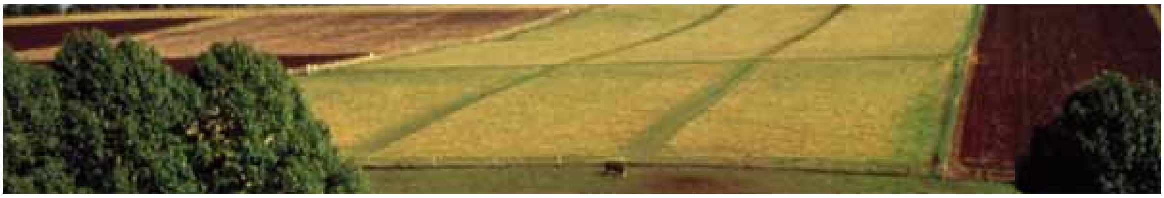
COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

NATURE, PREPARATION AND USE OF WATER ACCOUNTS IN AUSTRALIA

TECHNICAL REPORT
Report 04/2
March 2004

Manfred Lenzen



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Nature, Preparation, and Use of Water Accounts in Australia

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Preface

With the advent of water reform framework instigated by the Council of Australian Governments (COAG), water trading on both temporary and permanent basis has become a prominent feature in all major irrigation areas in Australia. It is important to understand the principal drivers for and constraints on water trading, and to enhance existing hydrologic models for better river management. In addition, there is also a need to assess the impact of the re-distribution of water resources through trade on local economy. Input-output analysis and integration of water accounts into input-output tables have been identified as a powerful methodological framework for regional impact analysis.

Input-output is essentially a method of compilation which describes the inter-dependence of industries in terms of the flow of goods and services. It is rich in detail and captures the structure of the national and regional economy. Input-output is the framework of accounts used at both state and federal levels in Australia. Water account describes the physical flow of the water resource from the environment through various economic sectors. In Australia, water accounts consist of water supply and use tables according to the Input-Output Broad Industry Group (IOBIG) classifications. This classification allows physical data on water to be matched with monetary/economic data available at the same level of detail. Water accounts are part of a broader environmental accounting framework.

This report on the nature and use of water accounts reviews major research activities and outcomes in this important area, especially the work carried out at ABS, CSIRO and University of Sydney in Australia. The report has outlined the methodology to integrate water accounts into input-output transaction tables for water multiplier calculations, and highlighted the data-intensive nature of input-output analysis and spatial issues associated with regional water accounts and input-output tables.

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Executive Summary

International efforts directed at incorporating resources and pollution into traditional accounting have resulted in a number satellite accounts in physical units (NAMEA - National Accounting Matrix including Environmental Accounts).

In order to integrate environmental and economic data, Australian Water Accounts have been developed in parallel to energy, greenhouse gas, mineral and fish accounts, following the guidelines in the United Nations' Integrated Environmental and Economic Accounting framework, which is a complement to the System of National Accounts (SNA). Water accounts provide a mechanism to tie together data from different sources such as Australia's National Accounts and other natural resource data sets, into one consolidated environmental account. The advantage of such an environmental account is that by linking together physical data and monetary data in a consistent framework it is possible to undertake impact modelling.

Water is a unique resource in the sense that there is a general lack of adequate monetary valuation in the market, and a paucity of water use statistics. In an economy with important agricultural sectors such as Australia, water is of key importance for policy making. In addition, Australia is of the driest continents, and experiences a spatially and temporally highly variable rainfall, recurring droughts, leading to a relatively unpredictable water supply.

Current Australian water accounts should be treated as experimental and be viewed in the light of the assumptions which have been made during their compilation process. These assumptions lead in some cases to systematic errors and considerable uncertainties.

For the purpose of setting up a regional input-output model that is augmented with physical data on water use, the ABS Water Accounts (Section 3.5) and the CSIRO Australian water statistics (Section 3.6) are the most suitable data sources.

A regional input-output model that covers the Lower Murrumbidgee or the Goulburn-Broken catchment is likely to be strongly interlinked in monetary terms with the rest of the economy. As a consequence, in order to comprehensively capture indirect and induced effects on the local economies, it is important to model feedback loops. A nested multi-region input-output approach is recommended for the purpose of modelling the impact on the local economy of regions such as the Lower Murrumbidgee or the Goulburn-Broken catchment.

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1. Introduction

Apart from being one of the driest continents, Australia experiences a spatially and temporally highly variable climate that includes periodic drought, leading to a relatively unpredictable water supply. On the other hand, Australian net water demand has increased by 19% between 1994 and 1997, mainly due to increased use on pastures, and to a lesser extent for cotton and rice, resulting in water being a critical resource in some Australian agricultural and urban areas. For example, in the Murray-Darling Basin in the south-east of the continent, which accounts for more than 50% of Australian water use, water resources are already fully committed, and State and Commonwealth governments recently agreed on capping water diversions from all sources at 1994 levels. Nevertheless, significant environmental damage has occurred because of considerable water diversion from the Murray and Snowy Rivers, and widespread soil and water salinisation. In this "water-stressed" region, irrigation-based industries are likely to face further environmental degradation as well as income losses, unless a number of adaptive initiatives in water management are pursued, such as transfers to more profitable users and less water-stressed regions, water pricing and trading, and increases in water use efficiency (AATSE & EIEA, 1999; Quiggin, 2001). It is for these reasons that water is of higher importance in Australian policy making and modelling, than in other countries. As a consequence, water accounts and their use in impact analysis are unique to Australian circumstances.

In the following Section 2, the concept of a water account will be explained, followed by a detailed review of existing water accounts in Australia in Section 3. Section 4 discusses the relationship of the water accounts with the Australia input-output tables, and Section 5 describes a few examples of how this combined system can be applied to impact analysis. Section 6 briefly discusses dynamic aspects, Section 7 gives recommendations, and Section 8 concludes.

2. The Concept of a Water Account

2.1 The Water Account within the Environmental Accounting Framework

According to the Australian Bureau of Statistics (ABS), "the aim of [... a] Water Account project [... is] to provide a mechanism to tie together data from different sources into one consolidated information set. It would then be possible to link physical data to economic data sets such as Australia's National Accounts and other natural resource data sets. Environmental accounts can facilitate an integrated approach to a range of issues that include:

- a broader assessment of the consequences of economic growth;
- the contribution of sectors to particular environmental problems; and
- sectoral implications of environmental policy measures (for example, regulation, charges and incentives).

The advantage of an environmental account is that by linking together physical data and monetary data in a consistent framework it is possible to undertake scenario modelling. Issues that could be modelled include assessing the efficiencies in different sectors of the economy and the environment, and resource implications of structural change."

Accordingly, water accounts contain supply and use tables that track the extraction of water from the 'environment' through to consumptive use, regulated discharges to the environment, and reuse. A supply table illustrates who is supplying water for use, and a use table shows who is using water. The data are expressed as physical quantities (megalitres).

The first issue of a further ABS publication (4612.0) entitled "Concepts, Sources and Methods for Australia's Water, Energy and Greenhouse Gas Emissions Accounts" is expected for release on 09/06/2004. The publication describes the methodology and conceptual frameworks used for developing Australia's environmental accounts on water (4610.0) and energy (4604.0). It explains stock and flow (supply and use) tables and how they are developed with reference to Australia's objectives and priorities, and the physical characteristics of resources. Linkages with the United Nations System for Integrating Environmental and Economic Accounts, and input-output frameworks and concepts are also discussed.

2.2 National Accounts and NAMEAs

With regard to natural resources, traditional National Accounts proceed as if the price for the exploitation of natural capital (resources and biodiversity) is completely determined by the associated cost of extraction and use; the resource or natural system itself is treated as free. Similarly, the price of consumer items is completely determined by production cost, while the absorption of harmful residuals usually occurs at no cost. During the past three decades however, it became obvious that natural capital and environmental capacity are far from inexhaustible, and that human activities are beginning to cause irreversible changes in the global ecological system, which in turn are resulting in adverse consequences to humans themselves.

Early attempts to account for environmental degradation were directed at natural assets and environmental abatement and damage cost in monetary units (Peskin 1981; Bartelmus *et al.,* 1991). More recently, efforts directed at incorporating resources and pollution into traditional accounting have resulted in satellite accounts in physical units (NAMEA - National Accounting Matrix including Environmental Accounts), such as energy, water and material accounts (see for example Australian Bureau of Statistics 1998b; a; 1999b; 2000; 2001 for Australia, Pedersen, 1996 for Denmark, Keuning *et al.*,1999 for the Netherlands, Tjahjadi *et al.,* 1999 for Germany, Vaze 1999 for the UK, Ike, 1999 for Japan, and Hellsten *et al.*, 1999 for Sweden). Musu and Siniscalco (1996) review (mostly European) proposals for integrated environmental and economic accounts, with an emphasis on Italy.

One of the first NAMEA-based integrated environmental-socio-economic policy analyses is Resosudarmo and Thorbecke's (1996) study on the effect of environmental policies on different socio-economic classes in Indonesia. These authors extend the traditional Social Accounting Matrix (SAM) with air pollutants, but also add health cost data, and thus provide a link from environmental quality back to the monetary economy. Weale (1997) incorporates three environmental quantities into an Indonesian SAM: land clearing and degradation as the capitalised value of land lost, logging damage as loss of timber in m^3, and depletion of oil reserves in millions of barrels. He presents a range of multipliers for these quantities, and also evaluates the additional requirements that would arise if increases in imports resulting from exogenous changes were matched by corresponding increases in exports, in order to maintain the balance of payments. Xie (2000) constructs an environmentally extended SAM for China. Its elements are, however, solely expressed in monetary units, including pollution abatement expenditure, and environmental taxes and investment. Xie presents various multipliers as well as a structural path analysis of the wastewater treatment sector. Alarcón *et al*., (2000) describe the compilation of a Bolivian SAM, extended with information on housing, greenhouse gas emissions and fuel use in physical units.

The need for environmentally extended National Accounts is also acknowledged by the Australian Bureau of Statistics in the Australian Water Accounts (Australian Bureau of Statistics, 2000):

> "Environmental accounting work is proceeding in many countries in response to national and international recommendations. The United Nations Conference on the Environment and Development in 1992 and the resulting document, Agenda 21, proposes 'a program to develop national systems of integrated environmental and economic accounting in all countries' [...].
>
> The System of National Accounts (SNA) supports policy making at a national level, however, historically the methods have had little regard for environmental matters. An important aim of environmental accounting is to assess the environmental sustainability of economic activities and economic growth by quantifying any depletion and degradation of a natural resource. An environmental account provides an information system which links the economic activities and uses of a resource to changes in the natural resource base.
>
> Environmental accounting provides a link with the economy by depicting quantitative information on natural resources that can then be linked to economic data sets such as Australia's National Accounts. This allows for monitoring of the flow of the resource through the economy."

2.3 Australian National Accounts and Input-Output Tables

The Australian National Accounts are published by the Australian Bureau of Statistics (ABS). Within the System of National Accounts 1993 (SNA93), National Income, National Expenditure and National Product are now benchmarked by the ABS on input-output tables. The ABS employs the commodity flow method, which is an input-output approach for compiling National Accounts (Barbetti and De Zilva 1998). The characteristic feature of the commodity flow method is that it balances total supply and use for each commodity while simultaneously balancing total production and input for each industry. In practice, the reconciliation of the three GDP estimates based on income, expenditure and production is achieved by an iterative confrontation and balancing process involving approximately 1000 commodities and 100 industries. As a result of this approach, previously common discrepancies within the National Accounts and between input-output tables and the National Accounts no longer occur. Furthermore, an Economic Activity Survey incorporating taxation statistics has been specifically designed by the ABS (Australian Bureau of Statistics 1999a) to support the input-output approach from 1994-95 onwards by expanding and detailing the industry data collection, and by facilitating the production of annual input-output tables (previously triennial).

The basic input-output tables contain matrices describing the supply, use, import, and margins of commodities in the Australian economy. Commodities and industries are distinguished in the published tables. A measure for the homogeneity of industries is the *supply matrix* **V**, which shows the total output of domestically produced commodities (columns *j*) by domestic industries (rows *i*). Characteristically, the largest entry in each commodity column belongs to the industry to which the respective commodity is primary. The market *share matrix* **D** (with elements D_{ij} showing the share of industry *i* in producing commodity *j*) is derived from the supply matrix by dividing each entry by the total commodity output: $D_{ij} = V_{ij}/\Sigma_i V_{ij}$.

The *use matrix* **U** (Fig. 1) shows how commodities (rows *i*) are absorbed in industries (columns *j*). The use matrix contains both domestically produced and imported commodities without distinction. Competing imports are allocated indirectly, that is, to the supplying sector that they are primary to, rather than directly to the sectors that use them. Complementary imports are excluded from intermediate demand, since there is no domestic sector that they are primary to (as they are not produced domestically). Excluded are also re-exports, that is commodities which are imported into Australia and then exported without having been used or transformed.

2.4 Input-Output Analysis

Input-output tables are constructed in many countries for one particular year from surveys of monetary transactions between classified industry sectors, and thus provide a 'snapshot' measure of economic interdependence at a particular stage of development. They have been widely used as a database to perform analyses of systemic economic impacts caused by exogenous shocks or perturbations. These types of analyses are called *input-output analyses.*

The technique of input-output analysis relies only on National Accounts that are regularly published by statistical bureaux, and has therefore been described by Nobel Prize laureate Richard Stone as "neutral from both an analytical and ideological point of view" (as cited by Hewings and Madden 1995, p.1, see also Rose 1995, p. 297). Elements of input-output analysis can be found in many analytical streams within economics, and have been applied during the past four decades in numerous studies of both market and planned economies, with little modification. "Moreover, [input-output analysis] does not incorporate any specific behavioural conditions for the individual or the state [...], except that an economy behave in a consistent manner" (Rose *et al.,* 1988, p. 12).

As Leontief (1986, p. 19) himself puts it, "the economic system to which [input-output analysis] is applied may be as large as a nation or even the entire world economy, or as small as the economy of a metropolitan area or even a single enterprise" (compare Leontief, 1974, Hirsch, 1963 and Farag, 1967).

The history of methodological developments has been reviewed by Stone (1984), Polenske (1989), Carter and Petri (1989), Forssell and Polenske (1998), and Rose and Miernyk (1989). Introductions into input-output theory can be found in work by Leontief (1953), Stone (1972), Leontief (1986), Duchin (1992) and Dixon (1996).

The increasing availability of sectoral environmental data in physical units (for example in NAMEAs) have enabled the practical application of Leontief and Ford's (1970) original suggestion of a combined financial and environmental-physical input-output account. In theory terms, and following a classification by Miller and Blair (1985), these *generalised* input-output models incorporate additional information on inputs of *production factors* into intermediate demand. The term "production factors" can be understood in a very general sense as additive indicators and quantities that *are in any way associated with industrial production*. These indicators are found in NAMEAs. They can be for example:

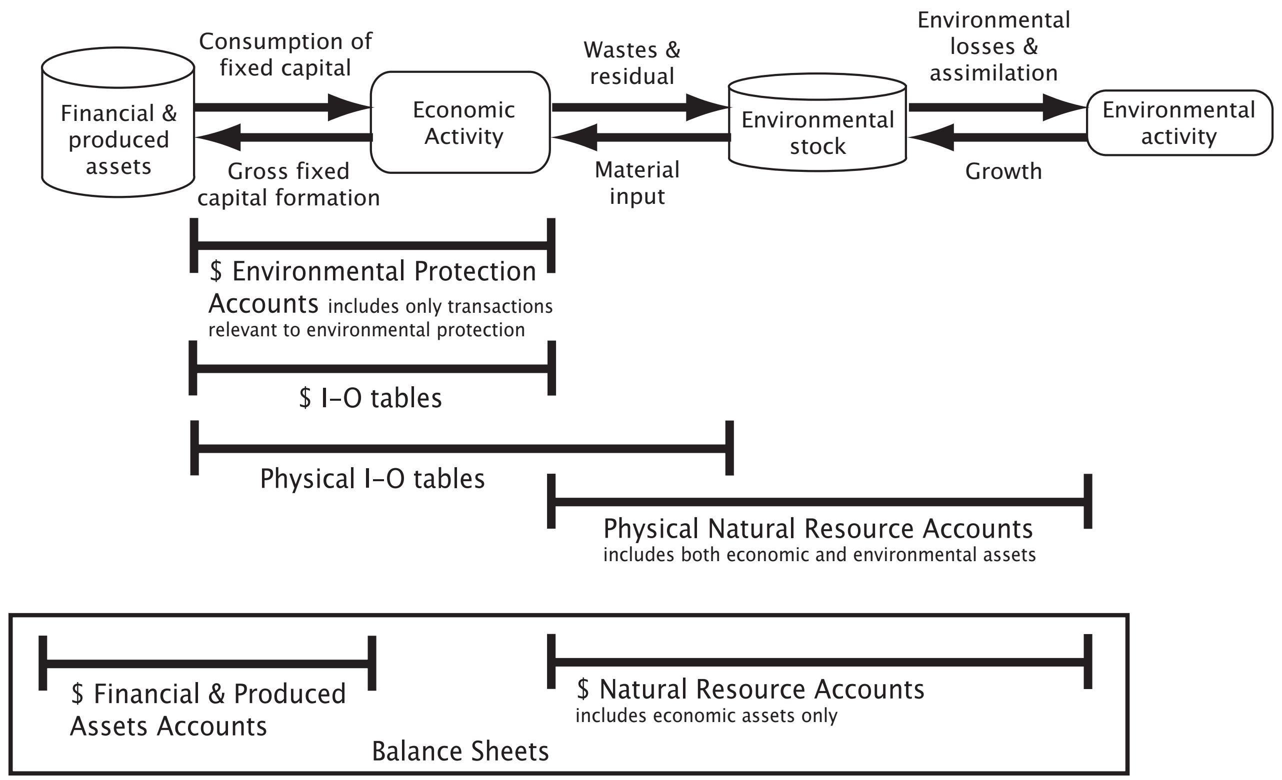
- economic parameters such as income, capital, or imports,
- social factors such as employment, income disparity or occupational health and safety,

- natural resources such as water, land, forest, minerals, metals and fuels, or
- environmental emissions of greenhouse gases and other air pollutants, general waste, toxic compounds in soil and water and effluent discharge into the ocean,
- other physical production- and consumption-related quantities such as transport flows or sustainability indicators.

As long as a factor is additive in its impacts, it can be treated with the input-output formalism and for impact studies. Generalised input-output techniques have been described in detail by Forssell and Polenske (1998), Isard *et al.,* (1972), Polenske (1976), Cumberland and Stram (1976), Miller and Blair (1985), Førsund (1985), and Hawdon and Pearson (1995). They have been applied extensively since the late 1960s.

2.5 Australian Water Accounts within the SNA

For a number of years the environmental accounts have been developed as an integrated information system for Australia that links environmental and resource issues to the national accounts, with water and energy being the most comprehensive. In order to integrate environmental and economic data the ABS has developed the Water Account following the guidelines in the United Nations' Integrated Environmental and Economic Accounting framework, which is a complement to the System of National Accounts 1993. Environmental accounts extend the boundaries of the System of National Accounts (SNA) framework to include environmental resources. The relationship between environmental accounts and national accounts is illustrated in the diagram below. Further detailed information on Australian water accounts is compiled in Section 3.



(Source: Australian Bureau of Statistics 2000).

Figure 1. Relationship Between Environmental Accounts and National Accounts

3. Existing Water Accounts

3.1 1985 Review of Australia's Water Resources and Water Use

The 1985 Review of Australia's Water Resources and Use was conducted by the Australian Water Resources Council (AWRC), and is documented[1] in the National Land and Water Resources Audit (NLWRA; see Section 3.3). It contains Australia's surface water and groundwater resources based on the best information available at December 1984. The underlying data was provided by State and Territory government authorities following standard guidelines of the Australian Water Resources Council. Nearly all audit data is in form of maps that are similar to the following map:

More maps relating to water *use* exist on the following quantities:

- total urban & industrial water use,
- total irrigation water use,
- total rural water use,
- gross water consumption from surface water sources, and
- gross water consumption from groundwater sources.

Maps relating to water *resources* exist on the following topics: basin outflow, total divertible surface water resources, total divertible fresh water resources, total divertible marginal water resources, total divertible brackish water resources, total divertible saline water resources, developed water resources, groundwater resources, total fresh groundwater resources, total marginal groundwater resources, total brackish groundwater resources, total saline groundwater resources.

The 1985 Review does not distinguish detailed industry sectors, but only 'urban', 'industrial', 'irrigation' and 'rural' water use. It covers only the year 1985. The spatial detail is, however, quite high: 12 drainage divisions, 77 water regions and 245 river basins are distinguished across Australia.

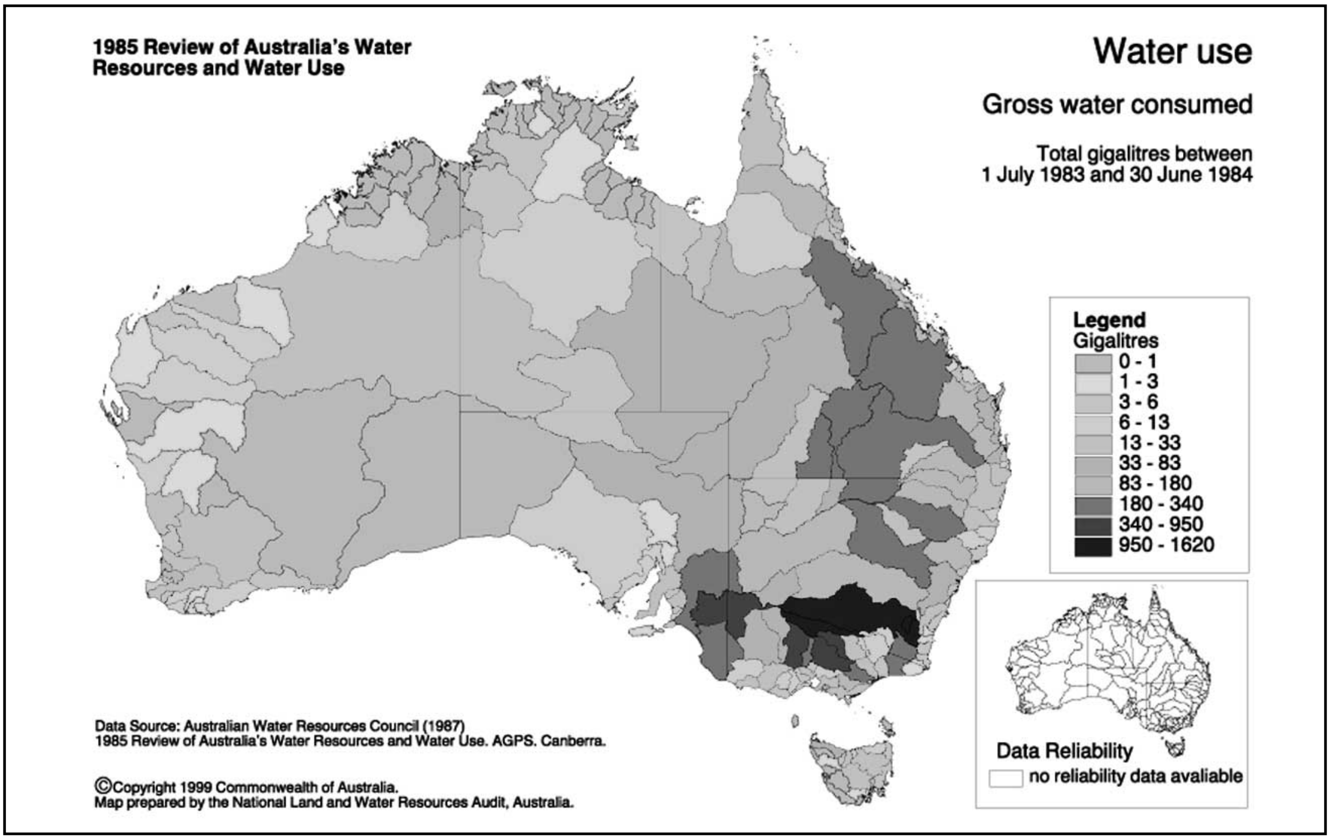


Figure 2. Gross Water Consumed (Source: 1985 Review on NLWRA website)

[1] http://www.nlwra.gov.au/full/20_products/05_by_subject/10_water_resources_and_mgt/00_Water_Review_1985/Water_Review_1985.html

3.2 Audit of Water Use in the Murray-Darling Basin

A detailed audit of water use in the Murray-Darling Basin was carried out by the Murray-Darling Basin Ministerial Council (1995). Water use data were collected from all tributaries of the river system, 95% of which was for irrigation. Annual water diversions were determined for the period 1988-89 to 1992-93 and reported by state and tributary system (see table below). Rather than giving a detailed account of water use, the audit is more concerned with future growth in water diversions and their impacts of the rivers' flow regime, river health, irrigators, and salinity. Key topics in the report are water entitlements and water trading.

3.3 Australian Academy of Technological Sciences and Engineering Study

A report entitled "Water and the Australian economy" by the Australian Academy of Technological Sciences and Engineering and the Institution of Engineers Australia (1999) describes the role of water as an input

Table 1. Audit of Surface Water Use in the Murray-Darling Basin

River System	Diversion for Irrigation (GL)	Domestic, Industrial, Stock and Town Use (GL)	Total Water Diversion (GL)	Diversions as a % of Total Basin Diversion
NSW				
Border Rivers	221	1	222	2.1
Gwydir	299	1	300	2.8
Namoi	244	4	248	2.3
Macquarie/Castlereagh/Bogan	465	6	471	4.4
Upper Darling	188	1	189	1.8
Lower Darling	128	85	213	2.0
Murrumbidgee	2424	19	2443	22.9
Murray	2024	29	2053	19.2
Total NSW	5993	146	6139	57.4
Victoria				
Upper Murray/Ovens/Kiewa	1531	36	1567	14.7
Lower Murray	264	20	284	2.7
Goulburn/Broken/Loddon	1656	54	1710	16.0
Campaspe	79	22	101	0.9
Total Victoria	3530	132	3662	34.3
South Australia				
Private Pumped Diversion	235	4	239	2.2
Government Pumped Diversion	129	100	229	2.1
Reclaimed Swamps	106	0	106	1.0
Total South Australia	470	104	574	5.4
Queensland				
Border Rivers	72	2	74	0.7
Macintyre Brook	10	0	10	0.1
Condamine/Balonne*	157	5	162	1.5
Total Queensland	239	7	246	2.3
ACT	0	63	63	0.6
Total for Basin	**10232**	**452**	**10684**	**100.0**

*Excludes water harvesting diversions

Key Points to Note from this Table
- Annual Diversion averaged 10676 GL/year.
- Over 95% of diversions were for irrigation.

(Source: Murray-Darling Basin Ministerial Council 1995, http://www.boardofstudies.nsw.edu.au/multimedia/waterlines/LIBRARY/AUDIT.PDF).

into the Australian economy, and options for the future. The report contains chapters on water resources, on current water use, water institutions and the political setting, a special analysis of irrigated agriculture, and an "unlimited" and a "constrained" scenario analysis. In particular, chapter 3 contains some water use data for the period 1995-96, in total for 55 industry sectors, and for particular mines and agricultural regions. The data is not presented in an account format, and may only serve to fill in gaps in accounts, or for reconciliation purposes.

3.4 National Land and Water Resources Audit

The National Land and Water Resources Audit (NLWRA) is funded through the National Heritage Trust Program. One of the Audit's objectives is to show the extent of the surface and groundwater resources, quality, supply, capacity, and use.

This NLWRA's website (http://www.nlwra.gov.au/) has two main sections: the *Audit Archive* and the Atlas & Data library. The Audit Archive in turn consists of two sources: 1) the 1985 Review of Australia's Water Resources and Water Use (see Section 3.1), and 2) the brochure "Water in a Dry Land"[2], which contains only little data.

The *Atlas & Data Library* contains 8 sources that are related to water, and other sources related to water resources:

1) The 2001 Australian Agriculture Assessment[3] contains tables and statistics, and also water resources maps of good detail. The report was published in October 2001, but the data are from various times, but mostly in the 5 years preceding 2001.

2) The document "Benchmarking Rural Industries' Practices and Productivity Performance and Review of Industries' Capacity to Change"[4] reports on the beef, cotton, dairy, grains, horticulture, sheep/wool and sugar industries. It contains data on the numbers of head/tonnes per hectare, percentages of produce exported and where to and the areas that the produce is farmed. The data can also be gathered for 3 specific regions of Australia - Northern, Southern and Western regions.

3) The 2001 report "Land - Dryland Salinity - groundwater flow systems - Australia"[5] contains maps, tables and fact sheets on groundwater flow systems. Source data[6] show the distribution of groundwater flow systems at a national scale. These flow systems were based on their hydrogeological characteristics using a combination of geology, geomorphology and topographical (Digital Elevation Model) information at a national scale. The groundwater flow systems identify the extent of groundwater processes contributing to salinity, together with the characteristic hydrogeological processes considered likely to result in dryland salinity given suitable climatic conditions.

4) An introduction on agricultural irrigation[7], and

5) Data on agricultural irrigation[8]. The data tables contain 1983-84, 1992-93 and 1996-97 irrigated areas and change in irrigated areas by state, by basin and by irrigation system. Irrigation data is available at several scales, depending on the data source. For example, the Australian Bureau of Statistics collected irrigated area data at the statistical local area (SLA) scale, while ANCID (Australian National Committee On Irrigation And Drainage) collects all of its data at the irrigation water provider scale. There are also several different years that data has been collected for, therefore care must be taken when comparing values from different data sources. For the purposes of the atlas (which this report is in), the majority of the data is presented at its original scale, with exceptions being the irrigated area data, which has been collated from SLA scale to AWRC (Australian Water Resources Council) Basin scale. State and National summaries have been produced for all data sources.

6) Production data on agricultural sectors using irrigation[9] contains the following tables: 1992-93 and 1996-97 value of production, by state, by livestock type, and by crop. Figures are also

[2] ftp://ftp.nlwra.gov.au/pub/public_v2/ 15_publications/20_brochures/water_dry_land.pdf
[3] http://audit.ea.gov.au/ANRA/ agriculture/docs/national/Agriculture_Contents.html
[4] http://audit.ea.gov.au/ANRA/ atlas_home.cfm
[5] http://audit.ea.gov.au/ANRA/land/land_frame.cfm?region_type=AUS&region_code=AUS&info=sal_gfs
[6] http://adl.brs.gov.au/ADLsearch/index.cfm?fuseaction=FULL_METADATA&inanzlic=ANZCW1202000001
[7] http://audit.ea.gov.au/ANRA/agriculture/agriculture_frame.cfm?region_type=AUS&region_code=AUS&info=irri_intro
[8] http://audit.ea.gov.au/ANRA/agriculture/agriculture_frame.cfm?region_type=AUS&region_code=AUS&info=irri_extent
[9] http://audit.ea.gov.au/ANRA/agriculture/agriculture_frame.cfm?region_type=AUS&region_code=AUS&info=irri_prod

provided on ratios of output value to water use, by crop and state. Data on gross value of irrigated production data were gathered from the recorded production at the wholesale prices realised in the market place. Other methods are not cited, but references to the sources of the data are given in most cases.

7) The data on water consumption for irrigation by state and water type (surface, ground)[10] contain no industry detail, and is referenced to total Australian water use.

8) The sub-report "Economics returns to the agricultural resource base" of the document "Economics in natural resource management: an overview - Australia"[11] has:

- Maps: agriculture profit at full equity for 1996/97, agricultural profit at full equity for the 1992/93 to 1996/97 five-year period, minimum area of Australia's agricultural lands needed to produce 80% of the profit at full equity;
- Graphs: profit at full equity ($m/yr) and irrigation costs as portion of total costs;
- Tables: profit at full equity by basin by area, 1996 water returns ($/ML) and water use (ML/ha) by crop type (Vegetables, Fruit, Tobacco, Grapes, Tree Nuts, Cotton, Coarse Grains, Dairy, Peanuts, Hay, Rice, Legumes, Sheep, Sugar Cane, Beef, Oilseeds, Cereals, All irrigated).

Profits at full equity measures presented in this report are derived from survey data, satellite data, government reports, gross margin handbooks and other sources. Other data do not have their sources cited, but these may be mostly from the report "Australians and Natural Resource Management 2002"[12].

The remaining sources are on water resources and therefore not related to water (use) accounts.

3.5 ABS Water Accounts

The water accounts published by the Australian Bureau of Statistics (2000) are the first attempt to systematically monitor Australian water flows in physical units. They update the 1985 Review of Australia's Water Resources and Water Use (Section 3.1). The motivation to produce water accounts at a detailed industry level were environmental problems resulting from inappropriate use of water, the realisation of the paucity of water data for Australia, and hence a lack of information to guide policy makers on designing measures to abate environmental pressure:

> "In compiling the Water Account, the ABS accessed readily available water resources data from various government and non-government organisations. This data was aggregated into a number of tables. The aim of this project was not to duplicate existing data collection activities but to tie together regional and state water resource data into a single system showing the economy wide impact of water resource management and usage across Australia."

A novelty of the ABS water accounts is that they follow UN guidelines on environmental and economic accounting and the System of National Accounts (SNA; see Section 2.4). Accordingly, physical data is arranged in form of a use and a supply matrix, similar to the make-use concept in input-output tables (see Gigantes 1970 and Schinnar 1978). This arrangement enables linking water data to economic data.

At the time of this report, ABS water accounts covered the years 1993-94, 1994-95, 1995-96 and 1996-97. Supply and use tables are produced for all states and for the whole of Australia. Four types of use are distinguished: Mains water, self-supplied (surface and groundwater), effluent reuse, and regulated discharge. All water is assumed to be extracted from the environment (surface water or groundwater). A subset of this amount is supplied through the mains water system by water suppliers, for specific economic and other uses. Finally, the accounts also report on *net* water consumption, which is total use excluding in-stream use (hydroelectricity and aquaculture) minus total supply.

[10] http://audit.ea.gov.au/ANRA/agriculture/agriculture_frame.cfm?region_type=AUS&region_code=AUS&info=irri_cons
[11] http://audit.ea.gov.au/ANRA/people/people_frame.cfm?region_type=AUS&region_code=AUS&info=nrm_overview
[12] http://audit.ea.gov.au/ANRA/people/docs/ national/anrm_report/anrm_contents.cfm

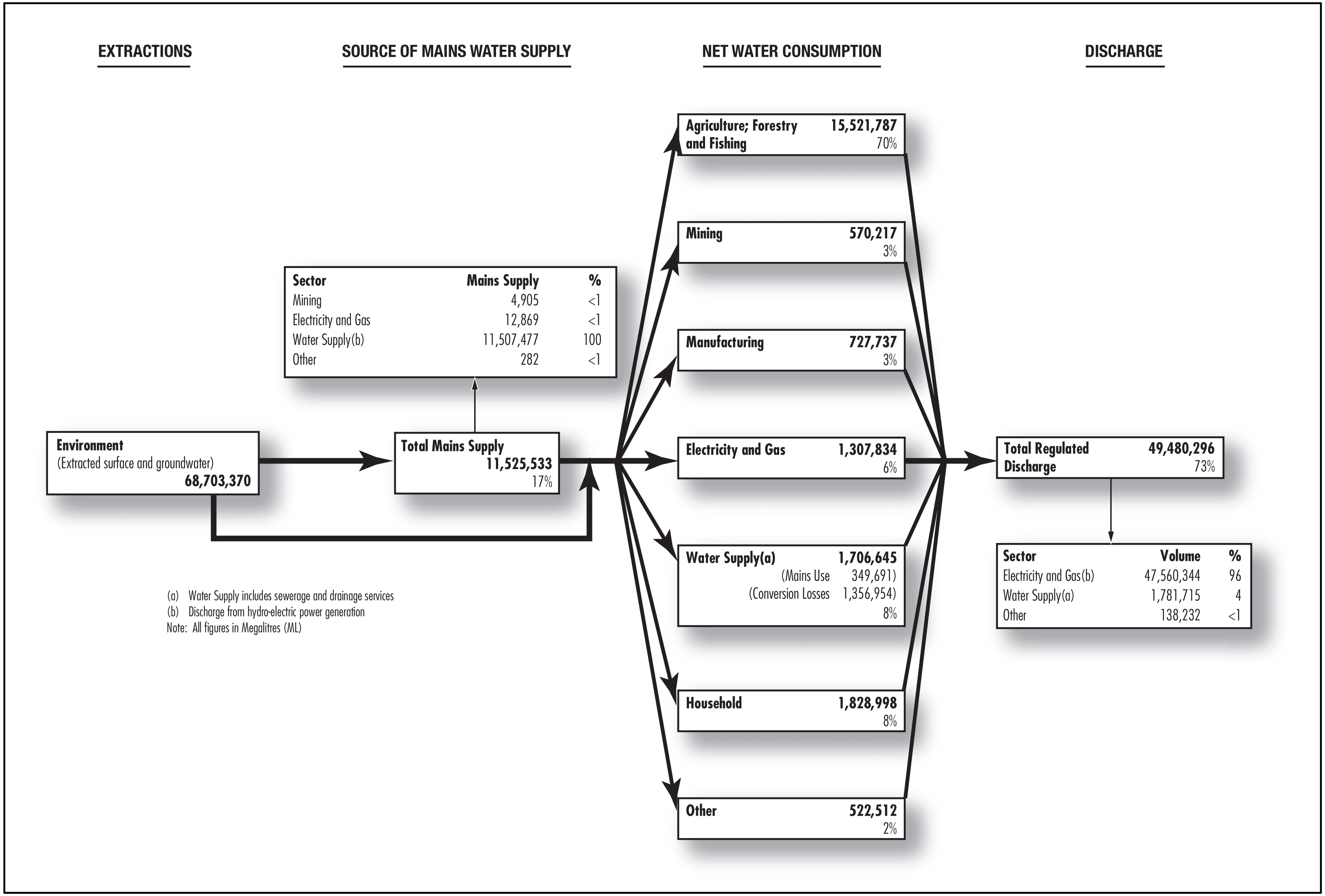


Figure 3. Water Flow through the Australian Economy 1996-97 (Source: Australian Bureau of Statistics 2000).

In addition to water supply and use accounts, measures of surface water and groundwater assets are compiled, but for Victoria only. Asset tables show the long-term availability of water resources, while a water pathway analysis reports the annual inputs, consumption and output of water for Victoria between 1993-94 and 1996-97. Data was supplied by the Department of Natural Resources, Victoria. Detailed data were not available for other States.

3.6 CSIRO Australian Water Statistics Compendium

Following the ABS Water Accounts, Dunlop (2001) of CSIRO Sustainable Ecosystems, Resource Futures Program, compiled the Australian Water Use Statistics (http://www.cse.csiro.au/research/Program5/publications/01-03f.pdf) as the second report in a series of four on Australian water futures coming from the project *Decision Points for Land and Water Futures* that is being funded by Land & Water Australia and CSIRO. The work attempts to reconcile irrigated areas, animal numbers, water use intensities and water use figures.

The report contains "for each of the 58 statistical division in Australia, for each state and the nation as a whole, summaries of areas of irrigated crops and pasture, and an attempt to account for the majority of water use. Estimated irrigation water use is tabulated for a number of crops, pasture and animals, and for domestic and other uses. Estimates of rainfall, surface and ground water resource and total water vapour flows [...] are also provided." An attempt was made in the report to reconcile area (ha) and use (ML) with water use intensity values (ML/ha), using AgStats and unpublished ABS data, and the 1985 Review of Australia's Water Resources and Water Use (see Section 3.1). The figure and table below shows an example for results produced in the CSIRO report. Similar output is documented for all states, and all Statistical Divisions (for example Sydney, Central West, Murrumbidgee, Illawarra, Murray, etc).

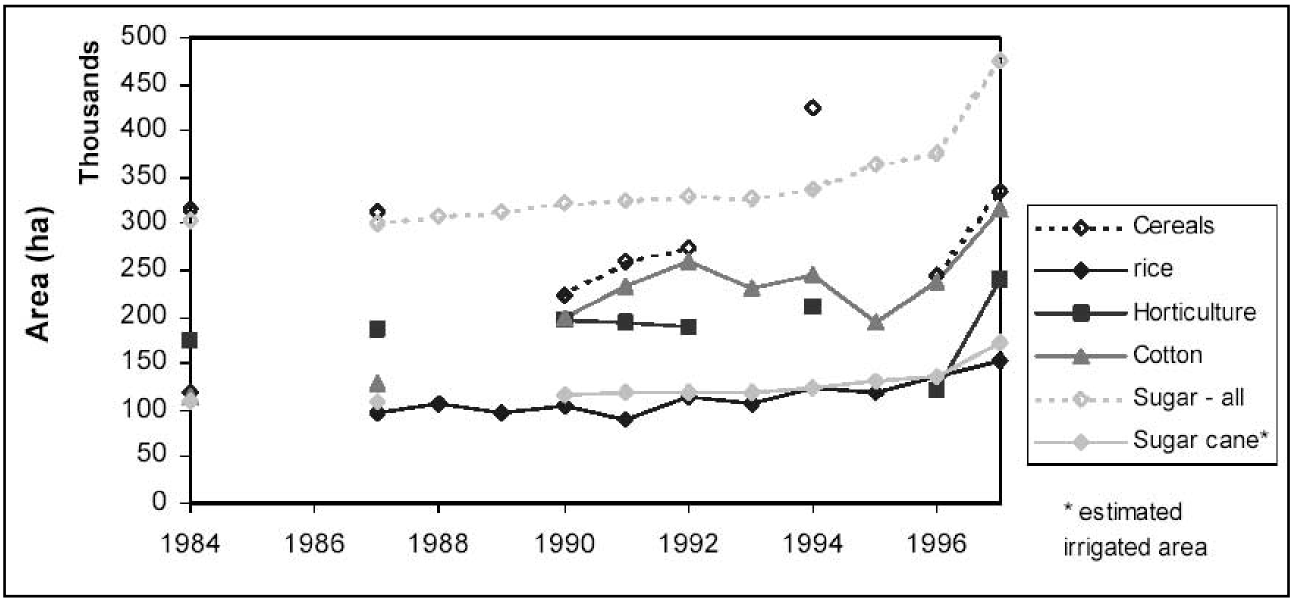


Figure 4. Extract from the Australian Water Use Statistics - Irrigation Areas in Australia (Source: Dunlop 2001).

Water use – AUSTRALIA

Agriculture

Crop	Area irrigated (ha)	Application rate[1,2] (ML/ha)	Water applied (ML)
All cereals	335,972	6.5	2,191,479
Rice	152,367	10.9	1,653,178
Horticulture[3]	241,346		1,987,366
Vegetables	88,782	7.2	634,913
Grapevines	69,120	9.3	643,124
Fruit (less grapes)	83,444	10.8	709,328
Sugar[4]	173,224	7.1	1,236,249
Cotton	314,957	5.8	1,841,341
Other crops[5]	56,718	7.5	423,448
Pasture	934,364	6.1	7,232,722
Total	2,056,580		14,912,660

1. Application rates were modelled to give the total state water use for each category derived from ABS unpublished – see text for explanation.
2. Application rates for cotton from ABS unpublished.
3. Horticulture includes vegetables, nuts, grapevines and other fruit.
4. Proportion of sugar that is irrigated estimated from state average (NSW,WA), or BSES/Canegrowers 1999 Benchmarking report (Qld).
5. Other crops includes oilseed, legumes, silage and hay.

Animal	Number	Application rate[1] (kL/head)	Water applied[1] (ML)
Sheep	120,228,131	1.43	172,654
Dairy cattle	2,940,637	26.7	78,742
Beef cattle	23,839,379	14.1	337,158
Pigs	2,555,223	0.56	1,445
Total[2]			590,240

1. Application rates were modelled to give the total state water use for each category derived from ABS unpublished – see text for explanation. There is considerable uncertainty associated with these data.
2. State and national totals only include water use for poultry.

Domestic and other

Class	Households 1997 (est.)	Use per h'hold[1] (kL/h)	Population	Use per person[2] (kL/p)	Water use (ML)
Household	7,156,920	256	17,877,891	102	1,828,999
Other		678			4,853,758

1. Application rates estimated from state averages (ABS 2000).
2. Derived from population and the calculated household use.

Water resource

Total Rainfall[1] (GL)	Average Rainfall[1] (mm)	Water Vapour[2] (GL)			Rainfall water vapour difference (GL)	Water vapour used by crops[2] (GL)	Irrig. water applied to crops[3] (GL)
		1788	1980	difference			
3,313,960	431	3,435,903	3,096,863	339,039	217,097	47,703	7,888

1. Rainfall estimated from Parkinson (1986) Atlas of Australian Resources: climate; average rainfall = total / area.
2. Subject to revision. See text for explanation and details of water vapour analyses.
3. This analysis.

Surface water resource[1] (GL)			Ground water resource[1] (GL)		Total freshwater resource (GL)	Total water used[2] (GL)
Av. annual runoff	Fresh divertible	Developed (1984)	Fresh divertible	Abstractions (1983/84)		
396,896	9,8175	21,458	8,663	2,637	106,838	22,186

1. Surface and ground water from AWRC (1987) 1985 Review of Australia's water resources and water use.
2. Sum of crop, pasture, animal, domestic and other water use.

Figure 5. Extract from the Australian Water Use Statistics (Source: Dunlop 2001)

The water use statistics are produced only for agriculture. According to the author, "even after revising some of the reported crop water use data the modelled crop water use intensities do not accord well with the values for the water requirements of different crops suggested from other (unpublished) sources. This indicates that: average irrigation water application in Australia is actually considerably in excess of that required for irrigation; or, the irrigated area data and/or the water use data that have been reported to the ABS differ significantly from the actual values. Similarly the inconsistencies in the modelled animal water use intensities indicate that the original source data, numbers of animals and water use, may be significantly in error. These variations could result from a number of causes including differences between states in the manner in which water use data is collected and indeed the definitions of water use. Further information and work is needed to improve this reconciled water account."

3.7 2002 State Supplementary Survey of Domestic Water Use NSW

The 2002 State Supplementary Survey of Domestic Water Use NSW was released in 2003 by the Australian Bureau of Statistics (2002). It neither contains water use figures in physical units nor statistics on industries. Covered are water sources by area of residence, water-using appliances and their age and usage pattern in households, penetration of swimming pools and gardens, and vehicle washing habits.

4. ABS Water Accounts and Input-Output Tables

4.1 Preparation of ABS Water Accounts

The ABS Water Accounts are so far the most detailed data source for the purpose of integration with input-output tables:

> "The tables have been compiled using input-output concepts and classifications. The industry classification which has been used is the Input-Output Broad Industry Group (IOBIG) classification. This classification structure was used so that physical data on water could be matched with monetary/economic data available at the same level of detail."

Data on actual water supply and use were sourced by the ABS in 1998 and 1999, in a survey of "a range of State, Territory and Local Government agencies, water authorities and private enterprises. For New South Wales, data were obtained from urban water boards, non-metropolitan local government authorities, and the Environment Protection Agency, Department of Land and Water Conservation and NSW Agriculture. In Victoria, data were sourced from water authorities, and the Department of Natural Resources and Environment. Urban and rural water boards, local government authorities, and the Department of Natural Resources provided data for Queensland. For South Australia, data were obtained from SA Water and the Department of Environment, Heritage, and Aboriginal Affairs. In Western Australia, data were provided by the Water Corporation, Water and Rivers Commission, Office of Water Regulation and other minor water service providers. In Tasmania, the Department of Primary Industries, Environment and Water, local government authorities, regional Water Boards, and the Hydro-Electric Corporation provided the data. The Power and Water Authority and the Department of Lands, Planning and Environment provided data for the Northern Territory. For the Australian Capital Territory, data were sourced from Environment ACT. Where appropriate, high water using industries in some States were requested to provide data, this included the electricity and gas; mining; paper, printing and publishing; and wood and wood products industries."

While the collection of water supply data was fairly straightforward, details of water consumption was unknown for some sectors. Water usage was known for about 6,300 businesses (usually top water users), the majority being major industrial and commercial water consumers. On the issue of data quality and uncertainty the ABS states:

> "These estimates should be treated as experimental and be viewed in light of the assumptions which have been made during the compilation process."

Data sources for the Water Accounts originate from a range of sources with a variable degree of consistency and reliability. When the ABS started the collection of water use data, respondents were requested to provide an indication of the reliability of the data provided. This question was removed from a second survey because of poor responses. Estimates about unreliability therefore stem only from the first survey. The following table shows the reliability of data for responses received from Victoria, Tasmania and Queensland. Generally the quality of the data varied greatly but it is the best data available in Australia. The data referring to the year 1996-97 are regarded as the most reliable (personal communication, ABS).

Table 2. Data Reliability, Victoria, Queensland and Tasmania (Based on approximately 200 responses from Victoria, Tasmania and Queensland; Source: Australian Bureau of Statistics 2000)

Category	Description	%
A	Based mainly on reliable recorded and surveyed data	22
B	Based on approximate hydrologic analysis and limited surveys	8
C	Based largely on reconnaissance data	3
D	Derived without investigation	8
A-D	Reliability varies for different components of the data supplied by respondents	26
No responses	No indication of data reliability received	33

4.2 Integration into Input-Output Tables

The fact that the data in the ABS Water Accounts are published at the IOBIG level poses a difficulty for integration into a more disaggregated input-output model, because of the problem of disaggregation of water use data. The reason for publication at IOBIG level was that the ABS was less confident about publishing at the IOPC level, which is due to a number of assumptions made at the more detailed level (see further below). Furthermore, confidentiality issues, unreliability, or simply lack of information precludes the release of some detailed industry water use data (personal communication, ABS).

Key assumptions for the purpose of integration of the Water Accounts with input-output tables are:"

- For the *electricity and gas* industry water usage by their employees was estimated and combined with data collected directly from this industry group covering their water usage in generating power.
- The *service* sector was based on a megalitre per employed person.
- For *zoos, parks and gardens* coefficients based on megalitres per hectare were derived based on data collected in an ABS Service Industries Survey.
- Case studies for the *manufacturing* sector were developed based on a megalitre per unit of turnover, and for sectors which had insufficient water data to match with manufacturing turnover data then a case study of megalitres per employed persons was developed. Some major manufacturers rely on large quantities of salt water in their operations. This amount was not included in the supply and use tables.
- Megalitre per unit of production rates were derived for all *mineral commodities* based on data collected for the Water Account and ABS Mining Census data. The production rates were applied to the remaining production of particular commodities for which no data were available. Mine de-watering was assumed to be self-extraction by the mining industry in all States. The water is usually utilised on-site or subsequently discharged. Not all mining companies that were surveyed were able to provide information on the volume of water discharged from mines. Some mining companies were unable to verify their reuse data and their definitions of what constitutes reuse may vary between locations. The collection and continuity of effluent reuse information from the mining industry will improve in the future. Only data from the major mining companies were requested to provide details of effluent reuse. The figures may be greater than what has been recorded.
- The supply of water for *agriculture* was well known, but the split into usage for different crops was not well understood. Agricultural water use was determined from available data and in case of insufficient detail, estimates based on the 1996-97 Agricultural Census data were used to estimate crop water usage.
- Data for the '*stock*' category comes mostly from Queensland with a minor (almost insignificant) proportion from Western Australia. The data source in WA is the Water and Rivers Commission licence information in which they categorised water usage for 'stock'. Data for Queensland comes from data on stock and domestic use in irrigation areas (minor amount) and the major component was a Dept of Natural Resources estimate of unregulated agricultural use of water for stock and domestic use. The domestic use component would not have been huge and so it was assumed it was all for stock use (personal communication, ABS).
- The '*other agriculture*' category represents a mix of industries (excluding cotton, rice, sugar, fruit, grapes, vegetables). Because of the aggregation to IOBIG carried out by the ABS, this 'other agriculture' category went into the category 'livestock, pasture, grains and other agriculture' (personal communication, ABS).
- The *water supply; sewerage and drainage services* industry cannot be split into separate industries based on the classification system used. Where a distinction is necessary, reference has been made to either the water or sewerage sector. Net water use by the water supply; sewerage and drainage services industry includes water consumed by that sector and losses (difference between intake and distribution as mains water). This can be due to a mixture of commitments to environmental flows, changes in storages, hydro-power releases, spills from reservoirs and natural inflows past diversion weirs, transmission losses within the distribution system up to points of final water provider distribution. Losses may include water releases for environmental flows, where these have been

implemented. Some water authorities in Victoria were able to provide more comprehensive data on releases for environmental flows than was available in other States and Territories.

- The usage of water by the *aquaculture* industry was assumed to occur in-stream."

As a consequence, the integration of the ABS Water Accounts into an input-output framework is straightforward if the input-output model is aggregated to IOBIG level. This reduction in resolution however would severely limit the capabilities of the model for impact analysis and decision-making. This especially true for the livestock industries, where neither the ABS Water Accounts nor the CSIRO Water Statistics Compendium (Dunlop 2001) provide a breakdown of water use for pastures for sheep or cattle.

Disaggregating the Water Accounts to (extended) IOPC[13] level requires the application of conversion factors that are based on the above assumptions. Such a set of factors was developed in a Sydney University / CSIRO study (Lenzen and Foran 2001) in collaboration with the ABS. The resulting extended water-input-output model exists for the years 1994-95 and 1996-97 (the most recent years of national input-output data at the time of this report). The factors exist however only on the national scale.

4.3 Scale Issues

Spatial issues are recognised as being important in the ABS Water Accounts:

> "Australia is divided into 245 river basins and 61 groundwater provinces [...]. Spatial disaggregation is important due to the variable hydrological conditions across Australia, however, spatially disaggregated data (river basin or groundwater province level) was unavailable for [... the Australian Water Accounts]. All States and Territories are undergoing a review of water resources as part of the National Land and Water Resources Audit (NLWRA), and it is envisaged that additional resource information will be available for future water account publications."

However, in preparing the current State Water Accounts, a number of assumptions and estimations were carried out. The following extract gives an idea of the procedures that were followed in generating a consistent data set, and of the associated shortcomings, and systematic errors and uncertainties (Australian Bureau of Statistics 2000):

> "State data were utilised to estimate missing data within the same state, for example a megalitre per person rate was derived from existing data and applied to the population for which water consumption was unknown within that particular state. [...] It was assumed that the industry structure varied between States, and profiles of industry structures were combined with known water usage to derive water consumption for those businesses for which no data had been provided.
>
> Accurate groundwater usage information was not available for New South Wales; metering, collection and collation activities of groundwater use is inconsistently carried out statewide [...]. There is groundwater extraction of up to at least one million megalitres, but only 605,000 megalitres [...] could be allocated to a usage. In New South Wales, licensed water users on unregulated rivers are not required to [... report on] how much water they have used. It is likely that the volume extracted from unregulated rivers is an underestimate of what was used. Estimates of unregulated water usage were only available for 1993-94 and 1994-95 [...]. No data were available for 1995-96 or 1996-97 hence the estimate for 1994-95 was used for those years. Metering has now commenced on the Barwon, Darling and Macquarie Rivers and it is expected that the estimate of water usage in unregulated rivers will increase (Gillespie 1999 I cannot find this reference in the reference list either). For

[13] In order to work with the ANZSIC classification, conversion tables have to be used. These conversion tables can be found at the end of the ABS publication 5209.0. They translate ANZSIC codes into IOPC codes and vice versa.

some rivers in Northern New South Wales data on licensed users was based on a year October to September instead of the financial year July to June. Some Victorian water authorities could not provide detailed data for the 1993-94 and 1994-95 years because of the restructuring of the water industry that occurred. In this instance data in later years was used as a basis for estimating the volume of water consumed.

In Victoria the water rights for private individuals are allocated within a water authorities bulk entitlement right and has therefore been included within mains water usage by water authorities.

The estimate of unregulated water use in Queensland was taken from a Department of Natural Resources estimate for 1994-95. The same figure was used in the other reference years with no climatic variation applied to the estimate. No better estimation technique for unregulated water in Queensland was available.

Self-extracted usage of water in South Australia includes licensed usage within Proclaimed Regions and data from a few companies, irrigation trusts and water boards that may operate outside these regions. In South Australia only estimates of licensed water usage within proclaimed regions were available. Other licensed water users for which data was known include water suppliers, irrigation trust and some mining companies (some exist outside proclaimed regions). Licensed use by agriculture was estimated [...] based on crop areas derived in 1992-93. The rate of agricultural water usage was considered fairly stable over the reference period [...]. Estimates of licensed usage by other industrial, commercial or household sectors outside the proclaimed regions were not included.

In Western Australia licensing data equates to usage and are updated every five years. It has been assumed that licences in other States equate to usage unless otherwise stated by the data suppliers. The Water and Rivers Commission (WRC) is currently updating licensed and unlicensed usage of water in Western Australia, and by mid 2000 this information will be available from either the NLWRA or WRC. [...] Estimates of water usage presently exclude unlicensed usage and are likely to overestimate the actual usage by the mining sector."

A more systematical approach was followed by Dunlop (2001) for the compilation of the Australian Water Use Statistics, by attempting a reconciliation between areas, water use intensity per unit of area (or head of livestock), and water use figures:

> "In this analysis we use the preliminary intensity data as seed values in a model that generates water use intensities that concord with the area and water use data. We used a matrix of areas of overlap between agro-ecological regions and statistical divisions to transform the water intensity data to statistical divisions. This was used to give the ratios of water use intensities between statistical divisions with each state and with in each commodity group. The preliminary water use intensity values were then varied, maintaining the ratios between statistical divisions, until they gave the correct state commodity water use sub-totals when multiplied by the statistical division irrigated area data.
>
> Water resource information is also provided at the statistical division level. This data was derived by transforming water resource information at the water region level (from the 1985 Review of Australia's Water Resources and Water Use [...]) to statistical division level using a matrix of overlapping areas. This transformation should be regarded as indicative, not definitive. It also does not account for any inter-basin or inter-region transfers of water."

However, inconsistencies arose as well in this project:

> "This procedure yielded some water use intensity values that were clearly not feasible, especially for "other crop" category in Western Australia. The clearly infeasible values, and the values for some other commodities including rice and cotton, were then adjusted using other

information about expected water use intensities (ABS unpublished, Wayne Meyer unpublished). This left 208 GL unaccounted for by irrigation in Western Australia so this amount was included with the livestock water use for Western Australia.

The author concludes that "intensities for the same animal category may vary by more than 1000 fold between states. No attempt was made to resolve these inconsistencies, hence the modelled animal water use data in this report are subject to considerable uncertainty."

Concluding, it appears that in order to generate complete water accounts at a sub-national spatial level, it is necessary to utilise both conversion factors by the ABS (for mining, manufacturing, utilities, and service industries), refined by disparate data for particular mines (for example from the Australian Academy of Technological Sciences and Engineering and Institution of Engineers Australia), and estimate agricultural water use from the CSIRO compendium.

4.4 A Simple Numerical Example for Integration of Water Accounts and Input-Output Tables

The schematic on the following page gives a simple numerical example for how to calculate water multipliers from a combined water and input-output account, for a hypothetical 3-sector economy.

First, accounts are set up as in 1). Then, the direct requirements matrix is calculated by dividing all entries by the total output as in 2). Then, this matrix is subtracted from a unity matrix I as in 3). Then, the resulting matrix is inverted, as in 4). The result of the inversion is the Leontief inverse, and total water multipliers, representing all upstream requirements. These can be used in impact studies, such as the water impact of a final demand bundle, as in 5).

Table 3. A Numerical Example for Intergrating Water Accounts and Input-output Tables

1) Hypothetical input-output table U including water account W and total output x

	Agriculture	Manufacturing	Services	Final demand	Total output
Agriculture	$10	$100	$10	$30	$150
Manufacturing	$30	$50	$40	$90	$210
Services	$10	$30	$30	$80	$150
WATER USE	10,000 L	250 L	50 L		10,300 L
Labour	$100	$30	$70		$200
Total input	$150	$210	$150	$200	$710

Financial data (in $)

Water data (in L)

2) Direct requirements matrix A
A = U / x

Direct water intensities
Q = W / x

	Agriculture	Manufacturing	Services
Agriculture	0.07 $/$	0.48 $/$	0.07 $/$
Manufacturing	0.20 $/$	0.24 $/$	0.27 $/$
Services	0.07 $/$	0.14 $/$	0.20 $/$
WATER USE	66.67 L/$	1.19 L/$	0.33 L/$
Labour	0.67 $/$	0.14 $/$	0.47 $/$

3) Subtraction from unity matrix
I - A
I - W

	Agriculture	Manufacturing	Services
Agriculture	0.93 $/$	-0.48 $/$	-0.07 $/$
Manufacturing	-0.20 $/$	0.76 $/$	-0.27 $/$
Services	-0.07 $/$	-0.14 $/$	0.80 $/$
WATER USE	-66.67 L/$	-1.19 L/$	-0.33 L/$
Labour	-0.67 $/$	-0.14 $/$	-0.47 $/$

4) Inversion: Leontief inverse
$L = (I - A)^{-1}$

Total water multipliers
$q = Q\,(I - A)^{-1}$

	Agriculture	Manufacturing	Services
Agriculture	1.29 $/$	0.88 $/$	0.40 $/$
Manufacturing	0.40 $/$	1.67 $/$	0.59 $/$
Services	0.18 $/$	0.37 $/$	1.39 $/$
WATER USE	86.46 L/$	60.83 L/$	27.90 L/$
Labour	1.00 $/$	1.00 $/$	1.00 $/$

5) Impact study: final demand bundle y

Water impact: q x y

	Final demand	Water
Agriculture	$3	259 L
Manufacturing	$15	912 L
Services	$9	251 L

5. Application of Water Accounts for Impact Analysis

5.1 International Studies

Input-output-based water multipliers have been calculated previously already in the late 1960s (Isard & Romanoff, 1967b,), and applied in an impact analysis for a hypothetical new town in Plymouth Bay, USA (Isard *et al*., 1967a). Victor (1972) presents an empirical input-output model of water use and waste disposal in Canada, 1961. Four types of water inputs were considered in a generalised commodity-by-industry framework. In a paper for the American Water Resources Association, Lee and Fenwick (1973) calculate input-output-based direct, indirect and induced effects of metallic compound pollutants. More recently, Lange (1998) incorporated water uptake data in her dynamic input-output model to assess the environmental implications of Indonesia's second long-term development plan.

Kim *et al.,* (2001) extend a two-region Korean input-output mode with data on waste and sewage water generated by industry and households, and also introduce a pollution abatement sector. Waste and sewage generation is linked to industry output, the number of employees, household income, and population, while the cost of the pollution abatement sector is covered by environmental taxes linked to flows of Biological Oxygen Demand. Environmental taxes also affect consumer demand through price increases, and in turn industry output and employment. The output of the model is a 'water quality' function that depends on the ratio of unabated pollutant flow over total water supply. The authors then present an empirical analysis of the objective of improving the water quality of the Han River to potability by increasing the pollutant treatment capacity financed by environmental taxes. Their results point towards reductions of overall industry output and employment that are caused by the reduced consumer demand due to the additional tax burden.

Duarte *et al.,* (2002) use the Spanish 'Satellite Water Accounts' in order to convert the Spanish input-output tables (24 sectors) into terms of water flows. They then apply the Hypothetical Extraction Method in order to determine 'internal' and 'external' effects of a hypothetical extraction of industry sectors, and backward and forward linkages of these sectors, in terms of quantities of irrigation water, drinking water and wastewater. Their study is not a practical impact study of a particular type of policy, but a more theoretical study of sector importance and sectoral interconnection, in terms of water.

5.2 Sydney University / CSIRO Water Use Input-Output Study

Lenzen and Foran (2001) dissect Australia's annual water use of 22,000 GL using input-output techniques, and show that 30% of Australia's water requirement was devoted to domestic food production and a further 30% to exports, compared with 7% required for direct consumption by households. They find a net annual trade deficit in embodied water of approximately 4,000 GL.

The authors re-classify water use data from the ABS' IOBIG classification to the more detailed IOPC. In accordance with practices applied during the compilation of the ABS Water Accounts, water use was prorated on a per-employee basis in service industries, on a per-hectare basis for zoos, parks and gardens, on a per-unit-of-turnover basis for manufacturing industries, and on a per-unit-of-production basis for mining industries (see Sections 4.1 and 4.2). Water usage classified in the ABS Water Accounts as "Stock Usage" (mostly in Queensland) was allocated to sheep and beef cattle. The Sydney University / CSIRO study made extensive usage of sectoral conversion coefficients provided by the ABS. The allocation in this study was ultimately based on source data purchased from the ABS.

An allocation across industry sectors according to the revenue of the IOIC industry "Water supply, sewerage and drainage" was not carried out because this would not map sectoral water usage, for two reasons: (1) only about 40% of this industry's revenue is from water supply, and (2) water prices vary considerably amongst using sectors (AATSE & EIEA, 1999, pp. 50-51). The input-output technique "re-allocates" water flows from producers to consumers, which is reflected in the two pie charts below.

The authors also derive National Accounts that are arranged as financial accounts, but expressed in 'embodied' water terms an in units of gigalitres (see example for mains water in table below, a similar table was compiled for self-extracted water).

Based on the ABS Household Expenditure Survey, Lenzen and Foran regress household water requirements against household expenditure and household size, and reveal a strong relationship between water requirement and household expenditure.

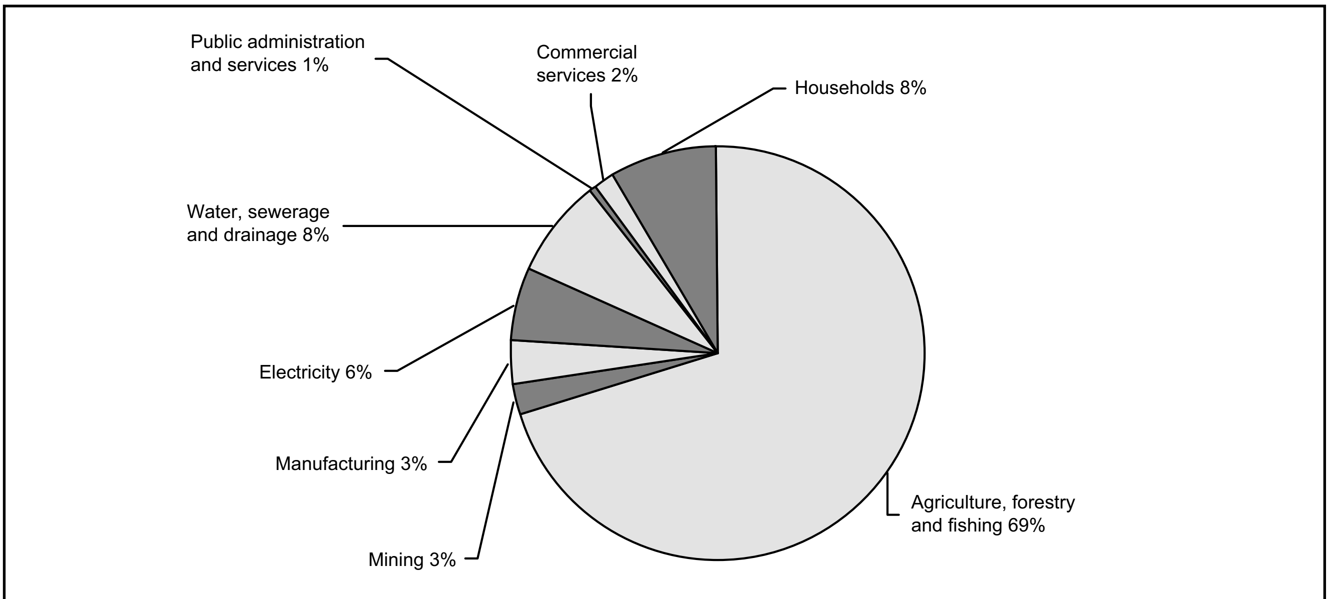


Figure 6. Breakdown of 1996-97 Australian Net Water Usage (22,186 GL) into Primary User Categories (Source: Australian Bureau of Statistics 2000).

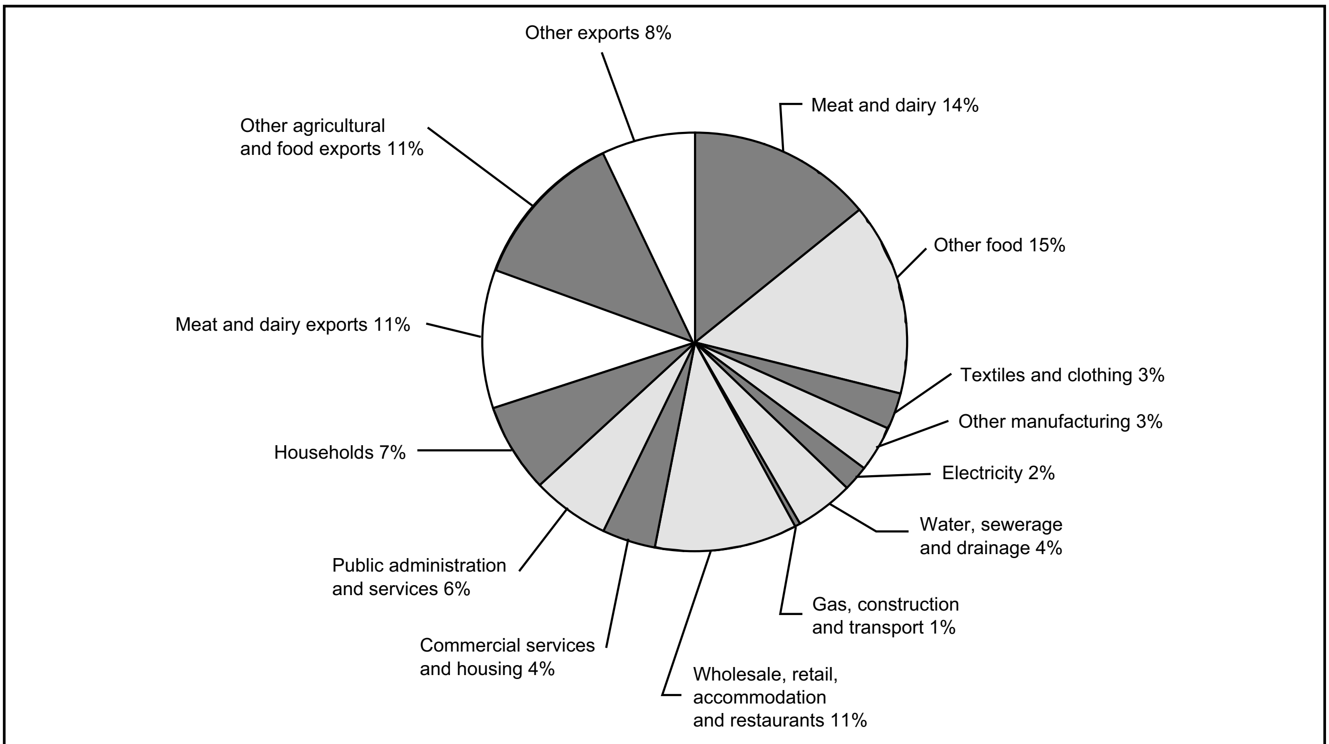


Figure 7. Breakdown of 1994-95 Australian Net Water Usage (21,537 GL) plus Water Embodiments in Imports (3,551 GL) into Final Consumption Categories. (after input-output analysis; Source: Lenzen and Foran 2001).

Table 4. 1994-95 National Mains Water Account
(all figures in GL, per-capita mains water use in L; Source: Lenzen and Foran 2001).

	Private Final Consumption	+ Government Final Cons.	+ Changes in Stocks	= GNE	+ Exports	= GNT	- Consumer Imports	- Imports into Stocks	- Industrial Imports	= GDP
Sheep and shorn wool	2.0	0.0	-45.1	-43.1	293.3	250.1	0.0	0.0	0.0	250.1
Grains	9.4	0.0	-39.7	-30.3	164.4	134.1	0.2	0.6	11.6	121.7
Beef cattle	19.9	0.0	55.7	75.6	84.9	160.5	0.0	0.0	0.0	160.5
Fruit and vegetables	431.5	0.0	-19.2	412.3	91.1	503.4	23.6	-7.4	63.6	423.6
Other agriculture	31.1	23.3	-13.4	41.0	112.7	153.6	0.5	0.0	3.0	150.2
Forestry	0.1	2.8	0.0	2.9	0.2	3.1	0.0	0.0	0.1	3.0
Fishing	14.1	1.6	0.0	15.7	7.1	22.8	0.5	0.0	0.3	22.0
Coal mining	0.1	0.0	-1.3	-1.2	27.4	26.2	0.0	0.0	0.0	26.1
Crude oil, natural gas and LPG	1.4	0.0	-2.4	-1.0	10.6	9.6	0.0	-1.2	11.5	-0.8
Other mining	0.1	0.5	-2.1	-1.5	45.2	43.8	0.0	2.6	2.2	39.0
Meat products	839.1	0.0	21.2	860.3	884.4	1744.7	13.0	0.6	7.2	1723.8
Dairy products	1280.6	0.0	-13.0	1267.6	640.4	1908.0	74.7	12.1	33.1	1788.1
Sugar	306.8	0.0	1.0	307.8	184.1	492.0	68.4	2.8	8.0	412.8
Other food products	1165.5	0.0	14.3	1179.8	294.2	1474.1	110.5	1.0	64.7	1297.8
Alcohol and tobacco	142.7	0.0	26.1	168.8	148.3	317.1	53.4	3.8	132.6	127.4
Textiles and clothing	365.6	0.0	6.3	371.9	146.8	518.6	146.3	1.9	172.2	198.2
Saw mill products	0.6	0.0	0.1	0.7	4.2	5.0	0.3	0.1	9.3	-4.7
Paper products	43.5	1.0	-4.4	40.1	7.5	47.6	9.9	-1.3	88.9	-49.9
Refinery products	14.6	0.0	2.7	17.3	4.2	21.5	1.8	0.6	8.4	10.8
Chemical products	58.7	23.1	6.3	88.2	33.8	122.0	17.6	3.3	127.0	-25.9
Non-metal construction materials	1.8	0.0	0.5	2.3	2.2	4.5	1.1	0.1	8.0	-4.7
Basic iron and steel	0.1	0.0	1.3	1.4	15.2	16.6	0.0	0.2	16.2	0.3
Aluminium	0.0	0.0	0.8	0.8	46.4	47.3	0.0	0.0	0.2	47.0
Other non-ferrous basic metals	2.7	0.0	-0.3	2.4	35.4	37.8	0.3	0.3	6.9	30.3
Metal products	4.1	0.0	0.8	4.9	5.2	10.0	1.6	0.2	14.4	-6.1
Motor vehicles	33.4	0.0	5.3	38.8	7.2	46.0	13.7	2.2	44.8	-14.8
Other transport equipment	1.3	0.0	-0.5	0.8	4.1	4.9	0.5	0.0	8.5	-4.1
Other manufacturing	75.0	0.0	5.7	80.7	27.4	108.1	36.8	4.2	141.9	-74.8
Electricity supply	33.8	1.2	0.0	35.0	0.2	35.2	0.0	0.0	0.0	35.2
Gas supply	1.4	0.0	0.0	1.4	0.0	1.4	0.0	0.0	0.0	1.4
Water supply	209.1	5.1	0.0	214.2	0.4	214.7	0.3	0.0	0.3	214.0
Construction	0.0	10.1	0.0	10.1	2.6	12.7	0.0	0.0	0.8	11.9
Wholesale and retail trade	672.1	0.1	1.8	674.0	54.4	728.4	4.4	0.0	0.0	723.9
Accommodation and restaurants	768.0	0.1	0.0	768.1	83.9	852.0	31.9	0.0	23.6	796.5
Road transport	15.3	3.1	0.5	19.0	7.0	26.0	1.2	0.0	0.2	24.6
Rail transport	10.1	2.4	-0.2	12.3	6.5	18.8	1.0	0.0	0.0	17.9
Water transport	1.1	0.0	-0.1	1.0	10.3	11.3	-0.9	0.0	8.7	3.6
Air transport	24.1	0.0	0.0	24.1	17.8	41.9	8.6	0.0	8.2	25.1
Ownership of dwellings [a]	193.6	-0.1	0.0	193.5	0.0	193.5	0.0	0.0	0.0	193.5
Commercial services	249.8	38.8	0.0	288.6	35.6	324.3	7.0	0.0	30.7	286.5
Public administration and service										

Notes: * Output of industry is rent for dwellings; GNE = Gross National Expenditure, GNT = Gross National Turnover, GDP = Gross National Product

Finally, conclusions are drawn from a water use perspective for water trade and reform, and water futures under population growth. A main finding is that if by 2050 Australia's population grows to 25 million people and per-capita expenditure doubles, the annual water requirement may more than double to 50,000 GL, equivalent to half the nation's water flows. The authors state that while this increase may be improbable it gives the challenge that the water required to deliver a unit of output across the whole economy may have to reduce by a factor of two, if population growth and economic growth are to meet policy expectations.

5.3 CSIRO Future Dilemmas Study

In their report to the Department of Immigration and Multicultural and Indigenous Affairs, Foran and Poldy (2002) apply the Australian Stocks and Flows Framework (ASFF) in order to forecast Australia's water future up to 2050. The ASFF is an iterative, user-controlled partial equilibrium model, that consists of 32 hierarchically nested modules covering different domains of the physical economy, such as demography, consumption, buildings, transport, construction, manufacturing, energy, agriculture, forestry, fishing, and mining. These "demographic-economic" modules are complemented by additional modules dealing with natural resources such as land, water and air. Population is the main driver in the model, and the model inherently determines requirements in terms of infrastructure, economic activity and resources, including flow-on effects. Some of the quantities demanded (minerals, energy etc) feed back into primary sectors, but these feedbacks are handled interactively by the user as 'control variables'. For example, tensions can occur between energy and materials demanded by productive expansion on one hand, and availability or environmental constraints on the other. At these tension points in the modelling process, the user decides on for example increasing capacity or international trade, or renders the scenario infeasible. The ASFF generates a temporal scenario in time steps of five years.

In terms of water, two scenarios are assessed in "Future Dilemmas": the base case and a 'water efficiency" scenario. The model was calibrated based on historical data taken from various water accounts (see Chapter 4). The base case scenario yields an increase of overall net water consumption from 22,000 GL/year in 1997 to 40,000 GL/year in 2050. The influence of population growth on this value is relatively small, i.e. in the order of a few percent. Much larger variations are caused by assumptions of technology and water efficiency. The authors estimate that a 30% reduction (i.e. to below 30,000 GL/year by 2050) can be achieved by exploiting technological opportunities for re-processing and saving urban water and reducing water losses in the irrigation system. The authors also point out the relative undervaluation of water in the economy, resulting in relative poor returns for exported commodities paid for with significant environmental degradation. These issues can serve to open a debate about more adequate water pricing.

6. Dynamic Aspects of the Water Accounts

In order to carry out analyses involving dynamic aspects, a time series is needed. In the case of Australian water accounts, this time series would have to be constructed from disparate data sources. In addition to this construction being quite time- and resource-intensive, attention would have to be paid to differing classifications, coverages, data quality, and missing data. Furthermore, the data in the ABS Water Accounts represents actual data, and therefore contains trends in the data that are based purely on climatic variations. In summary it appears that a sufficiently long time series could not be constructed from the ABS Water Accounts alone, and for a few decades probably only for an aggregate industry sector classification.

In any case, this time series would have to be complemented with a time series on input-output tables. These have undergone minor re-classification from any one year to the other, and a major re-classification in 1993. In addition, there are a number of years where an input-output table has not been produced at all by the ABS.

7. Recommendations

For the purpose of setting up a regional input-output model that is augmented with physical data on water use, the ABS Water Accounts (Section 3.5) and the CSIRO Australian water statistics (Section 3.6) are the most suitable data sources. If the water account was prepared at the IOPC level, it would be much easier to undertake impact analysis.

A regional input-output model that covers the Lower Murrumbidgee or the Goulburn-Broken catchment is likely to be strongly interlinked in monetary terms with the rest of the economy. As a consequence, in order to comprehensively capture indirect and induced effects on the local economies, it is important to model feedback loops. These feedback loops describe impacts that originate in the local area, but proceed via exports into the rest of the economy, and return to the local economy through imported goods and services. Feedback loops have been shown to be important even in the case of relatively weakly linked European national economies (Lenzen *et al.,* 2003).

Feedback loops are usually modeled using multi-region input-output models. In the case of a local Australian region such as the Lower Murrumbidgee or the Goulburn-Broken, a nested multi-region approach could be taken, as illustrated in the table below.

The table shows how the Murrumbidgee input-output table (lower left corner) becomes embedded in the input-output table for the rest of NSW, which in turn is embedded in the national (net) input-output table for the rest of Australia. As in conventional multi-region input-output modelling, trade matrices can be estimated using limited survey data, gravity coefficients, and the RAS technique.

Rest of Australia → Murrumbidgee	*Rest of Australia → Rest of NSW*	**Balance of Australia**
Rest of NSW → Murrumbidgee	**Balance of NSW**	*Rest of NSW → Rest of Australia*
Murrumbidgee	*Murrumbidgee → Rest of NSW*	*Murrumbidgee → Rest of Australia*

Figure 8. Schematic of Nested Multi-region Input-output Model for the Example of the Lower Murrumbidgee; Trade Matrices in Italics

8. Conclusions

Water is a unique resource in the sense that there is a general lack of adequate monetary valuation in the market, and a paucity of water use statistics. In an economy with important agricultural sectors such as Australia, water is of key importance for policy making. In addition, Australia is of the driest continents, and experiences a spatially and temporally highly variable rainfall, recurring droughts, leading to a relatively unpredictable water supply.

In order to integrate environmental and economic data, Australian Water Accounts have been developed, following the guidelines in the United Nations' Integrated Environmental and Economic Accounting framework, which is a complement to the System of National Accounts (SNA). Water accounts provide a mechanism to tie together data from different sources such as Australia's National Accounts and other natural resource data sets, into one consolidated environmental account. The advantage of such an environmental account is that by linking together physical data and monetary data in a consistent framework it is possible to undertake impact modelling.

Current Australian water accounts should be treated as experimental and be viewed in light of the assumptions that have been made during their compilation process. These assumptions lead in some cases to systematic errors and considerable uncertainties.

Acronyms

ABS	Australian Bureau of Statistics
ANCID	Australian National Committee On Irrigation And Drainage
ASFF	Australian Stocks and Flows Framework
AWRC	Australian Water Resources Council
GDP	Gross Domestic Product
GL	Gigalitres
IOBIG	Input-Output Broad Industry Group
IOPC	Input-Output Product Classification
ML	Megalitres
NAMEA	National Accounting Matrix including Environmental Accounts
NLWRA	National Land and Water Resources Audit
NSW	New South Wales
SNA	System of National Accounts
SAM	Social Accounting Matrix
WRC	Water and Rivers Commission

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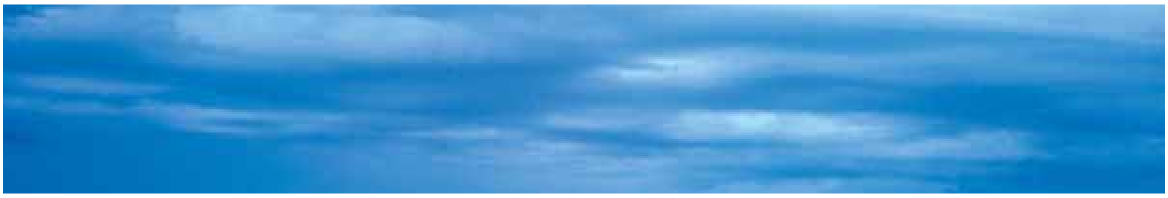

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