in a decreasing environmental load on locations where waste water is discharged. This total water requirement for secondary industry is approximately equal to the mean annual outflow from one river basin such as the Brisbane River in Queensland or the Hunter River in New South Wales.

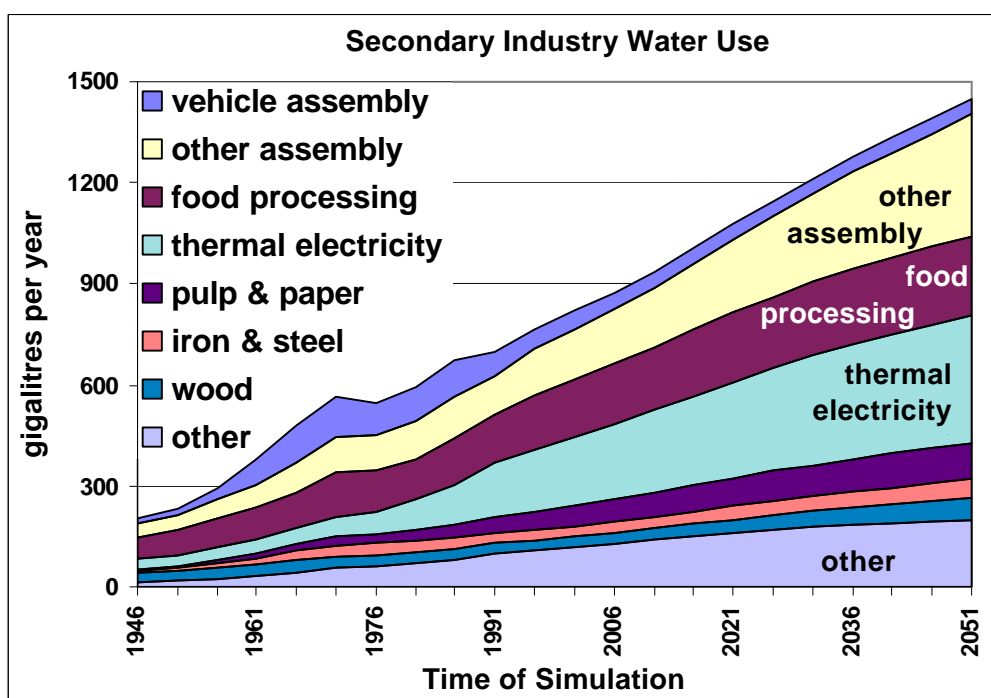


Figure 6.2. Total water required in gigalitres (10^9 litres) per year by secondary industry, in the base case scenario to 2050.

Mining

The water requirement for the mining industry rises from 400 gigalitres per year to nearly 1,000 gigalitres per year by 2050 in line with the assumptions in growth of output from the mining sector (Figure 6.3). Bauxite and coal together account for more than 70% of the industry's water

requirement. In coal and bauxite processing, water is generally used to remove contaminants, dirt and other minerals to improve the quality of the material delivered to the next stage of processing. Reducing the amount of water used in coal and bauxite treatment may be possible but subsequent use of the material may be negatively affected. When dirty coal is used for electricity generation, for example, combustion qualities are reduced and the efficiency of electricity generation declines. The 1998 greenhouse gas report (Australian Greenhouse Office, 2000) noted this effect, where thermal power station efficiencies fell during the 1990s due to the use of cheaper and poorer grades of coal. Similar effects could occur for bauxite mining, particularly in the conversion stage to alumina where poorer quality bauxite ore would require more energy and more chemicals for the treatment process. A number of innovations in metal concentration allow for dry treatment of some ores and increased efficiency of water use in others. Many metal types require one tonne of water (1,000 litres) for every tonne of ore processed and, while water recycling can reduce total amounts, the lack of water in drier regions sometimes restricts the development of ore bodies that would otherwise be attractive. Like manufacturing, mining is simulated to use about 3% of total water requirements by 2050, or the total yearly flow of one medium sized river. The quality of the water after processing is important environmentally, as minor concentrations of metals such as arsenic and cadmium can produce significant biological effects (Minerals Council of Australia, 1999). However, industry in this area strives to maintain best practice and is open to overt and continual scrutiny by environmental protection agencies.

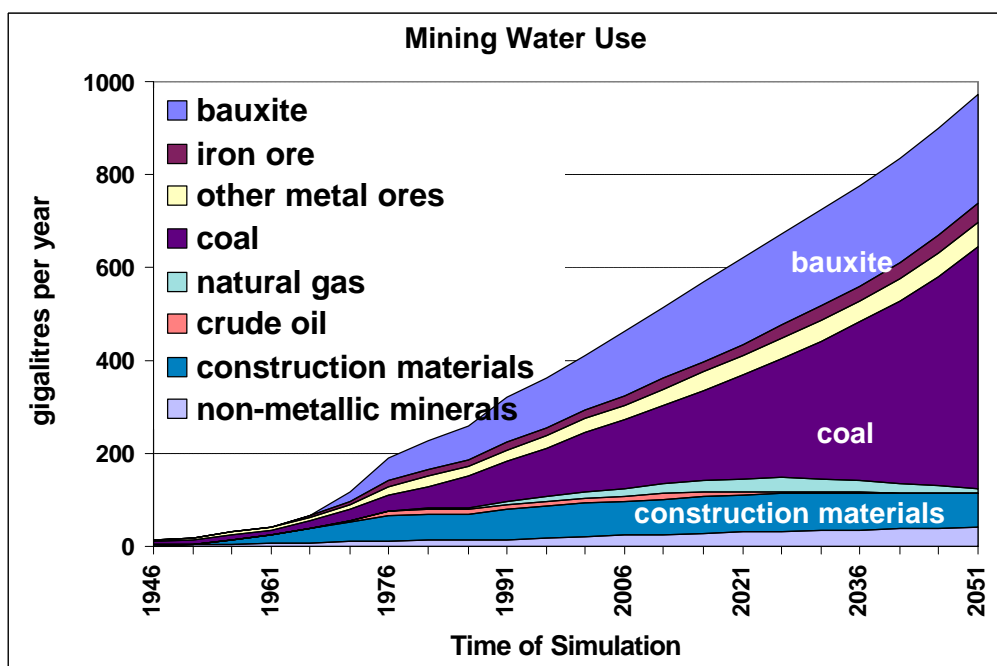


Figure 6.3. Total water required in gigalitres (10^9 litres) per year, in the base case scenario to 2050 for the requirements of mining.

Buildings

For the base case scenario, the total water requirement for buildings by 2050 is nearly 6,000 gigalitres per year compared to a contemporary value of about 3,000 gigalitres per year (Figure 6.4). Nearly 60% of the building water use is for a category entitled 'detached dwellings' which represents the normal Australian suburban home. The water use for dwellings appears to expand at a faster rate than the population for two reasons. (i) The model attaches water use per unit of floor area for all dwellings and this expands considerably on a per dwelling basis as affluence levels are assumed to rise over the next 50 years. While the number of people per household is declining, the increased water use could be interpreted as the amenity use of water for labour-saving devices such as dishwashers, the increase in the number of swimming pools and spas and the use of water for home

activities such as gardening. (ii) Expansion of inbound tourism and the service economy is accompanied by a steady expansion of that sector of the built environment, and with it, the requirement for water.

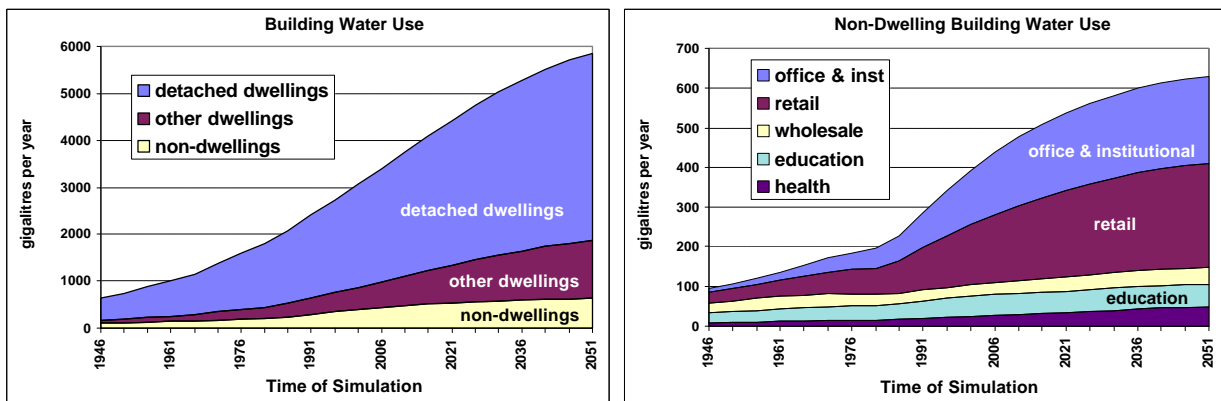


Figure 6.4. Total water required in gigalitres (10^9 litres) per year, in the base case scenario to 2050 for (a) domestic and (b) commercial buildings.

The breakdown in non-dwelling buildings shows that the major requirement for water by 2050 is due to the retail and office parts of the commercial sector with wholesale education and health taking less than 20% of the total (Figure 6.4). More than 80% of total water requirements for building is due to domestic dwellings. This is about 5,000 gigalitres per year, with New South Wales, Victoria and Queensland requiring the major portions (Table 6.5). Total building water use represents 14% of the total Australian water requirement by 2050, and combined with the manufacturing and mining requirements, represents 20%.

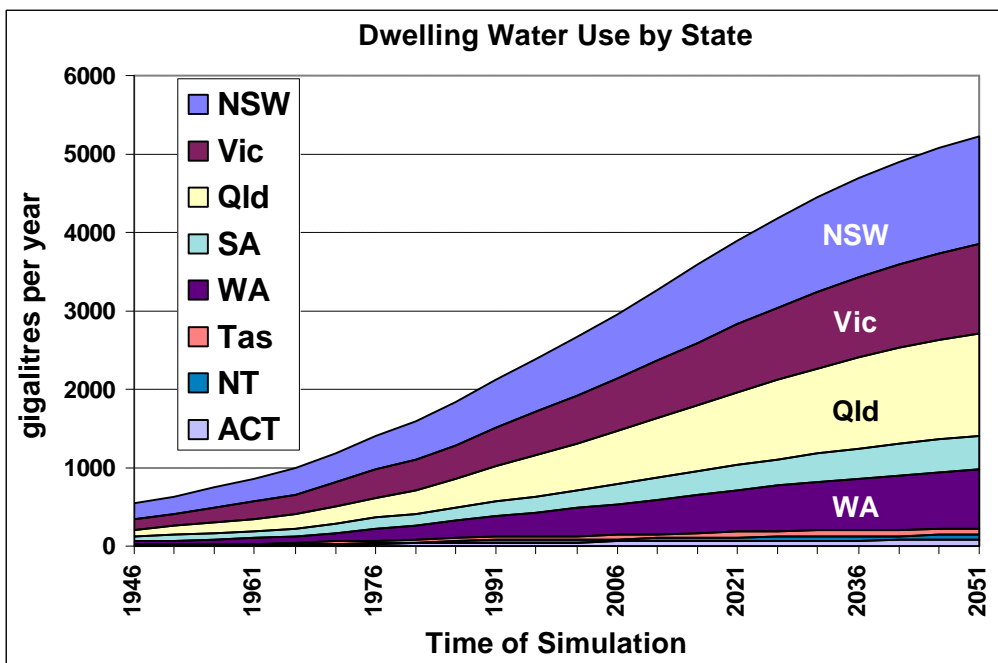


Figure 6.5. Total water required in gigalitres (10^9 litres) per year, in the base case scenario to 2050 to supply domestic buildings.

As noted in Chapter 3, there are significant infrastructure and management issues associated with maintaining clean catchments and ensuring the chemical and biological quality of water supplies for most major cities. However, for the base case scenario at least, there are a sufficient range of options in terms of takeback from other uses and industries and water savings in each home, to ensure

enough water is available. When the other population scenarios are compared to the base case, the requirements are 2,000 gegalitres per year more for the 0.67%pa scenario and 1,000 gegalitres less for the zero scenario (Figure 6.6). By 2100 however, a number of water availability tensions could appear as the building requirements are 12,000, 6,000 and 5,000 gegalitres per year for the 0.67%pa, the base case and the zero scenarios respectively. The requirement for the 0.67%pa scenario is six times that of current urban consumption (2,000 gegalitres per year) and about half the total consumption (24,000 gegalitres per year). Yet, it's possible that the high value of urban water would ensure additional dams, interbasin transfers and pipelines would supplement the current urban water supplies. The challenge becomes one of allocation of available water supply in an equitable manner, rather than a lack of water. The problem enters the preserve of politics and economics and moves outside the sphere of physical analysis.

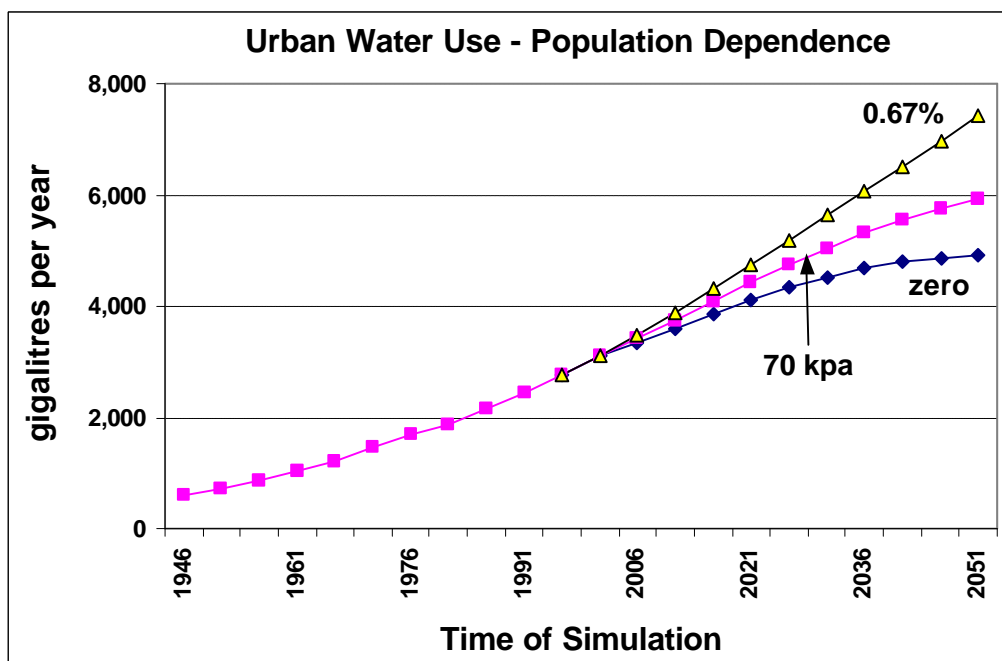


Figure 6.6. Simulated urban water requirement to 2050 in gegalitres (10^9 litres) per year , for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

Irrigated agriculture

The area of irrigated crop land doubles from today's level of 2.5 million hectares to 5 million hectares by 2050 (Figure 6.7). This expansion was necessary to meet the production expectations in the starting position and to increase the contribution of agriculture to physical trade and regional development. Some of the expansion was considered feasible in southern Australia for a range of crop types with lower irrigation requirements and the areas of irrigated land increased in New South Wales and Victoria. However due to constraints on the availability of water in southern Australia, all extra requirements from the year 2000 for water intensive crops such as rice, sugar cane, cotton and some horticulture were undertaken in the northern areas of Western Australia and the Northern Territory. Although this new area was less than one million hectares, it required an extra 10,000 gegalitres per year by 2050 or about the same amount as the total current irrigation crop water use. The water resources that are termed divertible and available for development total 46,000 gegalitres per year in the four large drainage divisions in northern Australia (DPIE, 1987), so the simulated requirement is about 25% of the potentially available water resource.

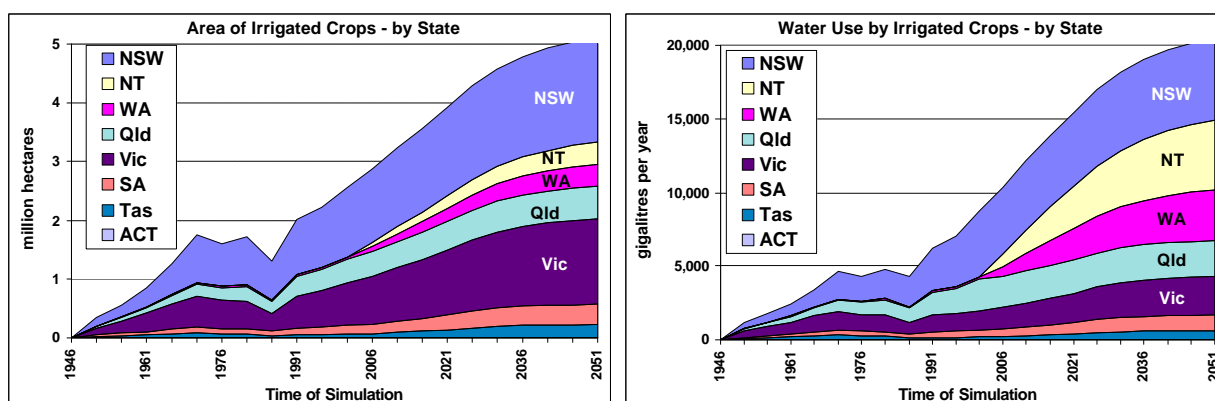


Figure 6.7. Total area of irrigated crop land (million hectares) and irrigation water (gegalitres= 10^9 litres) per year, in the base case scenario to 2050 for domestic and export agriculture.

The development of large-scale irrigation in northern Australia could see a repeat of the undesirable flow-on effects observed with previous irrigation development. There are several large projects already underway which aim to complement the original Ord River scheme of 14,000 hectares. These include the Ord Stage 2 with 64,000 hectares, the West Kimberley project with 20,000 hectares and the further developments based on groundwater in the Katherine and Douglas Daly areas of the Northern Territory. The information and technology required for more sustainable irrigation is now more available, with work focused specifically on the sustainability requirements for tropical irrigation. For example Muchow and Keating (1998) in simulation studies of sugar cane grown on the Ord River scheme, pointed to a high water requirement in excess of 40 megalitres per hectare per year and the need to refine irrigation scheduling to optimise sucrose yield and profit. The problems of pesticide contamination that occurred in the early period of Ord River development showed what can happen when cropping systems and their pests become unbalanced (Kookana et al., 1998). The continuing problem of irrigation salinity can be moderated by appropriate water pricing which restricts water application, and use of integrated measurement and information systems which can monitor the onset of salinity problems and allow timely management responses (Rhoades et al., 1997).

Overall water use

The total managed water use for Australia by 2050 under the base case scenario is 40,000 gegalitres per year (Figure 6.8). This compares to water usage of 22,000 gegalitres per year in 1996-97 reported in the national water account (Australian Bureau of Statistics, 2000), 24,000 gegalitres per year in the National Land and Water Audit (Commonwealth of Australia, 2001), and scenario estimates of 25,000 to 33,000 gegalitres per year for 2020-21 reported in the *Water and the Australian Economy* report (Australian Academy of Technological Sciences and Engineering, 1999). The main users of water are New South Wales, Victoria and Queensland, but water requirements in Western Australia and the Northern Territory increase appreciably over the simulation period because of the northern agricultural development. Due to the scenario assumptions, water use by crops and animals represents 80% of total water use, with the remainder due to buildings, secondary industry and mining. The large amount attributed to animals is for irrigated pasture for animal feeding, in particular dairying where cattle numbers double over the next 50 years in line with the assumptions relating to export trade opportunities.

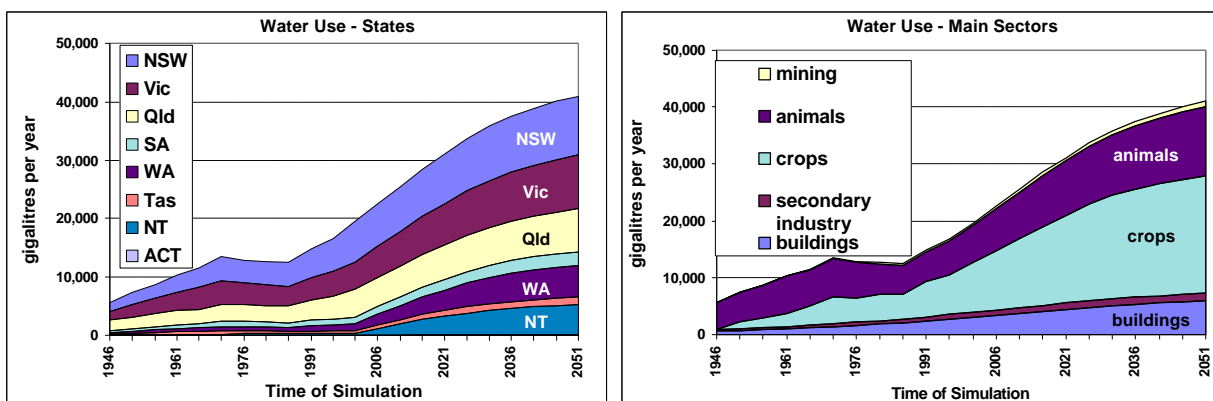


Figure 6.8. Total water requirement to 2050 by (a) state, and (b) by major use, in gigalitres (10^9 litres) per year for the base case scenario.

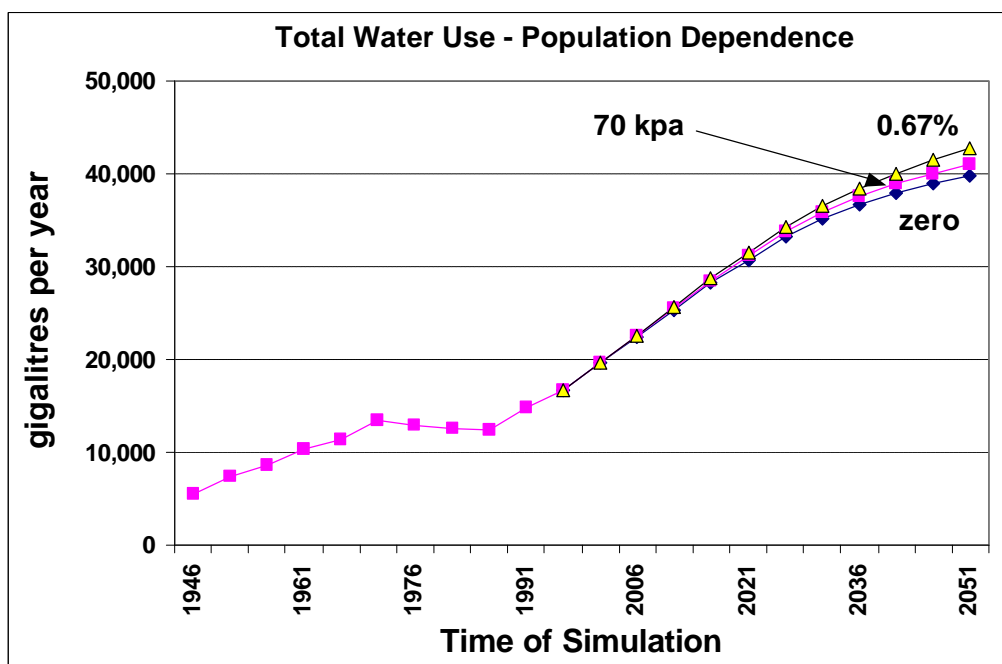


Figure 6.9. Simulated total water requirement to 2050 for all industries and population, in gigalitres (10^9 litres) per year for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67% pa).

Population numbers make a substantial difference to the amount of water required for urban usage by 2050 (Figure 6.6). Overall, population size by 2050 represents a range of 3,000 gigalitres per year in a total managed usage of 40,000 gigalitres per year, or 8% of the total (Figure 6.9). Crops and animals use most of the water to provide products for domestic use and export trade. Commodities such as grain, sugar and cotton are assumed to expand so that they exceed domestic requirements by a factor of 4 to 8. This excess agricultural production together with mining exports contributes strongly to the positive balance for physical trade discussed in the crosscutting sections of Chapter 7. Other commodities such as beef, lamb, poultry and milk products are produced at levels approximately twice the domestic requirements shown by the 0.67%pa scenario. Thus, the tertiary population influence — the trade effect — accounts for a large proportion of Australia's simulated water use out to 2050. A number of analytical approaches can be used to balance the use of water with its economic productivity and employment generation. The *Water Account for Australia* (Australian Bureau of Statistics, 2000) presents data suggesting that vegetables, fruit and grapevines give a gross dollar return of more than \$1000 per megalitre of water used. By comparison, sugar, pastures and rice give gross returns of approximately \$500 per megalitre of water used. In

productivity terms for the manufacturing industry, clothing and footwear, wood products and basic metals give lower values per unit of water used than plastic goods, machinery and transport equipment.

Without accessibility to water of appropriate quality, volume, and timeliness, a modern economic and social structure could not function. However, past actions to bring Australia's water resources under more direct human control have led to a range of negative effects such as irrigation salinity, depleted inland and estuarine fisheries and an altered biodiversity complement in swamps and wetlands. The integrity and cleanliness of urban catchment areas are essential to maintain flows of high quality cheap water to urban Australians. The future development and use of Australia's water resources do not have to repeat the lessons of the past. If elements of the 'develop northern Australian agriculture' scenario tested in this chapter were to proceed, the proponents and managers of these enterprises should be well warned by changes wrought over the past 150 years of water development in Australia.

Sub scenario for 30% water efficiency

There are many opportunities to improve the efficiency of water use, and to reduce its absolute use, the key aim being to maintain the quality of the good, the service or the amenity value while reducing its water content. The options available for urban areas are many. Some of them are technological (better designed washing machines, low flow shower heads, drip irrigation) while some are behavioural (watering the garden at night, shorter showers, dryland gardens, hand-washing dishes). When an assumption is made that the same level of water service and amenity can be delivered with 30% less water, then the urban water requirement for the 0.67%pa scenario can be reduced to the base case scenario requirement, and the base case requirement to that of the zero scenario (Figures 6.6b, 6.10).

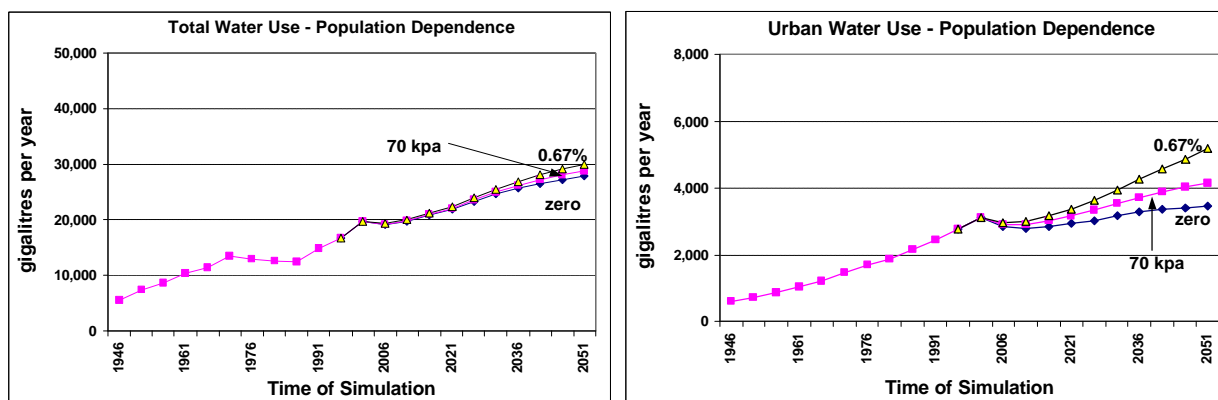


Figure 6.10. A sub-scenario of 30% reduction in water requirement for the same delivery of product, services and lifestyle to 2050 (a) for all industries and population and (b) for urban water requirement. Data are in gigalitres (10^9 litres) per year for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

A number of catchment and city specific details relating to drought risk, catchment integrity, water infrastructure and the possible effects of global warming need to be considered. It is possible that processing urban waste water flows for use in city parks and gardens could contribute a major portion of the 30% saving envisaged (CSIRO, 2000-b), so that one technological application with some behavioural change could allow Australia's current urban water flows to service the requirements of the three population scenarios. The Hunter River region in New South Wales has achieved a per capita water use reduction from about 230,000 litres per year in 1975-76 to 150,000 litres per year in 1995-96 through a combination of water pricing and education innovations. Sydney and Melbourne maintained a relatively constant usage throughout the same period. Climatic

differences will also play a role. More water is used per capita in Australia's northern regions and water use also increases during periods of heatwaves. The implications of global warming and climate change are not included in these water analyses. But the possibility looms of changing rainfall patterns, constraints in surface water supplies and longer periods of hot weather. The combination and severity of these effects in different regions will influence the management and investment required for the water system overall.

A similar result to that shown in Figure 6.10b is obtained for the entire water system (urban, manufacturing, mining and agriculture combined) under the 30% reduction sub-scenario (Figure 6.10a). Total water use by 2050 is about 30,000 gigalitres per year, which approximates the scenario estimates for 2020 in the *Water and the Australian Economy* report (Australian Academy of Technological Sciences and Engineering, 1999). The physical and economic feasibility of achieving such a reduction has not been fully analysed and there are a number of institutional, bio-physical, economic and technological barriers to overcome. At an institutional level, the delivery of irrigation water along open canals allows large losses — in the order of 30% — and water applications are often made on schedule (when the water is delivered along the canal) rather than when the orchard or crop requires it in plant physiological terms. Dealing with losses before the water is delivered to the paddock is an engineering problem and national trade offs are required to balance water infrastructure for farms versus those for cities, especially for cities that are growing. The problem then changes from a physical constraint to an economic and political one.

The realities of photosynthesis process and how plants grow in a productive manner also affect water use. High value crops, such as vegetables and fruit, must maintain the correct water balance in order to maximise product quality for discerning markets, and to meet timely delivery schedules. Over-watering in these circumstances can be a wise economic decision if the alternative is rejected and unsaleable produce. Water delivery systems that greatly reduce the absolute requirement for water are widely used but they are mainly applicable to high-value perennial crops. As well, focusing water delivery onto a restricted area of the root zone could exacerbate any problems due to water quality and soil interactions. Many irrigation systems and plants themselves require leaching ratios that remove the accumulated salts in the plant root zone. Farming systems with good management and economic practice deliver more product per unit of water used. In a study of the Victorian dairy industry, Doyle and Kelly (1998) found that the top 10% of farmers used 500 litres of irrigation water per litre of milk produced. By comparison, the average farmer used 700 litres per litre of milk, and the bottom 10% of farmers used 1,000 litres. In this case, a reduction of 50% in water use was possible. However, 500 litres of irrigation water per litre of milk produced could set a physical, economic and environmental threshold that cannot be changed. It is possible that a physical limit may have been reached!

Similar comments can apply to the many manufacturing and mining processes represented in the simulations. While each of these sectors, with about 1,000 gigalitres per year required by 2050, represents only 3% of national water use by that time, many industries and mines are region specific and cannot move to a water source, because of the large physical transactions required to be undertaken in situ. The development of a uranium mine in South Australia required the extraction of 15 megalitres of water per day (5.5 gigalitres per year) from the Great Artesian Basin and a possible expansion to 43 megalitres per day (16 gigalitres per year) with a doubling of mine output. There is no suggestion of negative effect in this example, but the water requirement should be compared to the water use in South Australia by pastoral industry bores of 130 megalitres per day (47 gigalitres per year) and seepages from natural springs of 66 megalitres per day (24 gigalitres per year) (Parliament of Australia, 1997). An assessment of water use in this case, is best made in relation to a

number of social, economic and national goals where competing uses (and no use) are ranged against each other.

DISCUSSION

Water and the world

A brief perusal of the world water literature reveals a challenge looming by 2020 when 34 countries will be water-poor. Substantial transfers from agriculture to industry and urban areas will be required, which may restrict the ability of many countries to feed their growing populations. While 40% of the world's accessible water is presently allocated for human use, Falkenmark (1998) suggests that this will have increased to 80% by 2025 because of anticipated pollution loadings in rivers and their requirement for dilution. In rating world water priorities, Falkenmark lists the three main security threats as (i) Water quality degradation reducing the alternative use options (ii) Food insecurity risk and (iii) Growing river depletion in response to intensified food production in the tropics and sub-tropics. The first and third of these threats are well on the way to becoming reality in a number of Australia's important river basins. Food security is not at risk if the reasonable assumptions in the starting scenario for agricultural production are maintained out to 2100.

Policy and management options

Blue, green and white water

Faced with the possibility of an increase in water requirement to 2050, particularly for crop and animal agriculture, five sets of water theory and practice can contribute to changing the way the nation views and manages its water resources. The first set concerns the concept of interactions between the blue, green and white portions of the nation's water resources (Falkenmark, 1995; Savenje, 2000). 'Blue' water is the managed water in rivers, dams and underground aquifers. 'Green' water is the water stored in the soil and available for plant growth while 'white' water is the water in the atmosphere generated by evapo-transpiration from plants and soil, and evaporation.

Human management of Australia's water cycle since European settlement has created imbalances in the blue-green-white water interactions. Because of tree clearing and annual cropping systems, not enough green water is transpired as white water, and this becomes blue water travelling through the landscape, producing dryland salinity and land loss, and also saline seepage causing river salinity. Enthusiastic irrigation practices have led to more blue water being added to regional hydrological systems resulting in irrigation salinity and further leakage to river systems that increases river salinity. If a balance can be found between these two issues, white water flows from landscapes to the atmosphere must increase, and less blue water and more green water must be used for agricultural production systems. More than 60% of the world's staple food production relies on rainfall and hence green water, while the crops that produce fresh attractive products in the market place (fruit and vegetables) or high quality (cotton, tobacco) are irrigated. Information and management systems may have to be implemented that allow decisions to be made on product mixes in relation to blue-green-white water mixes and flows.

Water allocation

Knowledge of the blue-green-white water mix can help reconcile the second issue concerning water allocation. The world water literature describes a three phase water transition where the first phase represents continuing development of water resources, the second is scarcity and competition between users, and in the third phase, people are forced to use water more efficiently and to reduce pollution (Hoekstra, 2000). These phases map easily onto the cultural theory types of Thompson et al. (1990) where phase one is 'individualist' and prefers free market approaches, phase two is

'hierarchical' and prefers government regulation and phase three is 'egalitarian' and requires community cooperation and shared responsibility (Hoekstra, 1998). Australian water appears to be through phase one, well into phase two and experimenting in some regions with phase three.

There are a number of widely differing views on how to achieve better outcomes for the whole water system and its knock-on effects. In comparing the 'panglossian' (blindly or naively optimistic) and 'pragmatic' views of contemporary water economics, Green (2000) claims the 'panglossian' view is content to stay with economic theory and impose a 'one size fits all' solution on the intricate and complex world represented by national water systems. The 'pragmatic' view refutes the pure concepts of efficiency, perfect markets, prices and behavioural change and asserts that privatisation is the only route to the delivery of efficient water services. At a more socio-political level, Allan (1999) asserts that the real job of water policy is to achieve equitable and efficient allocation of water resources, and that decision makers mostly take the water efficiency route which has few political downsides and good economic returns for the makers of pipes, pumps and equipment. By contrast, Allan claims that the real gains for the water system are to be made in understanding the trade in virtual water embodied in traded food and manufactured goods and making appropriate national allocations of water within that context. These issues have important parallels with energy issues, where efficiency policies cause rebounds and many externalities (airshed emissions, greenhouse gases) which go uncosted. However, in comparison to energy and greenhouse issues, the cap on water use in the Murray Darling Basin (Murray Darling Basin Commission Ministerial Council, 1996) sets a physical benchmark and brings physical reality to which social and economic systems will have to adjust.

Trade in virtual water

The third practice that can contribute to a change in water management is the trade in virtual water, i.e., water embodied in the goods and services imported and exported in globalised trade. At a global level, many countries obtain their food necessities through the virtual water trade, by bartering commodities such as oil and elaborately transformed manufactures through the medium of international currency exchange. In a managed water use of 24,000 ggalitres per year, Australia exports the equivalent of 7,500 ggalitres of water embodied in goods and services and imports the equivalent of 3,500 ggalitres. This leaves a net outflow of about 4,000 ggalitres per year, roughly equivalent to the water consumption of the entire urban sector excluding manufacturing (Table 6.8; Lenzen and Foran, 2001). If 'white' water or 'transpired' water is used, then the export in agricultural produce is about 28,000 ggalitres per year (Dunlop, pers. comm.). Similar analytical procedures for embodied energy show that trade exchanges (imports versus exports) which have been roughly in balance, are now moving into a deficit (Lenzen, 1999). Given the possibility of future environmental and social fragilities in Australia's water system (river salinity, depleted inland fisheries, rural decline) an important national question to be addressed is whether Australia receives adequate monetary return for the net outflow of 4,000 ggalitres of its managed water resource. The current status of export farm prices, the physical trade balance, the current account deficit, and the status of international debt levels suggest that the trade in 'virtual or embodied' water could be a loss leader for the nation and many of its land and water regions.

A nation seeking to garner reasonable economic returns from international trade could adopt a strategic approach to the monetary returns expected from the virtual water trade. It is well documented that there are countries with a looming problem of water stress and water scarcity (Raskin et al., 1996; Ohlsson, 2000; Falkenmark, 1999). National water scarcity is usually declared at a threshold of 1,000 cubic metres per capita of water flow per year (one cubic metre equals 1,000 litres). Trading partners such as Japan have more than 4,000 cubic metres per capita and with a stable or declining population, the country's relative water security is assured. Other countries such as the Republic of Korea (1470 m³ per capita), Singapore (220 m³ per capita), Saudi Arabia (225 m³

per capita), United Arab Emirates (566 m³ per capita), former Soviet Union (1240 m³ per capita), and Venezuela (208 m³ per capita) all have oil reserves and/or advanced manufacturing capability that Australia might require in the future. A series of trade negotiations which attempt to balance the export price received for goods and services with various embodiments of water, energy, labour, intellect and environmental integrity, could help fund re-investment into the repair and maintenance of Australia's water resources. Focusing on countries with looming water deficits does not avoid Australia's obligation for food aid and crisis assistance to a wide range of countries that are already badly stressed in water and food terms. Rather it focuses on building reasonable foundations for physical and monetary exchange mechanisms over timeframes of human generations. Then, the prices exchanged in international trade could cover the full cost of the exchanged goods and services.

Table 6.8. Gegalitres (10⁹L) of water embodied in exports and imports in the 1995-96 national water account and monetary input-output tables (adapted from Lenzen and Foran, 2001).

	Exports	Consumer imports	Industrial imports
Mains water supply	3,555	630	1,059
Self extracted water supply	3,884	669	1,207
Total	7,439	1,299	2,266

Water management boundaries

The fourth issue relates to the need to reconcile the political, economic, social and physical boundaries within which the nation's water resources are managed. By defining management authorities that deal with entire spatial issues such as The Great Barrier Reef or the Murray Darling Basin, Australia has acknowledged leadership in the area of institutional reform. New Zealand led the way in the late 1940s when it co-located its regional government boundaries with the catchment boundaries of the major river basins. Global water policy circles acknowledge that 'whole of river basin' approaches are the only effective way to manage and integrate the many issues involved in water management. While it may take 50-100 years or more to see the bio-physical returns from social and financial investments in river catchments and their human capital, there is world consensus that this is the only way forward (Bjerregaard, 1998). Although Australia may not yet have the allocative mechanisms in place to ensure equity of access to and use of water, the Council of Australian Governments (COAG) water reforms are already in place and moving at a steady pace towards policy conclusion in 2020 (Agriculture Fisheries and Forestry Australia, 2000). This is good news!

Global climate change

The fifth issue, not analysed at all in these scenarios, is the effect of global climate change in altering the hydrological regimes which contribute to the balances between blue, green and white water flows. Spatial studies of temperature/rainfall/runoff characteristics at a global level (Hulme et al., 1999), in the United Kingdom (Sefton and Boorman, 1997) and for continental Europe (Arnell, 1999) show the possibility of large geographic and time shifts in major precipitation events and the same is possible for Australia. CSIRO (2000, 2001) regional modelling experiments show that Queensland could be warmer with more downpours, with the possibility of more cyclones, storm surges and flood events. The effect of regional climate change on particular sectors has been examined for rangelands (Howden et al., 1999-a) and for wheat cropping (Howden et al., 1999-b). These studies show, that while it is possible to adapt production systems in many areas, and that some areas may in fact benefit, in other areas production systems could become marginalised and

disappear altogether. The blue and green water systems will be driven by global change and human management, and more resilient systems have the best chance of long-term survival.

The population effect

By 2050, many areas of the world could be suffering impaired living standards and quality of life due to water scarcity. Withdrawals from natural water sources and bodies have far exceeded the growth in population numbers — about two and a half times more rapid (Falkenmark and Lundqvist, 1998). Around the year 2025, about 3 billion people are likely to live in areas of water scarcity and water stress (Falkenmark and Rockstrom, 1993). While Australia may be a water poor continent in world terms, even with a population of 32 million people by 2050 presented by the 0.67%pa scenario, it will still be relatively well off compared to many of its neighbours and trading partners. However in some regions, water supply and water quality may present real challenges.

Table 6.9. A comparison of the population effect on water use at 2050 in gigalitres (10⁹L) per year. A proportional use in comparison to the base case is shown in brackets (base case equals 100% at 2050).

Category of water use	Zero scenario at 2050 (proportion of base case in brackets)	Base case scenario at 2050 (proportion of base case in brackets)	0.67%pa scenario at 2050 (proportion of base case in brackets)
All buildings	4,839 (82%)	5,875 (100%)	7,395 (126%)
Manufacturing	370 (90%)	409 (100%)	476 (116%)
Food processing	195 (82%)	236 (100%)	301 (127%)
Material and energy transformation	662 (86%)	768 (100%)	942 (123%)
Mining	959 (98%)	974 (100%)	1,023 (105%)
Crop agriculture	20,483 (100%)	20,483 (100%)	20,483 (100%)
Animal agriculture	12,268 (100%)	12,268 (100%)	12,268 (100%)

The direct population effect for water use at 2050 is shown in Table 6.9. As already noted (Figure 6.5), the direct requirement by buildings spans a range of 2,500 gigalitres per year and reflects the difference in population levels with minor differences due mainly to inbound tourism. The population effect for manufacturing spans a range of 100 gigalitres per year and does not directly reflect a population effect due mainly to assumptions about import-export ratios of manufactured goods. Food processing shows a population effect of about 100 gigalitres per year between the zero and the 0.67%pa scenarios and directly reflects population differences. Material and energy transformation shows a population effect of about 300 gigalitres per year with direct population effects due to building materials and electricity generation, but with some dilution due to export industries such as aluminium. The mining sector shows differences of 100 gigalitres per year due to population effects and most of this is due to mining of basic inputs for building construction and roads. Both crop and animal agriculture are the same for all population scenarios, assuming that all production not for domestic requirements is exported. The direct water requirements for urban Australia, even including manufacturing and materials processing, are relatively small in relation to the total use. Technological innovations will ensure that water recycling is standard, and that urban quality standards are met. In terms of a direct population effect, Australia appears to have sufficient water availability. There are

however challenging problems in future in the area of water quality (CSIRO, 2000-c, 2001-b; Fisher, 2000).

By 2050, the tertiary trade effect of population will continue to have the dominating influence on the nation's water usage and subsequent water quality and river depletion problems linked to it. If issues such as lifestyle/affluence and the intellectual/technological capability to export advanced goods and services become decoupled, then Australia's physical trade balance and international debt levels may become problems in the eyes of the world's financial managers. Continuing to manage debt levels and trade balances may increasingly depend on areas where Australia retains some comparative advantage such as mineral resources and land area, relatively low population, reasonable water supplies and proximity to large markets requiring food and fibre. In these situations, supplies of water may still be adequate, but, if history is any guide, water quality and river depletion issues will continue to increase.

This bleak prognosis need not occur! If difficult decisions are made about the water content of all exported goods and services and the embodied water is reconciled with the energy used, the labour required, the export dollars gleaned and the ecosystem services required and altered, then reasonable balances will be maintained between water use, water no-use and the environmental water flows required to maintain ecosystems, fish populations, waste processing functions and the amenity given by healthy waterways. De Jong et al. (1995) conclude with the following, 'the major challenge that faces us is whether we are really prepared to implement theoretically and practically the integration that is needed'.

CONCLUSIONS

By the year 2050 Australia's managed water use could be about 40,000 gigalitres per year based on the direct population requirements and the needs of the domestic and export industries that contribute to the tertiary trade effects and the quaternary international debt effect. This compares to a water use today of about 24,000 gigalitres. The direct population effect in 2050 for total urban requirements is 5,000, 6,000 and 7,500 gigalitres per year for the zero, base case and 0.67%pa scenarios respectively. By comparison, the manufacturing industry will require 1,500 gigalitres and the mining industry, 1,000 gigalitres per year at that time.

Crop and animal agriculture requires more than 80% of the total water use by 2050 (more than 30,000 gigalitres per year). The expansion of irrigated production requires the development of more than one million hectares of irrigation in northern Australia because of constraints in water availability and water quality in traditional irrigation areas. It is possible that improvements in the efficiency of water usage could allow the higher population levels to function comfortably and equitably for the same water requirement as the zero population scenario without technology improvement. Equally, at the level of the whole economy, technically feasible improvements could reduce the total water requirement to 30,000 gigalitres per year, but achieving this reduction involves a range of plant growth, infrastructure, economic and social effects which produce constraints, generally outside the boundary of the paddock where the water is applied.

The most critical issue for the future of water in Australia is not about finding and acquiring enough to use. Rather it relates to the plethora of side effects associated with our requirement for, and use of water. The issues of irrigation salinity, river salinity, depletion of inland fisheries, maintenance of economic and social vitality in regional areas, heavy metal and pesticide contamination and the beauty and amenity of our urban areas are tied to water use (Young 2001).

It is relatively easy to promote the cause of water use efficiency as there are many employment prospects and company profits tied to the sale of pipes, valves and pumps. Much more difficult and usually evaded by decision makers, are the challenges of just and equitable allocation of water. Tied into this allocation challenge is the physical aspect of how much water is embodied in each product we consume domestically or export, and whether just monetary and social costs are being obtained in the international market place for the water used. A lateral view might conclude that a country with a balanced physical trade account, and a low level of international debt, would not have to rely on water based agriculture to the same extent as Australia does today. The nation's water system could then be more relaxed and possibly more natural.

A nation with a long-term strategic view would know the extent to which water, precious to its people, its industries and its environmental integrity, is embodied in each good, service and product that it produces for domestic consumption, for export or that it imports. Such analyses could form the basis of understanding which allows water use to be aligned with the values for physical production, monetary return, labour generation, energy use, export trade and environmental externalities. Equitable decisions could then be made on the integration of economic, social and environmental considerations.

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