The University of Sydney
AUSTRALIA

The Virtual Water Cycle of Victoria

Dam of the Clunes Water Supply

Harris Dam near Collie, WA

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Integrated Sustainability Analysis ™

The Virtual Water Cycle of Victoria

Results of consultancy work

undertaken in collaboration with GHD Pty Ltd

for the Smart Water Fund & The Victorian Water Trust

by Manfred Lenzen, ISA, The University of Sydney

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1 Project Objective

This work seeks to define and quantify the virtual water Cycle for Victoria. virtual water is the water embodied in all products and services consumed in Victoria, rather than merely the direct water used.

An understanding and improvement in efficiencies in our virtual water use has the potential to provide significant water saving leverage, and to affect water use beyond the boundaries of the State over the longer term.

In particular, this project aims to enhance the understanding of the link between irrigation water use and the consumption of Victoria's residents, and to provide improved awareness that lifestyle and consumption in the urban setting has a direct affect on how water is used throughout the whole of Australia, and to reinforce the message that improved rural water management is not a problem for farmers alone to tackle.

The project meets the *objectives* of the Victorian Water Trust:

- *Enhance the health and sustainability of the water resources of Victoria* – an understanding of virtual water use by Victorian residents can have a positive impact on water use beyond the city boundary.

- *Provide greater security for meeting the future water needs of Victorians* – the virtual water cycle means that Victorians can think of all water use not just urban water use.

- *Improve efficiencies in the use of water across Victoria* – by considering virtual or embodied water use, Victoria's residents will have a vested interest in improving efficiencies in the amount of water used to produce the goods and services they consume.

- *Generate additional investment from sources other than the State Government* – industries who have a good understanding of the amount of water involved in their supply and production chains will have an incentive to reduce virtual water use to minimize the business risks associated with water shortage.

2 Approach

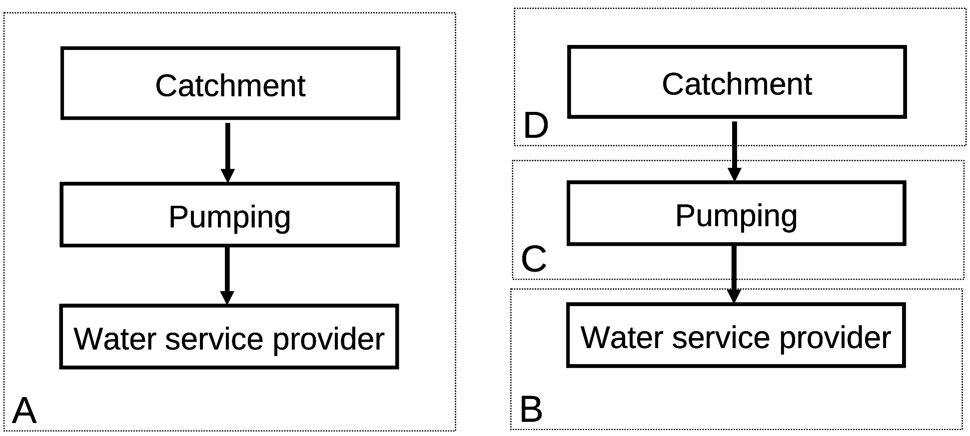
2.1 Supply-chain accounting

The methodology used in this work is based on the national TBL report *Balancing Act* (http://www.isa.org.usyd.edu.au/publications/balance.shtml). The Balancing Act study extends previous TBL studies because of the fact that it looks at the *entire life-cycle* of the impacts of economic activities. Balancing Act distinguishes two types of impacts of economic activities: Some impacts occur within the premises of an organisation employing a certain type of production or technology: for example, the use of natural gas which generates CO_2 emissions when being combusted. They are called *direct*, or *on-site* impacts. Some other impacts occur off-site: this happens because inputs that an organisation purchases for the operation of its technologies were produced by other organisations (its suppliers), causing impacts within their premises. These impacts are called *indirect* impacts. Generally, what an organisation does within its premises causes impacts throughout a multitude of upstream suppliers, spread across the whole country, and even overseas. Accounting for all these indirect, upstream impacts is usually referred to as a *life-cycle assessment*. The ISA methodology applied in this work is based on a complete life-cycle assessment of organisations' or sectors' impacts.

2.2 Indirect impacts

Why should organisations or sectors report all indirect impacts? Including indirect impacts into an organisations' sustainability report means that the figures reported are higher than they would be if only on-site impacts were reported. So why do this? There are at least five good reasons to do this:

1) To enable meaningful benchmarking
Imagine you are a working for a water suppliers' association, and you wanted to benchmark various urban water suppliers. Assume water supplier A manages the catchment, pumps water into urban areas, and distributes and bills customers; A is said to be vertically integrated. Assume D in another region manages the catchment, and C sells bulk water to B, which distributes and bills. The commodity 'water' is ultimately delivered by A and B, but comparing A and B on a per-litre-of-water basis will likely to result in B having a much smaller impacts, simply because its on-site operations are more limited. It is clear that a comparison of A and B is only meaningful if upstream supply-chains are included.



2) To avoid loopholes in reporting

The TBL Reporting guidelines of the Global Reporting Initiative do not require an assessment of indirect, upstream impacts. Imagine you worked for water supplier A and realised that the figures in the annual sustainability report of your competitor B2 are much smaller. If you were concerned about losing a competitive edge because of the negative image cast on your operations, you could simply change the structure of your business, and outsource or demerge into A1 and A2, with A2 taking care of your catchment and the pumping. All of a sudden, the new A1 would look much cleaner and greener, even though operations haven't changed at all! This obviously doesn't make sense, and constitutes a loophole which sooner or later must be plugged. Supply-chain accounting will treat A and B in the same way, whether they source from company-internal or –external supply chains.

3) To reward and encourage the greening of supply chains
Imagine you worked for water supplier A, and you were thinking about how to improve your environmental performance. You know that your pumps use up a lot of electricity causing greenhouse gas emissions which feature in your (GRI-type) sustainability report. However, replacing pumps with better ones is very expensive. You know that your purchases of basic chemicals entails a lot of embodied emissions, and you might have thought of a way to drastically reduce the use of chemicals for a particular water treatment process. However, there is no incentive to do so, because emissions embodied in the chemicals you buy are an indirect, upstream impact, and not asked for in GRI-type reports. You forgo this effective and economical way of reducing your impact; your choice of abatement options is restricted to on-site measures, which may not be the low-hanging fruit you were looking for. Supply-chain accounting shows you which measures give you the best improvements for the least cost, upstream or on site.

4) To increase attractiveness to customers
Imagine if everybody reported including all upstream impacts. Not only would you be rewarded for measures that greened your supply chain, but also by greening your own business you will look more attractive to existing and potential customers, because your on-site impacts would appear as upstream impacts in their sustainability report. That's why it's in your customer's interest to switch from their existing suppliers to your company.

5) To inform about real risk
Imagine you talked to a manager of an ethical investment portfolio. You hear that no urban water supplier is included in the portfolio. When companies were screened, water suppliers became ineligible because of their high greenhouse gas emissions stemming from water treatment processes. These emissions were seen as a financial risk under anticipated greenhouse taxes. You find that many manufacturing firms are part of the portfolio, and that some of these use large amounts of aluminium. You look up how much electricity is needed to make aluminium, and estimate the greenhouse gases embodied in manufactured aluminium. To your surprise you find that some of the manufacturing firms create a higher greenhouse burden than your own water company A, and therefore are associated with a higher financial risk under future greenhouse taxes. The only difference is that the manufacturing firms' risks are "hidden" in their upstream supply chains, which the investment manager overlooked. Supply-chain accounting reveals hidden risks.

Supply-chain issues for Corporate Sustainability Reporting are becoming increasingly topical, which is reflected for example in a quote by the World Business Council on Sustainable Development. Sustainable Development Reporting ([1], p. 55):

"Current reporting practices are often performed within the boundaries of the reporting organization. In the coming years, it is likely that companies will increasingly report across the value chain. This will represent a new challenge in terms of reporting on the upstream (supplier related) issues linked to human rights, environmental and societal impacts, and also of coping with the wider downstream (consumer related) impact of products and services".

2.3 Analysis

In this work we link the *Water Accounts* of the Australian Bureau of Statistics and the Australian *input-output tables* into a sophisticated model. By linking together physical data on water and monetary data it is possible to undertake life-cycle impact and trade flow modelling throughout the entire supply-chain system of the Australian economy.

2.3.1 Water accounts within the environmental accounting framework

According to the Australian Bureau of Statistics [2], "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 modeling. Issues that could be modeled 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 shows who is supplying water for use, and a use table shows who is using water. The data are expressed as physical quantities (megalitres).

2.3.2 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 [3]. 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 [4] 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, which are commodities that are imported into Australia and then exported without having been used or transformed.

2.3.3 Input-output analysis

Input-output analyses of economic interdependence rely only on National Accounts that are regularly published by statistical bureaux, and have 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 [5], p.1, see also Rose [6], 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" ([7], p. 12).

As Leontief ([8], 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 [9], [10] and [11]).

The history of methodological developments has been reviewed by Stone [12], Polenske [13], Carter and Petri [14], Forssell and Polenske [15], and Rose and Miernyk [16]. Introductions into input-output theory can be found in work by Leontief [8, 17], Stone [18], Duchin [19] and Dixon [20].

The increasing availability of sectoral environmental data in physical units has enabled the practical application of Leontief and Ford's [21] original suggestion of a combined financial and environmental-physical input-output account. In theory terms, and following a classification by Miller and Blair [22], 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*. 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 – such as water, 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 [15], Isard and co-workers [23], Polenske [24], Cumberland and Stram [25], Miller and Blair [22], Førsund [26]), and Hawdon and Pearson [27]. They have been applied extensively since the late 1960s.

2.4 Calculation of the Victorian virtual water Cycle

In this study, Victoria's virtual water Cycle is enumerated by calculating *water intensities*. Using Water Accounts and input-output tables, these water intensities are calculated according to the methodology outlined in the CSIRO / Sydney University Triple Bottom Line report *Balancing Act* ([28], http://www.isa.org.usyd.edu.au/publications/balance.shtml). In addition to the methodology applied to calculate water intensities in *Balancing Act*, there are a number of areas where this work has overcome shortcomings of the previous methodology:

- a completely new, updated data set was used, relating to base years between 1998 and 2001, instead of 1994-95 for the Balancing Act study;
- an extended industry classification was used, distinguishing 344 industry sectors instead of previously 135;
- the national input-output framework was disaggregated into all 8 States and Territories.

3 Calculation Methodology

3.1 Data collection and processing

Water is a resource for which there is often a lack of adequate monetary valuation in the market and a paucity of high quality water use statistics. In economies 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, particularly in southern Australia where the majority of the population resides and agricultural production occurs. The need for adequate water data is therefore recognised by the Australian Bureau of Statistics, who put significant effort into compiling Water Accounts.

3.1.1 Data sources

In this work we made use of water data specific for Victoria in the Australian Water Accounts [29]. However, in order to calculate intensities that form the input for the IO-analysis, monetary companion data on gross output has to be sourced for Victoria as well. These companion data have to match the water data, in their classification, and scope, so that derived intensities are meaningful. It is this two-fold matching requirement that will ultimately determine the detail of the final results. Finally, in order to specify trade in and out of Victoria, the national economy and national water use has to be appraised. Summarising, within this work, a range of data sources were used. They are

for primary water data:

- Australian Bureau of Statistics (2004). *Water Account for Australia 2000-01*. ABS Catalogue No. 4610.0, Australian Bureau of Statistics, Canberra, Australia [29];
- Australian Bureau of Statistics (2002). *Domestic water use NSW*. ABS Catalogue No. 4616.1, Australian Bureau of Statistics, Canberra, Australia [30];
- Australian Bureau of Statistics (2006). *Water Use on Australian Farms 2002-03*. ABS Catalogue No. 4618.0, Australian Bureau of Statistics, Canberra, Australia [31];
- Tailored water data purchased previously by the University of Sydney from the ABS;

for water proxy data:

- Australian Bureau of Statistics (2005). Australian National Accounts, Input-Output Tables, 1998-99, Commodity Details (Sales data on water services). Electronic file (unpublished) [32];
- Australian Bureau of Statistics (2001). Integrated Regional Data Base. Electronic database (unpublished), Australian Bureau of Statistics [33];
- Australian Bureau of Statistics (2000). 1998-99 Household Expenditure Survey - Detailed Expenditure Items, Expenditure on Water, Confidentialised Unit Record File. Electronic file (unpublished), Australian Bureau of Statistics, Canberra, Australia [34];

for monetary companion data to calculate intensities:

- Australian Bureau of Statistics (2004). *Australian National Accounts, Input-Output Tables, 1998-99*. ABS Catalogue No. 5209.0, Australian Bureau of Statistics, Canberra, Australia [35];

- Australian Bureau of Statistics (1998). *Business Register Counts 1998*. Customised Report No. 98/, Australian Bureau of Statistics, Canberra, Australia [36];
- Australian Bureau of Statistics (2001). *Business Register Counts 2001*. Customised Report No. 01/, Australian Bureau of Statistics, Canberra, Australia [37].

3.1.2 Detail of disaggregation in the industry and product classification

There are a range of prorating techniques that can be used to disaggregate the existing water accounts:

1) The University of Sydney has purchased additional water data from the ABS.

2) There exists monetary proxy data detailing water services deliveries for at least 109 sectors.

3) There exist more detailed breakdowns of water use on farms.

4) The ABS keeps IO data on more than 1200 sectors. However only 344 of these sectors have non-confidential data, hence the upper limit of 344.

The upper limit of any sectoral breakdown is hence given by the maximum non-confidential sectors in the detailed unpublished ABS IO data, which is 344 sectors. The final number of sectors is mainly be determined by the quality of monetary companion data on Gross State Output (GSO) by industry sector. The latter data are essential to calculate intensities that form the basis of the input-output analysis.

3.1.3 Differentiation between by industries and products

Most water data - and this holds in general for physical data, for example energy, GHG emissions etc - is available by industry sector. The ABS tables are initially published as 'Supply' and 'Use' matrices showing both commodities and industries. These two matrices will be combined to form an industry-by-industry flow matrix, which will then be used for inversion and embodiment / virtual water calculations.

Note that previous calculations comparing commodity and industry intensities did not yield significantly different results. This is because the IO tables are constructed in a way that minimises joint production. In more technical words: The ABS Supply matrix is almost completely diagonal.

3.2 Integrating ABS Water Accounts and input-output tables

There is an enormous body of literature on what is often referred to as *generalised input-output analysis*, a stream of research based on Leontief's initial idea [21], seeking to integrate input-output data with sectoral industry data external to the input-output system. Such integrated accounts have been employed in numerous impacts studies. In order to use Australian water use data for such analyses, they first have to be aligned with the industry classification in the Australian input-output tables. This problem is far from trivial, as it involves the reconciliation of disparate data sources, featuring varying definitions, base years, and classifications.

The following Section describes the integration procedure followed in this work, of the ABS Water Accounts, which are the most detailed data source for the purpose of integration with the ABS 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” [29].

3.2.1 Integration of disparate data sources

Before embarking on potentially protracted computations, it is useful to carry out a careful design of an integration strategy. Based on available data, this strategy involves considering

- the aspired level of overall sectoral detail,
- proportionality assumptions underlying pro-rata techniques,
- the degree of inconsistency in the raw data,
- concordances between different classification systems, and
- balancing methods to be employed.

3.2.1.1 Choice of level of detail

The IOBIG classification of the ABS Water Accounts is more aggregated than the published IOPC input-output model. The integration of the ABS Water Accounts into an input-output framework would be straightforward if the input-output model was aggregated to IOBIG level. This reduction in resolution however would severely limit the capabilities of the resulting model for impact analysis and decision-making. Especially, if additional indicators (energy, land, etc) are to be integrated into a comprehensive Environmental and Economic Accounts System, it is desirable to compile the system of accounts at the maximum level of detail, and aggregate the results after impact analysis if necessary.

Working at a high detail is desirable because it is likely that physical data on different indicators contains varying detail for different industry sectors. For example, energy data is likely to be detailed for energy-intensive metal sectors, while employment data is likely to be detailed for service sectors, both of which often do not feature detailed water use data. A consequence of this strategy is that some disaggregation can be achieved only through prorating according to proxy variables (see the following Section). Such prorated data is of course not very accurate. However, sectors affected by prorating are also not likely to be important in terms of their contribution to overall flows. Hewings and co-workers [38] have shown that large uncertainties occurring even in a large number of small elements of input-output tables hardly affect the magnitude of multipliers. Hence, there is no penalty in keeping a large number of uncertain but small data, as long as important (large) data items are sufficiently accurate, and as long as uncertain data are either aggregated or clearly marked in the presentation of subsequent impact analysis results.

A practical example may highlight the importance of working at the highest possible detail: Consider the embodied water passed on from bauxite mining to aluminium smelting. Assume that bauxite mining was aggregated with gold mining operations needing less water, and that gold processing was part of the non-ferrous metal sector, together with aluminium. In an aggregated framework, considerable embodied water would be passed on to gold processing, even though gold mining used only little water. In a disaggregated analysis, this embodied water would only affect aluminium. Even if both sectors were aggregated after impact analysis, the results would be different from those of an aggregated impact analysis, because of the different downstream sales structures of bauxite and gold mining. An empirical study demonstrating this effect is Reference [39].

Recent work by the ISA[1] group at the University of Sydney has set the task of creating a standardised procedure to generate the most detailed generalised regional input-output framework possible. Choices of detail had to be made with respect to the industry classification, and the spatial delineation.

In Australia, industry classification detail is mainly limited by confidentiality of the IOPC8[2] classification of the ABS. ISA researchers have identified that when using all non-confidential input-output data over a period of about 30 years, a maximum of 344 classes can be distinguished. In the following, this classification is referred to as ISA Product Classification (ISAPC). The existence of auxiliary economic and physical data at the regional level allows a disaggregation of the framework for all 8 States and Territories.[3]

3.2.1.2 Proxy data

In Australia, physical data are generally more aggregated than economic data. Hence, disaggregation is necessary, based on prorating via proxy quantities. The ABS Water Accounts provide an example for such proxies: water use is assumed to be proportional to

- irrigated area for the agricultural sectors,
- material flow for the mining sectors,
- turnover for the manufacturing sectors,
- employment for the service sectors.

These assumption were followed in all integration procedures. The proxy data sources are

- Australian Bureau of Statistics (2005). Australian National Accounts, Input-Output Tables, 1998-99, Commodity Details (Sales data on water services). Electronic file (unpublished) [32];
- Australian Bureau of Statistics (2001). Integrated Regional Data Base. Electronic database (unpublished), Australian Bureau of Statistics [33];
- Australian Bureau of Statistics (2000). 1998-99 Household Expenditure Survey - Detailed Expenditure Items, Expenditure on Water, Confidentialised Unit Record File. Electronic file (unpublished), Australian Bureau of Statistics, Canberra, Australia [34].

3.2.1.3 Concordances, data inconsistencies and balancing methods

Much of the auxiliary data (business registers, integrated regional databases, State Greenhouse Gas Inventories etc) are classified in different classification systems (for example ANZSIC[4]), requiring concordance matrices to be defined. The concordance between classification systems can be calibrated if national data is available in both systems, however this calibration problem is underdetermined, and requires the application of RAS balancing routines.

Many of the physical data available in Australia are conflicting, due to sampling and/or rounding errors, or due to differences in definitions or base years. For example, ABARE energy data by State by sector by fuel type by equipment type [40] may add up to different subtotals, depending on whether sums over States, equipment types, fuel types, or sectors are summed. Data often refer to different years. Strictly speaking, a temporal misalignment of surveys calls for a simultaneous

[1] Integrated Sustainability Analysis (http://www.isa.org.usyd.edu.au).
[2] Input-Output Product Classification, 8-digit.
[3] New South Wales, Victoria, Queensland, Western Australia, South Australia, Tasmania, Northern Territory, Australian Capital Territory.
[4] Australian and New Zealand Standard Industry Classification.

balancing procedure of all data over all periods, imposing certain temporal stability conditions (compare [41]).

Conflicting data causes conventional RAS balancing techniques [42] to oscillate, thus preventing convergence. The more serious the data discrepancies, the more imperfect the final RAS result. Such non-convergence can only be dealt with using optimisation techniques. These techniques have been the subject of recent issues in the expert literature (notably *Economic Systems Research*), and shall not be dealt with further here.

3.2.2 Integration of State Water Accounts into ISAPC

The challenges of a practical integration procedure are perhaps best illustrated using a real-world example. Creating water accounts for all Australian States and Territories at the ISAPC sectoral detail requires the following actions:

- Estimate Gross State Output (GSO) data by ISAPC:
  - Extract number of business locations by State by turnover range by ANZSIC from the 2001 Business Register [37],
  - Estimate not provided ("n.p.") entries using RAS,
  - Estimate (unknown) turnover by State by ANZSIC from (known) number of business locations by turnover range, by fitting a piece-wise continuous, strictly positive business-number-density functions consisting of quadratic and cubic spline functions across discrete turnover ranges, and finally integrating these density functions over turnover,
  - Calibrate an ISAPC-ANZSIC concordance matrix using existing turnover / gross output data in ANZSIC and ISAPC for the whole of Australia, and apply this concordance matrix to State data; the definition of "turnover" and "gross output" may differ slightly although totals were in the same magnitude.
- Estimate employment by State by ISAPC:
  - Extract employment by State by ANZSIC from the 1998 Business Register [36],
  - Estimate not provided ("n.p.") entries using RAS,
  - Calibrate a new ISAPC-ANZSIC concordance matrix using employment data classified in ANZSIC and ISAPC for the whole of Australia, and apply this concordance matrix to State employment data.
- Estimate material flow data by State by ISAPC:
  - Extract material flow data from the 2004 Commodity Statistics ([43]).
- Use GSO, employment and material flow data as proxies in order to create an initial estimate for water use by State by ISAPC, by prorating water use across disaggregated sectors (see 3.2.1.2).
- Reconcile the initial estimate with all available constraints derived from survey data such as ABS Water Accounts:
  - Use ABS Water Accounts to formulate constraints on the detailed ISAPC Water Accounts, and use these constraints as an input for a RAS balancing routine.
  - RAS-balance the initial estimate based on constraints on total sums over water use by sector, and by State, or based on sub-totals over certain sectors; terminate RAS when results do not converge any further, that is, when conflicting constraints cause oscillation.
  - Apply optimisation to find the best compromise between conflicting constraints, based on uncertainty of the survey data. For example, if for a certain subtotal, one constraint prescribes a value of 50ML±10%, and another constraint prescribes 70ML±25%, the optimised constraint may be 55ML.

3.2.3 Uncertainties

GSO was calculated from Australian Business Register (ABR) data on Business Locations by ANZSIC4 by State by Turnover Range [36]. The ABR does not provide turnover figures, but only *the number of establishments by turnover ranges*:

ABR turnover bracket	1	2	3	4	5
ABR range	< $50k	$50k-$100k	$100k-$1m	$1m-$20m	> $20m
Range used in this work	$5k-$50k	$50k-$100k	$100k-$1m	$1m-$20m	$20m-$200m

The lower turnover range boundary in bracket 1 and the upper range boundary in bracket 5 have to be set. In practice, these setting will influence overall (national) Gross Turnover (Gross output), with the upper boundary having a much larger influence than the lower boundary. The upper boundary can be set so that the sum over all balanced turnover brackets over all states and industries equals the Gross Output according to the ABS' input-output tables. This requirement leads to a value of $200m.

In order to estimate Gross Output, the size distribution within each turnover bracket has to be known, but is not supplied with the Australian Business Register. Therefore, the internal size distribution must be estimated from the size distribution across the entire turnover ranges. This estimation procedure introduces an uncertainty in the GSO figures. It would be useful to have available better monetary data on GSO, so that the estimation procedure described above can be circumvented.

There is a lack of information on inter-state trade flows, for example in the State Accounts [44]. Fortunately, this circumstance is well known amongst regional scientists, and a number of data recovery techniques have been established during intensive research over the past 4 decades: The topic of inter-regional trade has been prominent in the Regional Science literature for a long time. Intra-national regions usually show a much stronger interdependence on trade (than say nations between each other), because of a multitude of reasons such as transport distances, technical standards, currency exchange issues, language and negotiation, protectionist domestic policies, etc. When it comes to regional dynamics, inter-regional trade is likely to be a defining feature of industrial ecosystems. This is especially true for Australia, where the eight States and Territories exhibit considerably different endowments in resources and production factors.

In this work we have used various well-established historical assumptions, such as the commodity balance, supply-demand pools, location quotients, cross-industry quotients, and gravity model principles that have been used for model building in Regional Science in order to estimate missing data on regional production coefficients and inter-regional trade. We use these approaches to arrive at a multi-regional inter-industry input-output flow matrix for Australia. By querying the consistency of this estimate with constraints imposed by superior data (such as the State Accounts), we are able to construct a regional input-output system that best describes real Australian inter-industry inter-regional trade flows. Nevertheless, once again it would be useful if better data for inter-state trade flows could be taken into account.

3.2.4

Summary: Shortcomings and future challenges

The procedure sketched above may give a feeling about how involved the reconciliation of more than two or three disparate data sources can be. A number of issues require further attention:

a) in theory, there should be only one concordance matrix between two classification systems, for example ISAPC and ANZSIC. However, attempts to estimate such a matrix using cross-calibration of two national data sets (turnover and employment) generated to substantially different concordance matrices, hence either employment and/or turnover in one or both classification systems must be associated with significant errors.
b) RAS balancing techniques do not work when data are conflicting. Often, analysts trace inconsistencies manually, and/or make subjective selections based on data quality. Optimisation techniques can greatly assist and streamline previously manual adjustments to conflicting survey data.
c) Based on ISA's experience, even optimisation techniques exhibit convergence problems if the initial estimate is vastly different from the required reconciled value. More research into the behaviour of adequate target functions and optimisation algorithms is needed.
d) Faced with numerical problems such as above, an effort could be made to streamline data collection by using only one classification system. At present, the lack of such harmonisation is ubiquitous, not only for Australian data, and has been deplored by analysts for a long time [45].
e) There is a lack of monetary data on inter-state trade flows.

Integrated environmental and economic accounts can be created, using some of the sophisticated techniques described above, but under considerable effort. Overcoming only some of the above obstacles would greatly enhance both accuracy and timeliness of integrated accounts, and hence relevance for impact analyses such as described in the following.

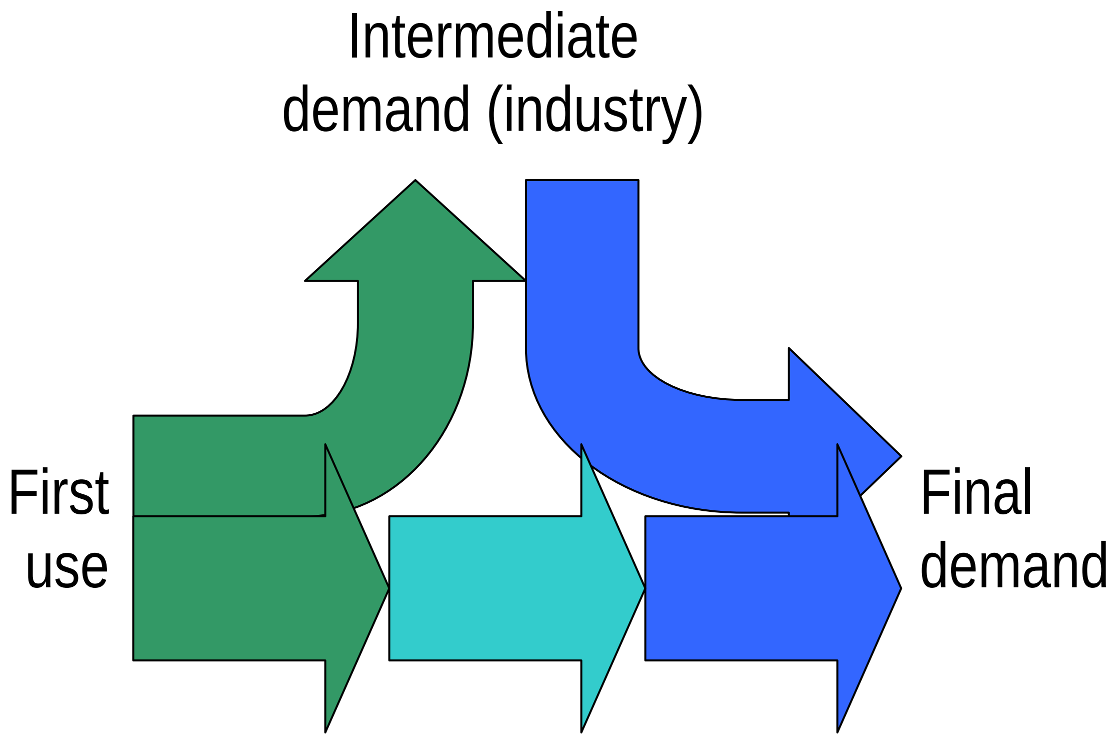
3.3 Calculating intensities

As in the widely publicised Triple Bottom Line (TBL) Report *Balancing Act* (http://www.isa.org.usyd.edu.au/publications/balance.shtml), this report uses the well developed analytical approach of 'generalised input-output analysis' to develop numerate water accounts for the State of Victoria. Water data are developed as *intensities*, that is, per one dollar of final demand, which is roughly one dollar spent for consumption in everyday life. Water intensities are generated with a supply chain approach where all activities are included or 'embodied' in the final indicator number. A detailed mathematical exposition of the project methodology can be found in the Appendix. The average water intensity for the economy as a whole is 41 litres per dollar.

No sector should be 'expected' to equal the economy wide average given the diversity of sectoral structure and function throughout the economy. Service sectors such as banking, insurance and finance have lower than average water intensity, while agricultural sectors have above average water intensity.

4 Understanding virtual water flows

virtual water use is different from direct water use, because the consumer cannot see virtual water. Once used in production, it becomes embodied in commodities for consumption. In the economy, there are two groups of consumers: *intermediate* consumers and *final* consumers. The National Accounts define intermediate demand as the inputs into production. Intermediate consumers are hence companies, farms, service providers, etc. Final demand[5] is defined as the consumption of private households, the government, stocks and long-term investment, and exports. For the purpose of analysing virtual water flows, it is important to understand that virtual water is passed on between intermediate consumers (ie companies supplying each other), until it reaches a final consumer, where the virtual water flow ends.



Water is extracted from underground and surface water bodies, and delivered metered or unmetered to the first industrial user, for example a dairy producer. This dairy producer "embodies" water into dairy products that are then sold to customers ("demanders"). The embodied water flows either to other industries such as restaurants or retail (intermediate demand; upper green arrow), or it flows straight to households, the government etc (final demand; lower green straight arrow). To produce dairy products for households etc requires water inputs not only by the dairy industry (lower blue arrow), but also by numerous other industries in the supply chain of those dairy products (upper blue arrow).[6]

The following Sections 4.1 to 4.3 covers these three perspectives in detail. They are:

[5] In this report we use the definition of final demand as "final" in the short term. This definition includes consumption for investment, because in the short term, or current account, investment is final. There is a formulation of the National Accounts where investment is endogenised as intermediate demand. This formulation is used for long-term analyses. In general, National Statistical Agencies (such as the ABS) do not publish the information required to endogenise capital investment, so that the short-term formulation will be used here.
[6] The same three-tiered decomposition is used in the Triple Bottom Line report *Balancing Act*.

1. Water used *within one industry* to produce its particular product *for intermediate and final demand* (green);
2. Water used *within one industry* to produce that product *for final demand only* (turquoise; part of green, and simultaneously part of blue);
3. Water used *within all supply-chain industries* to ultimately produce that product *for final demand only* (blue, includes turquoise).

Perspective 1) depicts virtual water as one-step flows between all (intermediate and final) consumers. Perspective 2) depicts one-step flows ending only in final consumers. Perspective 3) depicts multi-step *supply-chain* flows ending only in final consumers.[7] Flows of type 1) and 2) are called *direct* flows, those of type 3) *total* flows.

Both the green and the blue arrows include the turquoise arrow. Whether perspective 1) or 3) leads to a larger water use depends on which water flow is higher: a) the direct water used by the dairy industry to produce for other industries, or b) the total water needed by all other (supply-chain) industries to ultimately produce dairy products for final demand. The Triple Bottom Line report *Balancing Act* lists many cases in which either the portion a) or the portion b) is the larger one.

4.1 Direct virtual water flows

Figure 1 depicts direct virtual water flows out of Victoria. Victorian producers use water to produce goods and services. Some of these are used within Victoria, and some are used by either producers (intermediate) or households (final) in other States. For example, a Victorian dairy farm produces milk, say for a South Australian dairy products manufacturer, and for South Australian households, amongst others. The irrigation water is embodied in the milk delivered from Victoria to South Australia. The blue arrows represent these virtual water flows.

Note that the South Australian dairy manufacturer is probably going to deliver dairy products further on, to restaurants, retailers or households. While the virtual water flow from Victoria directly to the South Australian households ends there (final consumer), the virtual water flow to the South Australian dairy manufacturer is going to continue, perhaps into other States, or even back into Victoria.

However, this is not traced any further in Figure 1. Since this Figure contains only direct flows, the ongoing flow from the South Australian dairy manufacturer belongs as a direct flow to South Australia, and not to Victoria. Such flows are depicted in Figure 2. This figure contains only those flows that terminate in Victoria, either in a Victorian company, farm, etc, or in a Victorian household.

In Figure 1 and following figures, the use of arrows shall signify that a virtual water flow may terminate with an intermediate consumer, and thus may continue to one or more further destinations. The arrow leaving Australia signifies exported virtual water.

[7] Note that if supply-chain flows ending in intermediate consumers (companies, farms etc) were included in perspective 3), there would be double-counting, because for example the water used for irrigating wheat delivered to a flour mill that produces flour for a bakery selling to households appears in the supply chain of the flour mill, the bakery, and the household. This is why a supply-chain picture of virtual water flows must only contain flows that end in households (compare [46]).

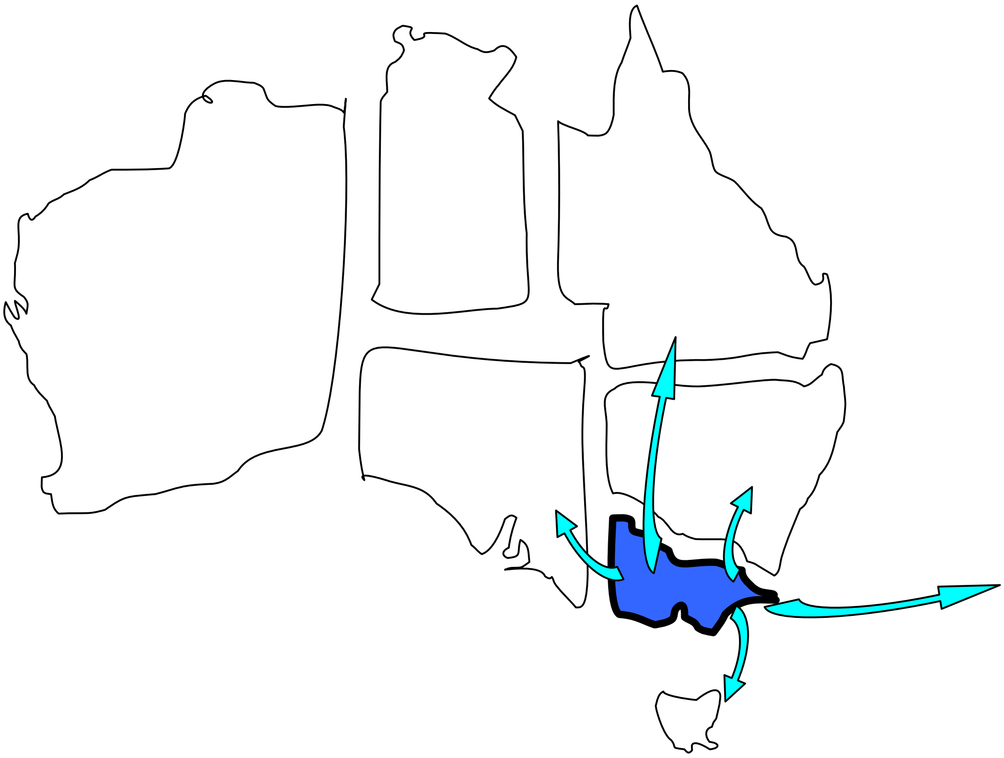


Fig. 1: Direct virtual water flows out of Victoria.

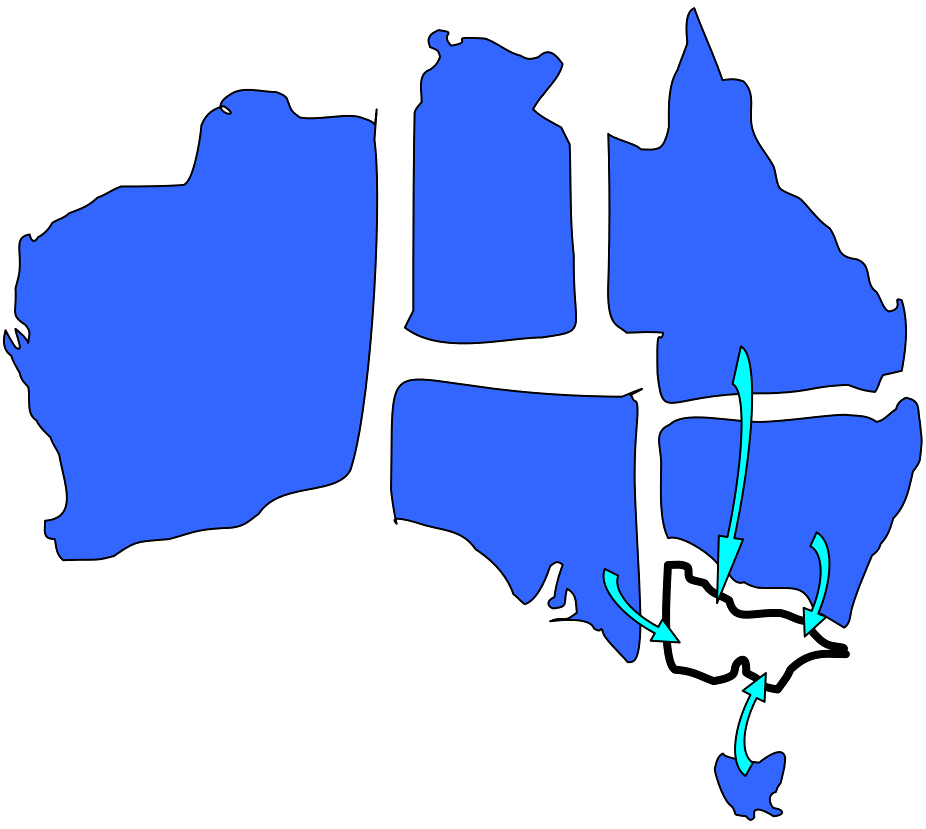


Fig. 2: Direct virtual water flows into Victoria.

4.2 Direct virtual water flows for final demand

virtual water flows between producers are intermediate, that is they belong to a multi-step supply-chain that ultimately ends up with some final consumer. Figure 3 depicts virtual water flows out of Victoria, but only those that end in a final consumer. All virtual water flowing from Victorian producers to producers in other States has been excluded. The use of a "sunk arrow" shall signify that a virtual water flow terminates with a final consumer, and thus will not continue to any further destinations. Figure 4 has the same relationship to Figure 2 as Figure 3 has to Figure 1: It includes only virtual water flows that terminate with final consumers in Victoria.

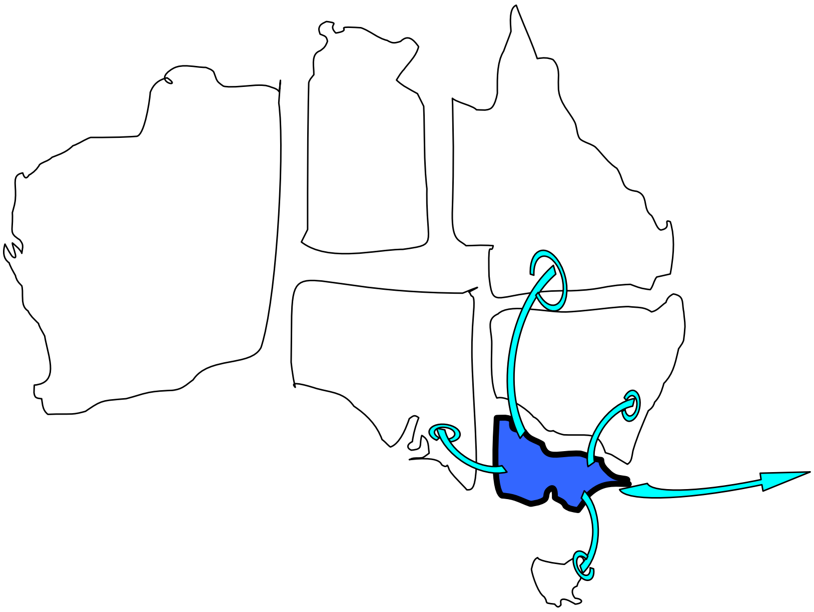


Fig. 3: Direct virtual water flows out of Victoria terminating in other States.

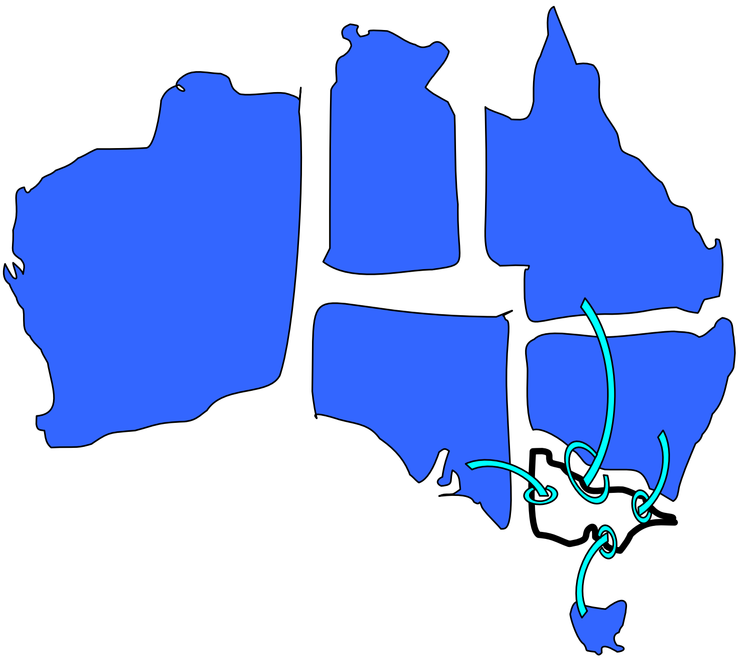


Fig. 4: Direct virtual water flows terminating in Victoria.

4.3 Total virtual water flows

Intermediate flows between producers, which were excluded in the previous Figures 3 and 4, are now added back into the picture (Figures 5 and 6), but this time as supply chains of terminating flows. (This is exactly what input-output analysis does: It takes all intermediate flows and re-arranges them as mutually exclusive and collectively exhaustive supply chains supporting final demand.) For example, a flow that was represented in Figure 1 as irrigation water used by a dairy farm in Victoria, passed on as virtual water to a dairy producer in Tasmania, may continue to a Victorian household buying Tasmanian cheese made with Victorian milk. In a full-supply-chain picture showing multi-step flows, this represents a virtual water flow *out of* and *into* Victoria, and the portion from the Victorian farm to the Tasmanian dairy producer is just one part of this flow (Figure 6).

If this virtual water flow continued from the Tasmanian dairy producer to a South Australian restaurant hosting NSW residents, then the portion from the Victorian farm to the Tasmanian dairy producer would be just one part of a virtual water flow *out of* Victoria terminating in NSW (Figure 5).

The transparent arrows  shall signify virtual water flows that terminate with an intermediate consumer, and thus must continue to one or more further destinations until they end with a final flow.

Fig. 5: Total virtual water flows out of Victoria terminating in other States.

In this supply-chain representation, virtual water flows can embody water sourced in different States. For example, water used in Queensland to grow sugar cane, turned into raw sugar in Queensland, supplied to a Victorian confectionary business making confectionary for Victorians is

"QLD water embodied in Victorian confectionary". The supply chain "Tasmanian grapes for South Australian wine making for Victorian restaurants" contains "TAS water" (growing), "SA water" (water for cleaning wine making equipment), and "VIC water" (for washing dishes in the restaurant). All water origins are distinguished in the results of this work, and all States are therefore coloured in blue in Figure 5.

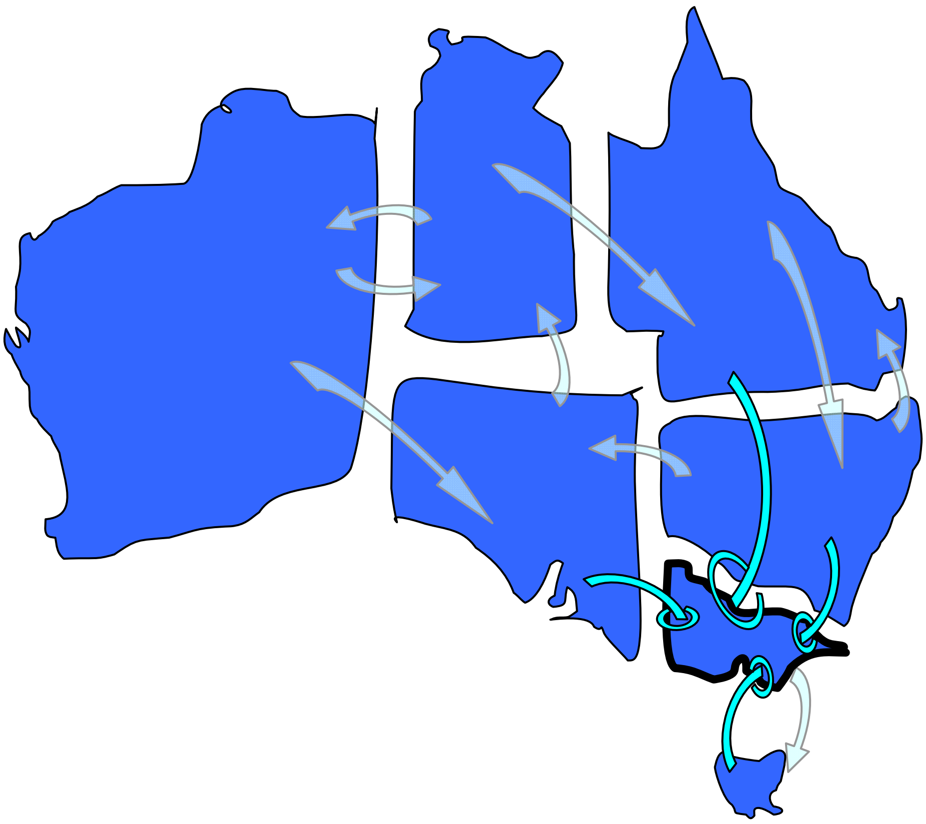


Fig. 6: Total virtual water flows terminating in Victoria.

Direct virtual water flows into Victoria could not contain "VIC water" (Victoria is white in Figures 2 and 4). Now, in Figure 6, total virtual water flows terminating in Victoria can contain "VIC water". Take the irrigation water used by a dairy farm in Victoria, passed on as virtual water to a dairy producer in Tasmania, and continuing back into a Victorian household buying Tasmanian cheese made with Victorian milk: This is a two-step "loop flow", starting in Victoria and terminating in Victoria. Victoria is therefore coloured in blue in Figure 6.

5 Results

The results described in this Section adhere to definitions of categories of water use published by the Australian Bureau of Statistics. These are:

– Self-extracted water: Includes water extracted directly from the environment for use.

– Mains water: Includes water supplied to a user usually through a non-natural network (piped/open channel or other carrier) where an economic transaction has occurred for the exchange of water regardless of method of delivery.

– Re-use water: Refers to wastewater that may have been treated to some extend and supplied to another user. It excludes water reused on-site.

– In-stream water: This is a subset of Self-extracted water use.

Note that according to the ABS, the majority of water used by the electricity sector is 'in-stream' and is often used again down stream by other water users. Furthermore, water use in the water supply sector includes losses from seepages and evapotranspiration (where measured). Note also that items not covered by the supply and use tables include:

– the reuse of water on-farm or on-site

– non-point or diffuse discharges

– the impact of stormwater infiltration into the sewerage reticulation system.

Further notes in the 2000-01 ABS Water Accounts apply.

In addition to the water use categories above, the ABS defines *water consumption* as

Water consumption = Self-extracted use + Mains water use + Reuse water use - Mains water supply - In-stream use.

This work follows these definitions, so that all results presented in the following are in terms of *water consumption*. In Victoria 2000-01, total water consumption was 5,375 GL, while total industrial water consumption (excluding residences) was 4,910 GL. Residences accounted for 465 GL [47].

Note that the virtual water balances in the following Sections include water used outside of Australia that is embodied in commodities that are directly imported into Victoria. They exclude water used outside of Australia embodied in commodities imported into other States, and then traded into Victoria. The latter calculation requires setting up a complete multi-regional flow table for imported commodities. Note also that the figures on virtual water imported into Victoria are calculated based on the assumption that overseas industries produce with water intensities equal to those in Victoria. This assumption enables estimating how much water would have been used additionally in Victoria, had the imports been produced there. It is in principle possible to set up a model that accurately represents water used outside of Australia, and that traces the embodiments of “foreign” water into Australia and Victoria. To carry out such an analysis, one would need genuine water use data from a suite of important countries of Victorian imports origins.

The following Sections describe the three perspectives on virtual water flows presented in Section 4. These perpectives are also taken in the national framework of the Triple Bottom Line Report *Balancing Act*, in the Tables on ‘TBL Factors’ in the results Section – a) directly in the whole

5.1 Direct virtual water flows

Table 1 and Figure 7 show direct flows of virtual water in and out of the State of Victoria (compare Section 4.1), together with uncertainties obtained from several gravity model runs. They comprise flows into Victorian industries and households, and out of Victorian industries. These flows are *direct flows*: They represent water used directly in industries that produce commodities which are used in Victoria. For example, the link from NSW to Victoria represents "NSW water" that was consumed by NSW industries and that leaves NSW embodied in those industries' commodities, which in turn are consumed by Victorian intermediate demanders (industries) and final demanders (households, State and local government, Victorian final consumption of fixed capital).[8] The link from Victoria to Queensland represents "VIC water" that was used by Victorian industries and that leaves Victoria embodied in commodities produced in Victoria, to be consumed by Queensland industries (intermediate) and households (final). In other words, these links are *one-step links*. They are a snapshot of one trade iteration in and out of Victoria, and they exclude previous and subsequent iterations (they exclude for example QLD water embodied in QLD commodities traded into NSW and then into VIC, or VIC water embodied in VIC commodities traded into QLD and then into NT). In other words, they exclude upstream and downstream supply chains. These flows conform to what in ABS National Accounting and input-output terms are known as *direct requirements*. Note that the VIC-VIC link is "VIC water" used to produce commodities delivered to VIC industries and households.

	In	Out	Uncertainty (In)	Uncertainty (Out)
NSW	216	72	50%	50%
VIC	4,248	4,248	25%	25%
QLD	23	16	50%	50%
WA	11	14	50%	50%
SA	14	30	50%	50%
TAS	12	24	50%	50%
NT	13	8	50%	50%
ACT	3	18	50%	50%
O/s	687	481	n.a.	25%
Sum	5,226	4,910	n.a.	ABS data

Tab. 1: Direct virtual water flows (GL) in and out of Victoria.

[8] For the sake of simplicity, intermediate demanders will be referred to as "industries", while final demanders will be referred to as "households". Note that households comprise only a part, but the dominant part of final demand.

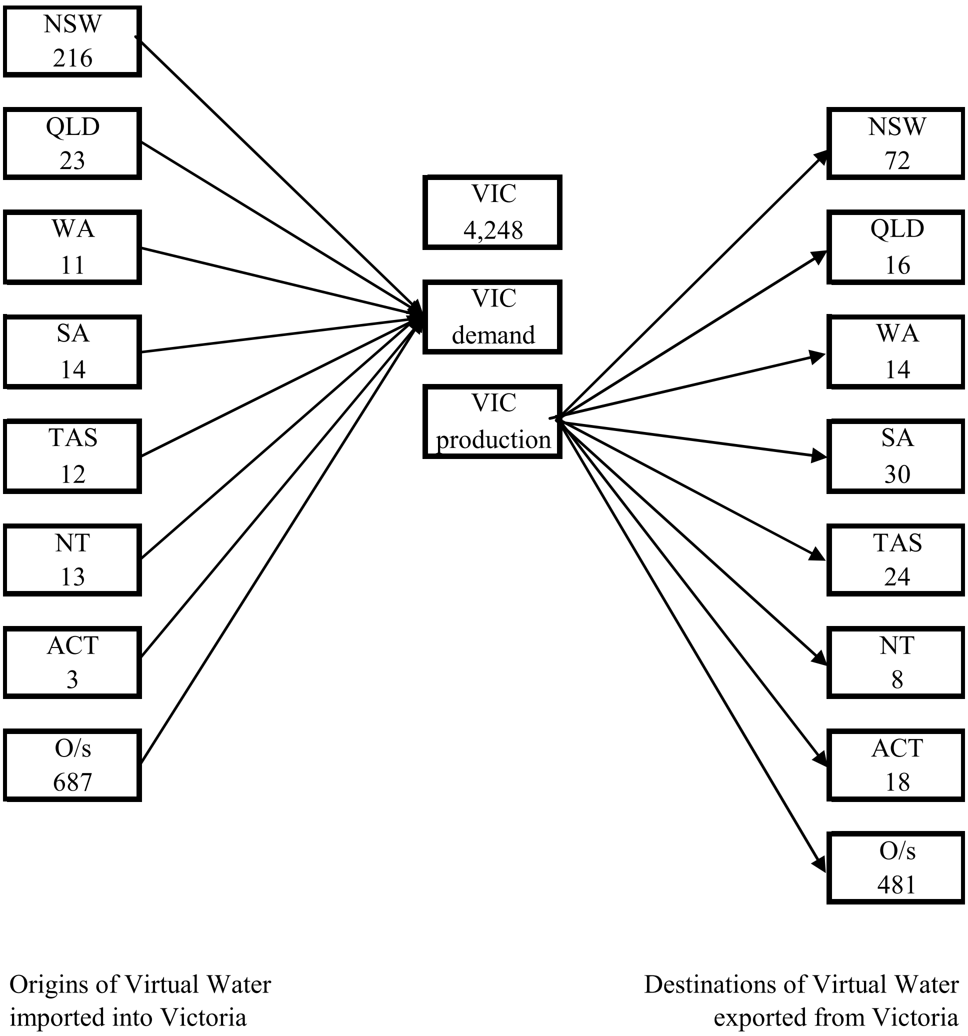


Fig. 7: Direct virtual water flows (GL) in and out of Victoria

Tab. 1 and Fig. 7 show that in term of direct water flows, Victoria is a net water importer. The main two reasons for this are a) rice imports from NSW, and b) overseas imports. While component a) will be explained in the next Sub-section, component b) is supported by Tab. 2.

Gross State Expenditure	$b151.2
- Imports	-$b38.7
+ Exports	$b23.9
+ Net inter-State trade	$b16.9
= Gross State Product	$b153.3

Tab. 2: Victoria's State Account Balance [44].

Inter-State trade is reflected in the so-called "Balancing Item" (net inter-State trade of $16.9b). In fact, this account item is the only direct data point on inter-State trade that the authors could locate within official ABS statistics. A balancing item exists for every State and Territory, and the gravity model recognises these values as external constraints. However, the commodity and origin/destination composition of the balancing items results purely out of the supply-demand balancing procedure employed by the gravity model (see Section 3). The results for inter-State virtual water trade are therefore associated with high uncertainties (Tab. 1). Note that total outflows equal Victoria's direct water use of 4,910 GL.

The direct water balance does not reflect any supply chain interactions. It should be kept in mind that Victoria does export a significant amount of dairy products and wine, for example, which are *indirectly, but not directly* water-intensive. Amongst the water-intensive commodities, such as dairy cattle, untreated milk, and grapes for wine, Victoria exports very little. This also explains why the total water balance presented in Section 5.3 is much higher in its overall magnitude.

In particular, the results for the direct water flows in and out of Victoria are strongly dependent on a number of assumptions made during the construction and estimation of the inter-State trade model. The most important assumptions and their influence on the trade balance are listed in the following, together with some key components of inter-State virtual water trade.

5.1.1 Rice

Victoria requires rice in the husk to be supplied from New South Wales in order to meet the demand of the Victorian rice products industry. This supply can be estimated as follows: The Australian input-output tables list $646m of input of 'grains' into 'flour mill and cereal products', compared to gross output of 'flour mill and cereal products' of about $3.2b. This yields a grain-to-product input coefficient of about 0.2. Given that most of rice is grown in NSW and not in Victoria, the gravity model estimates that the rice and other cereal products sector in NSW produces the bulk of rice products (rice input coefficient of about 0.4), while in Victoria other cereal products dominate (rice input coefficient of about 0.12).

In the ABS manufacturing survey [48], rice products are aggregated together with other worked cereal products for confidentiality reasons. The gross output of 'flour mill and cereal products' sector in Victoria in 1998-99 (of which the rice products sector is a part) was about $800m [48]. After subtracting non-confidential commodities such as wheat flour and breakfast foods, we estimate the gross output of the remainder to be about $250m. At least $42m of this are husked rice and rice bran [49].

Combining this figure with the rice input coefficient of 0.12 yields a requirement of the Victorian rice products industry of about $30m worth of rice in the husk. Victoria produces about $3m within its own borders, leaving $27m to be imported from NSW. The gravity model estimates $30m.

In 2000-01, NSW rice had a water intensity of about 6,700 L/$ (2,197 GL / $330m) [47, 48]. Therefore the $30m worth of rice supplied to Victoria embody 6,700 L/$ × $30m ≈ 200 GL. This is the largest single item in Victoria's direct virtual water trade balance. As noted above, most of Australia's rice is grown in NSW but processed in three mills owned by the Sunrice Company at Leeton and Deniliquin in NSW, and at Echuca in Victoria. In the years analysed, about 600,000 tonnes of rice was exported with about 65% or nearly 400,000 tonnes are exported through Victoria, mainly through the port of Melbourne and to a lesser degree Geelong. These data suggest that a reasonable amount of value adding (milling, rice flour, packing, stock foods, transport etc) and employment is generated by the NSW rice crop in Victoria, as well as by domestic consumption of around 8 kg per capita. Thus in a proportional sense, the virtual water content of these production chains are attributed to Victoria's account since they reach final demand or enter the market in that state.

5.1.2 Untreated milk

Because it is bulky, has relatively low value and is biologically active and requires cooling during tanker transport, untreated milk is seldom transported inter-State. All capital cities with the exception of Darwin and Canberra have fresh milk production systems in their hinterland, but processed dairy products (butter, cheese and yoghurts) are transported widely by the main supermarket chains. Over the last twenty years the reorganisation of the Australian dairy industry has seen production, processing and exports centralise in Victoria with over 65% of untreated milk currently produced there, and 85% of total dairy exports sent through the port of Melbourne. In this work, all inter-State flows of untreated milk were forced to be zero during the balancing of the trade model. Given the high water intensity of untreated milk (order of 800 L/$ in Victoria), a departure from this assumption would significantly influence the virtual water balance.

5.1.3 Beef cattle

With the exception of the Northern Territory, beef cattle are not traded across State borders [50], but there can be large flows to feedlots and for drought agistment during protracted dry periods.

5.1.4 Dairy cattle

During the period between 1999 and 2001 the number of Victorian dairy cows has not changed significantly (Tab. 3). It was therefore concluded that – at least in this period – there was no significant inter-State trade of dairy cattle. The respective model flows were forced to be zero.

	NSW	VIC	QLD*	SA	WA	TAS	AUST
At March 31							
1979/80	311	1,047	247	103	71	103	1,880
1989/90	238	968	201	89	64	92	1,654
1994/95	230	1,113	189	97	73	119	1,882
1995/96	235	1,161	189	97	71	130	1,884
1996/97	244	1,229	195	101	71	137	1,977
1997/98	266	1,268	203	107	73	143	2,060
1998/99	282	1,340	197	117	65	154	2,155
1999/00	289	1,377	195	105	65	139	2,171
At June 30							
2000/01**	268	1,377	186	124	72	148	2,176
2001/02	264	1,363	174	110	75	134	2,123
2002/03	250	1,303	159	117	77	142	2,050
2003/04	248	1,297	171	116	74	133	2,038
2004/05	245	1,295	150	115	70	135	2,010
2005/06	245	1,280	145	115	65	135	1,985

* For 1999 and 2000, Queensland state figure includes Northern Territory cow numbers.
** From 2001 census date is June 30, NT and ACT numbers are included in national total.

Tab. 3: Number of dairy cows (‘000 head) [51].

5.1.5 Fruit and vegetables

Australia has been self-sufficient in fruit and vegetables with around four million tonnes (two million tonnes each of fruit and vegetables) produced annually. However because the influence of dominant food retailers and global trade, there are considerable changes from year to year on where supplies are drawn from for example significant volumes of green peas, asparagus and tinned tomatoes are now imported from abroad, while production of table grapes and mangoes are widely dispersed throughout Australia to meet specific retailing windows. In 2005, Australia moved to be a net importer of vegetables in financial terms. For example Tasmanian vegetable production is 25%, 50% and 25% for local consumption, interstate consumption and exports respectively. But overall, inter-State trade in fruit and vegetables varies widely between 20% and 60% of local production [52, 53] (see for example Fig. 8).

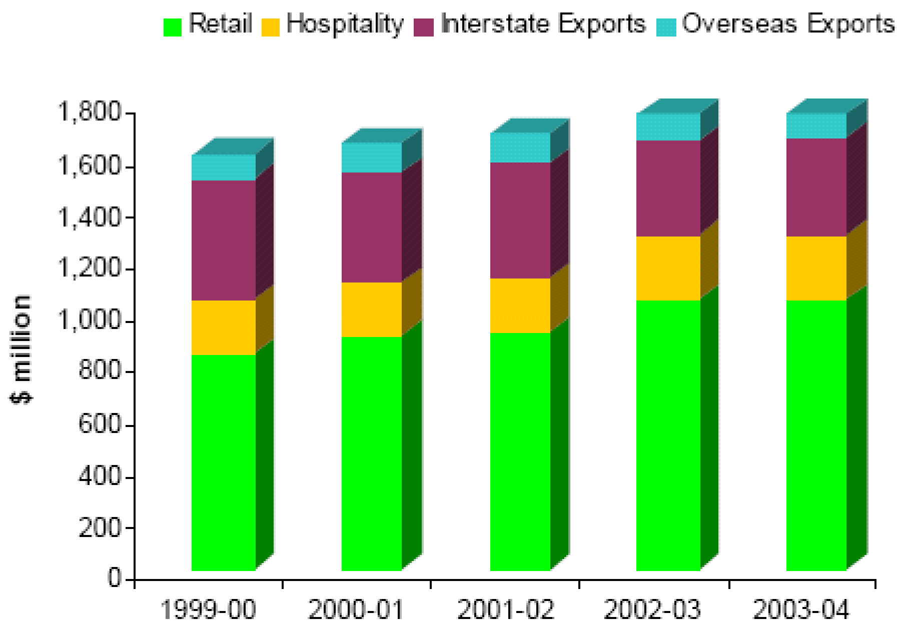


Fig. 8: Composition of South Australian Gross Horticulture Revenue, 2000/2004 [52].

We could not obtain a detailed quantitative estimate for the trade in fruit and vegetables in and out of Victoria.[9] Asking for all regional supply and demand pools to be balanced, the multi-regional gravity model employed in this work results in an inter-State trade in fruit and vegetables of about 10% of Victorian gross turnover, with a virtual water content of about 10 GL.

5.1.6 Grapes for wine

Information on the inter-State trade of grapes for wine varies widely. While the traditional wine growing areas of South Australia report only negligible cross-border transfers [55], Victoria reports that "the shift towards purchasing winegrapes from the three major inland regions has added to the oversupply problem caused by the recent planting of premium red varieties such as Cabernet Sauvignon, Merlot and Shiraz in Victoria's cool climate regions and to a lesser extent Pinot Noir. At the time of the 2005 vintage the cool climate zones accounted for 40 per cent of Australian

[9] Similar uncertainties exist for other States: For example, South Australia "is a relatively small producer (6%) of tomatoes within the Nation, with the majority produced within Victoria (57%), QLD (22%) and New South Wales (15.5%). […] the actual configuration of the national tomato trade is difficult to assess, as tomato flows into and out of the State will vary considerably depending on market conditions" [54].

winegrape plantings but only 20 per cent of Australian wine sales. While Victoria's level of exposure to this is less than South Australia's, Victoria cannot be insulated from interstate trade in grapes and wine, especially given the dominance of the top four wine companies in terms of production and share of wine sales" [56]. Tasmania reports a quantitative estimate of 25% of grapes being sold inter-State [57].

A corresponding estimate for Victoria in 1999 could not be easily obtained because of the industries reporting regions, where the Murray Valley including both NSW and Victorian grapes, are reported as one region [58]. In the non-Murray Valley part of Victoria, more than 65% of the grapes crushed are supplied by contract growers, some potentially from outside the region and the state. In the Murray Valley region over 90% of grapes crushed are from contract growers and reflect the location of large winemakers in the region and well as its close proximity to large irrigated vineyards along the Murray River in three states of South Australia, Victoria and New South Wales. When Murray region is combined with the non-Murray regions in Victoria, a total grape crushing of 371,564 is reported. In 2003/04, the Victorian harvest exceeded the crushed volume by about 150,000 tonnes [59], suggesting that in this year about 30% of the Victorian harvest was transported to, and crushed in other States.

Given the Victorian industry's large size, wine grape inter-State sales were balanced to 5% of Victorian turnover, distributed across the neighbouring States of South Australia, New South Wales, and Tasmania. Based on this assumption, inter-State virtual water embodied wine grapes traded out of Victoria amounts to about 10 GL.

5.1.7 Sugar cane and raw sugar

Because of its bulk and low value, sugar cane is grown and processed in sugar refineries within about 50 km of the growing areas. In some regions such as the Atherton Tableland, the cane is pressed to produce cane juice which is then taken by road tanker to an established refinery. Thus, cane is not transported out of the State where it is grown (Queensland or NSW). However a refinery by-product, molasses (left from sugar cane juice after raw and refined sugar is crystallised) is traded inter-State as an energy rich supplement in processed animal feeds used particularly in the dairy cattle and beef cattle production sectors. Molasses belongs to the IOPC sector 'raw sugar', so that all imports are accounted there. Since the water use in the raw sugar (processing) sector is negligible compared to water used in sugar cane growing, the direct water flows is negligible as well. The water embodied in the full supply chain is dealt with in Section 5.3.4.

5.1.8 Cotton

The Australian Business Register counts ([36], 1998 and [37], 2001) do not list any Victorian establishments involved in cotton processing, neither growing nor ginning. All cotton ginning is located within one hundred kilometres of cotton growing areas which are in NSW and Queensland. However the 'cottonseed' by-product from cotton ginning is used extensively as a high protein supplement for the dairy, pig and poultry production sectors. The gravity model was therefore forced to suppress any flows into Victoria from cotton growing, but not onwards from cotton ginning. The embodiment of "cotton water" in Victorian commodities is therefore described by total, not direct flows. These total flows are dealt with in Section 5.3.3.

5.1.9 Electricity

Victoria is linked with New South Wales, Queensland and South Australia in the South-East electricity grid. Amongst the four States, Victoria and Queensland have generated more electricity than was consumed in their States ([60], Tab. 4). The gravity model assumes an electricity flow from Queensland to New South Wales, with New South Wales's remainder being taken up by Victoria, and a flow from Victoria to South Australia. Assuming a proportionality between virtual water and electricity, about 17% of virtual water embodied in "disposable" electricity is hence traded out of Victoria, corresponding to about 15 GL.

	NSW	Vic	Qld	SA	All
Electricity generation	60,058	49,442	40,231	8,305	158,036
minus transmission losses	53,031	43,657	35,524	7,333	139,546
Electricity consumption	59,544	36,314	33,268	10,456	139,582
Trade	-6,513	7,343	2,256	-3,123	

Tab. 4: Electricity generation and consumption (GWh) in the South-East grid, 1999 [60].

5.1.10 Water supply

Due to its bulk and transportation requirements, metered water as supplied by the 'Water supply, sewage and drainage services' industry is not transported inter-State. Therefore, all inter-State flows of metered water were forced to be zero during the balancing of the trade model.

5.1.11 International imports and exports

In monetary terms, Victoria is a net importer (Tab. 2), with significant commodities being electronic equipment, motor vehicles and clothing. Imports exceed exports by more than 50%, and this is reflected in the international virtual water trade balance (Tab. 3). On average, imported and exported goods have a direct water intensity of about 20 L/$, which is close to the average of Victoria's production.

5.2 Direct virtual water flows for final demand

A part of the virtual water flows contained in Table 1 and Figure 7 passes through Victoria. These are the flows of water embodied in commodities produced elsewhere, used by Victorian industries for producing Victorian commodities that are in turn used elsewhere. Similarly, a part of the virtual water flows leaving Victoria embodied in Victorian commodities passes through the State of trade destination. Let's now subtract these flows from those in Table 1 and Figure 7. Table 5 and Figure 9 show direct flows of virtual water in and out of the State of Victoria, but this time the inward flows comprise only those that end with Victorian households (final), and not Victorian industries (intermediate). Similarly, the outward flows comprise only those that end with the destination State's households (final), and not with that State's industries (compare Section 4.2).

Flows in Table 5 and Figure 9 are a part of those in Table 1 and Figure 7, they are the one-step links that *terminate in Victoria and elsewhere*. Therefore all figures in Table 5 are smaller than those in Table 1. All the inter-industry virtual water flows have been eliminated.

	In	Out
NSW	7	27
VIC	1,306	1,306
QLD	11	9
WA	3	8
SA	9	15
TAS	4	4
NT	3	3
ACT	1	4
O/s	144	481
Sum	1,489	1,857

Tab. 5: Direct virtual water flows (GL) in and out of Victoria, terminating in final demand.

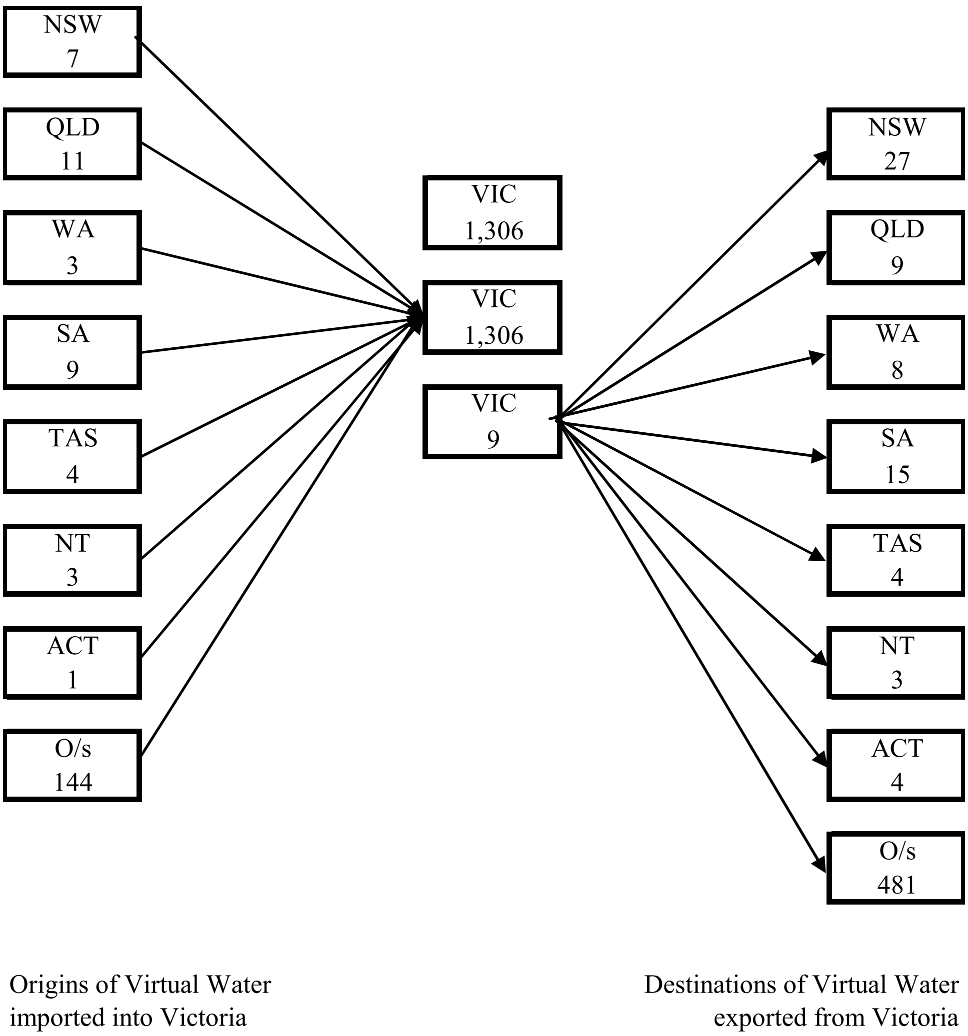


Fig. 9: Direct virtual water flows (GL) in and out of Victoria, terminating in final demand.

Of the significant commodities treated in Section 5.1, only fruit, vegetables, and electricity are traded from other States directly into Victorian final demand. The remainder such as rice, wine grapes etc, are traded into intermediate demand of industries that manufacture products which may be on-sold into other States. Fruit and vegetables for final demand account for about 11 GL out of the 30 GL of direct water flows (see Section 5.1.5), with the remainder used for further processing into fruit and vegetable products, or for hospitality. Electricity statistics [60] reveal that of electricity generated, about 40% is used in residences. The gravity model yields a comparable result for water flows, with 6 GL out of 15 GL embodied in traded electricity destined for final demand.

Of virtual water embodied in international imports (687 GL), about 20% (144 GL) is destined for final demand, while the remainder is embodied in products used in Victorian industries for further processing. Note that this estimate applies Victorian water intensities to overseas production. The virtual water estimate for exports in Tab. 5 (487 GL) is identical to the one in Tab. 1 because for the purpose of accounting in Victoria, all exports are considered final.

5.3 Total virtual water flows

Table 6 and Figure 10 show total flows of virtual water in and out of the State of Victoria (compare Section 4.3), as well as uncertainties obtained from several gravity model runs. They comprise flows into Victorian households, and out of Victorian industries. These flows are *total flows*: They represent water used directly and indirectly in industries that produce commodities which are traded inter-State. For example, the link from NSW to Victoria represents “NSW water” that was used directly by NSW industries and that leaves NSW, to become embodied in commodities that are finally consumed by Victorian households. The link from Victoria to Queensland represents “VIC water” that was used directly by Victorian and other industries, and that leaves Victoria to become embodied in commodities that are finally consumed by Queensland households. In other words, these links are *multi-step links*. They are an accumulation of multiple trade iterations in and out of all States and Territories, and they include previous and subsequent iterations (they include for example two-stage links such as QLD into NSW into VIC, or VIC into QLD into NT, or three-stage links such as WA into QLD into NSW into VIC, or VIC into QLD into NT into QLD). In other words, they include all upstream supply chains. These flows conform to what in ABS National Accounting and input-output terms is known as *total requirements*. Note that the VIC-VIC link is “VIC water” used to produce commodities in Victoria, which are finally delivered to VIC households. This includes links such as VIC into QLD into NSW into VIC, which is a circular link – Victorian water leaving the state but becoming ultimately embodied in something finally consumed in Victoria. However, international circular links are excluded, because information on international trade flows between countries other than Australia was not considered.[10]

[10] An international trade flow calculation is feasible, but requires the construction of a multi-region input-output model (see [39]).

	In	Out	Uncertainty (In)	Uncertainty (Out)
NSW	216	185	40%	40%
VIC	2,615	2,615	25%	25%
QLD	277	90	40%	40%
WA	10	77	40%	40%
SA	10	50	40%	40%
TAS	8	17	40%	40%
NT	6	5	40%	40%
ACT	2	11	40%	40%
O/s	307	2,345	n.a.	25%
Sum	3,449	5,395	n.a.	20%

Tab. 5: Total virtual water flows (GL) in and out of Victoria, terminating in final demand.

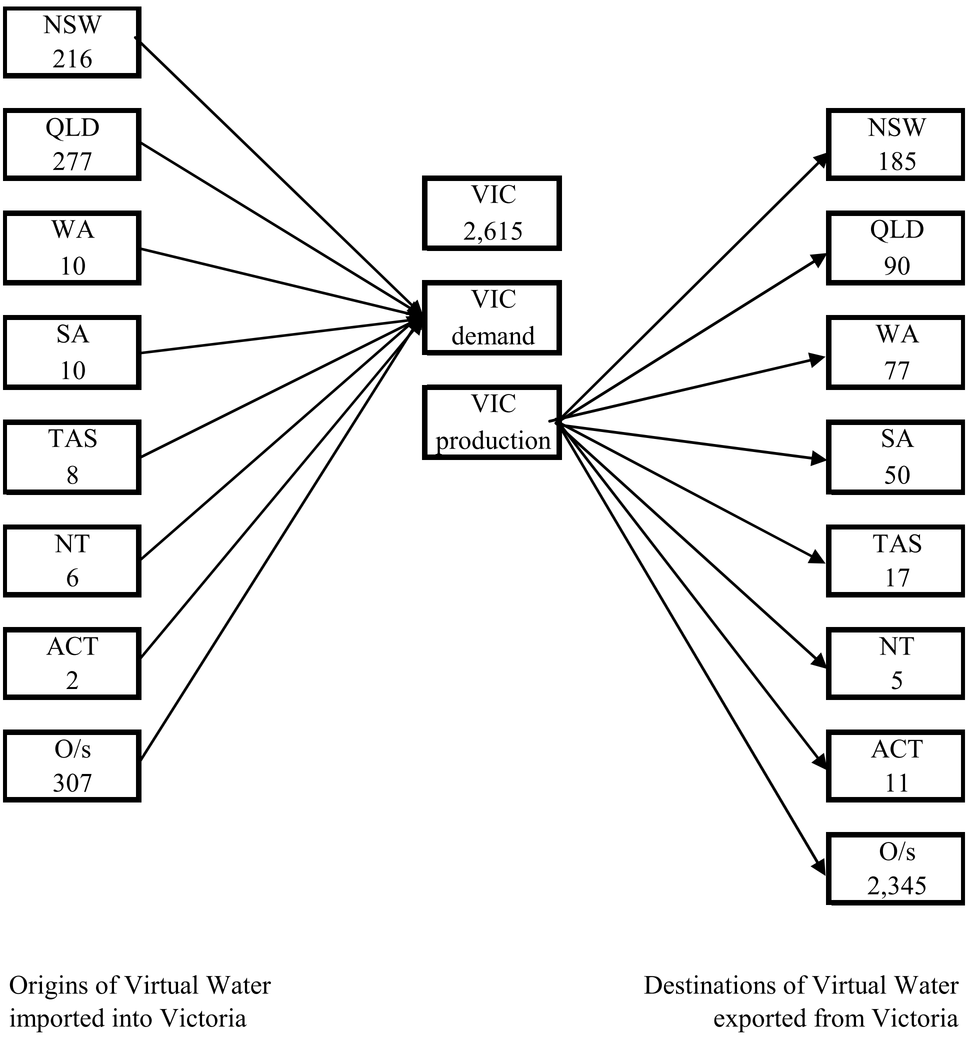


Fig. 10: Total virtual water flows (GL) in and out of Victoria, terminating in final demand.

How are the figures in Tables 1, 5 and 6 different? Table 1 includes under “NSW into VIC” some water that was used say in a NSW industry, and left that industry embodied in an intermediate product used by a Victorian industry to produce a commodity consumed elsewhere. Tables 2 and 3 would exclude this flow because it doesn't end up in Victorian final demand. Table 3 includes some water that was used say in a QLD industry, and left that industries embodied in an intermediate product used by a NSW industry to produce a commodity bought by a Victorian household. This is excluded in Tables 1 and 5 because it is not a direct link, but a two-stage link.

The information in Tables 1, 5 and 6 is associated with varying degrees of uncertainty. While the sums in the bottom rows (the total trade in and out of Victoria) are fairly reliable, the distribution of in- and out-flows amongst the States could vary if more reliable data on Gross State Output and inter-State trade were collected. The present distribution amongst States is determined by the gravity model, which considers a mixture of parameters, such as commodity weight, transport distances, and the size of the State economies. In general, a State will be allocated a large proportion of trade flows in and out of Victoria if

- it neighbours Victoria (for example NSW, TAS and SA), and
- if it has a large economy (for example NSW and QLD).

This is reflected in the results. The first condition will hold especially for bulky and heavy commodities. For example, metered water is not traded at all across State boundaries, and that has been reflected in the model. On the other hand, the distance parameter does not influence services as much as goods because they are more easily traded across large distances.

5.3.1 Livestock, wool and grains

About 25 GL of NSW water used for livestock and grain growing are embodied in products consumed in Victoria. This is mostly in form of traded processed meat and cereal products, rather than in primary form such as traded livestock, carcasses, and grains. The same industries contribute about another 20 GL of QLD water, and small amounts of WA water, SA water, TAS water, and NT water.

Australia is the origin of 70% of the world's traded wool. The strategic location of Melbourne with easy transport access to the major wool producing regions of the Riverina, Western District, Western NSW and South-East South Australia has led to Melbourne being the both the largest greasy wool sale centre and export port in the world. As a consequence in 2001/02, 39% (or $1,344 b) of wool produced in Australia is exported from Victoria [61]. Assuming the same export percentage for Victorian-grown wool, about 50 GL of VIC water each leaves Australia in form of exported wool and sheep meat. The top 5 destinations for Victorian wool exports in 2001/02 were China, Italy, Korea, India and Japan [61].

Another 50 GL of Victorian water is embodied in about $200m of wheat exports, another 25 GL in $100m worth of exported barley, and another 25 GL in $100m of exported oilseeds and legumes [62].

5.3.2 Rice

The Household Expenditure Survey reports the private final consumption of an average household in Victoria as 48 ¢/week of rice, $1.79/week of breakfast cereals, $1.18/week of pasta, and 10 ¢/week of other cereal products. For the 1.74 million households in Victoria, this means an annual consumption of $174m, $43m, $109m and $9m, on the three respective products. Reconciling the Household Expenditure Survey with the Australian input-output tables, we estimate that another $20m of rice products are consumed in various forms in Victoria, in addition to $43m of husked rice bought off the supermarket shelf. This estimate is in agreement with apportioning the figure of \$300m in domestic revenue of processed rice given by the Australian Rice Growers Association [63], to about a quarter of Australia's population. Including rice contained in meals out, sake, and take-away food, we estimate that about 100 GL of NSW water used for rice growing are embodied in rice products consumed in Victoria. This is about 5% of the total water use of the NSW rice industry.

5.3.3 Cotton

About 50 GL of NSW water used for cotton growing are embodied in cotton products consumed in Victoria, representing about 2.5% of the total water used in NSW cotton growing. Some of this could be cotton seed meal, which is half the physical weight of the raw cotton boll. Cotton seed meal is used for feeding of dairy cows, chicken, and pigs.

5.3.4 Sugar cane and raw sugar

The manufacturing survey's coverage of Victorian sugar refining industries is incomplete; however the 2001 Business Register lists 8 sugar refining establishments in Victoria. Queensland's sugar production turnover is given as about \$2b [48]. Given the considerable exports of the sugar industry, it is perceivable that 20% of Queensland turnover would go into Victoria in order to support local food and hospitality industries. In fact, the gravity model estimates Victorian imports of raw sugar from Queensland of about \$350m. The ABS Water Accounts state that Queensland sugar cane growing consumed about 1,100 GL of water. This means that about 200 GL of QLD water are embodied in food consumed in Victoria.

5.3.5 Fruit and vegetables

As with direct water flows, total water flows into Victorian final demand can be estimated at about 5 GL, coming mostly and about equally from NSW, Queensland, South Australia, and Tasmania.

5.3.6 Dairy products

Victoria's inter-State export balance is dominated by dairy products; about 50% of virtual water traded inter-State out of Victoria is embodied in dairy products. Moreover, of the total estimated virtual water content of international exports, about 1,000 GL is embodied in about \$2b of dairy products exported from Victoria [64, 65]. All other commodities play a relatively minor role.

5.3.7 Wine

Victorian wine accounts for about 60 GL of virtual water traded out of Victoria, with 30 GL embodied in international exports.

5.3.8 Water supply, sewage and drainage services

About 35 GL of water lost and consumed in non-Victorian water supply industries are embodied in commodities finally consumed in Victoria. This consumption includes losses from seepages and evapotranspiration (where measured). About 30 GL of this water is estimated to be NSW and QLD water, with the remainder distributed evenly over the remaining States. About 65 GL of VIC "water supply" water is embodied in the final demand of other States and Territories.

5.4 Virtual water balance of Victorian final demand

Table 7 is a detailed representation of virtual water flowing into, and terminating in the State of Victoria (Table 3 left column, excluding imports). The commodity breakdown is a subset of the ABS' detailed 8-digit IOPC classification.

The table is organised as follows. Columns 1-3 refer to the Victorian production side of water consumption:

- Column 1 gives direct water consumption (Tab. 1 'Out' column);
- Column 2 gives gross sectoral output for the State of Victoria;
- Column 3 equals Col.1/Col.2 and signifies the direct water intensity ($\boldsymbol{q}$ in Eq. 11 in the Appendix).

Columns 4-6 refer to the Victorian final demand side of water use:

- Column 4 gives total water intensity, which is comprised of the direct water intensity (column 3) plus all upstream contributions (calculated according to $\boldsymbol{q}\mathbf{L}$ in Eq. 11 in the Appendix);
- Column 5 gives final demand of households in the State of Victoria;
- Column 6 gives the embodiment of water in Victoria's final demand (Tab. 5 'In' column).

The values in column 6 do not equal column 4 × column 5, because Victorians consume goods and services produced both inside and outside Victoria. If column 4 was multiplied by column 5, this would yield *water embodiments in Victorian final demand produced with Victorian water intensity*, and not *water embodiment in Victorian final demand produced with Australian water intensity*. Column 6 includes water used in all other States and Territories, entering Victoria embodied in goods and services. Naturally, it excludes water embodied in goods and services finally demanded elsewhere in Australia and overseas.

As mentioned previously, final demand comprises private and government final consumption, private, public enterprise and government gross fixed capital expenditure, increases in stocks and overseas exports. Columns 5 and 6 in Tab. 7 are broken down into these components in Tab. 8.

Victoria's Virtual Water Cycle	Production			Consumption		
Sector	Direct water consumption in Victoria (GL)	Gross sectoral output ($m)	Direct water intensity in Victoria (L/$)	Total water intensity in Victoria (L/$)	Final demand in Victoria ($m)	Virtual water in Victorian final demand (GL)
Sheep and wool	253	1,036	**244**	**260**	104	27
Grains	252	1,004	**251**	**262**	50	13
Rice	26	2.9	**8,724**	**8,767**	0	0
Oilseeds and legumes	48	191	**251**	**253**	9	2
Beef cattle	211	840	**251**	**268**	114	30
Dairy cattle & milk	1,928	2,425	**795**	**841**	257	**216**
Pigs, poultry & eggs	119	474	**251**	**287**	237	68
Fruit	190	813	**234**	**262**	329	86
Vegetables	96	520	**185**	**201**	408	85
Sugar cane						
Cotton						
Other agriculture	171	927	**184**	**198**	785	**188**
Forestry	3	275	12	13	51	1
Fishing	2	190	12	15	887	22
Coal mining	22	380	58	56	38	2
Oil & gas extraction	2	337	6	8	103	0
Iron ores						
Non-ferrous metal ores	4	870	5	8	19	0
Mineral sands						
Stone, gravel & sand	3	788	4	15	362	5
Limestone, clay, salt & phosphate rock	0	93	4	11	9	0
Mineral exploration	0	320	0	1	58	0
Meat	6	3,265	2	**186**	1,068	**195**
Dairy products	9	4,733	2	**496**	921	**457**
Vegetable products	2	896	2	75	519	39
Fruit products	1	468	2	74	270	20
Oils & fats	1	304	2	36	181	7
Rice products	0	244	2	**1,003**	67	68
Flour	1	393	2	72	58	3
Fodder and feed	0	7	2	61	3	0
Breakfast cereals and pasta	1	348	2	68	185	12
Pies, cakes and biscuits	2	810	2	78	411	32
Bread	1	327	2	26	344	9
Confectionary	2	808	2	**176**	238	42
Sugar	0	230	2	**402**	203	84
Seafood	1	284	2	12	253	4
Other food products	2	913	2	55	613	33
Animal food	1	653	2	**280**	151	35
Soft drinks	1	726	2	72	604	43
Beer and malt	1	500	2	61	444	27
Spirits	0	80	2	**115**	172	20
Wine	288	901	**320**	**219**	307	65
Tobacco	2	1,034	2	28	299	9
Wool scouring	0	174	1	**230**	19	4
Human-made fibres	0	389	1	45	44	2
Cotton fabrics	0	298	1	**349**	29	10
Wool fabrics	0	138	1	**222**	11	2
Textile products	1	1,421	1	17	321	5
Knitting mill products	1	814	1	47	204	10
Clothing	2	1,938	1	12	1,356	17
Footwear & leather	1	936	1	17	279	5
Sawmill products	5	641	7	11	23	0
Pulp & paper	8	1,037	7	16	30	0
Wood products	9	1,282	7	13	135	2

Tab. 7: Victoria's virtual water Cycle

Paper products	9	1,257	7	13	364	5
Printing & stationery	0	1,522	0	7	129	1
Publishing	1	2,831	0	8	465	3
Newspapers, books & periodicals	0	891	0	7	494	3
Petrol & diesel	1	1,054	1	2	648	2
Gas oil, fuel oil	1	508	1	2	62	0
Kerosene, LPG, bitumen & other refinery products	1	698	1	4	324	1
Basic chemicals	3	2,110	1	13	27	0
Medicinal goods	3	1,945	1	10	903	9
Soap & detergents	0	315	1	18	238	4
Cosmetics & toiletry products	0	238	1	18	283	5
Explosives, munitons, inks, glue & other chemical products	1	631	1	13	74	1
Tyres & other rubber products	1	704	1	6	162	1
Plastic products	4	2,809	1	9	245	2
Fertilisers	1	773	1	7	189	1
Glass products	0	416	1	7	17	0
Ceramic products	0	383	1	7	35	0
Cement, lime, plaster & concrete	2	1,519	1	8	101	1
Working stone, glass fibre and other non-metal mineral products	0	394	1	8	145	1
Basic iron & steel	2	3,394	0	7	137	1
Basic non-ferrous metals	2	4,364	0	1	488	0
Structural and fabricated metal products	2	5,117	0	6	481	3
Transport equipment	3	14,531	0	4	5,512	25
Appliances & other equipment	2	8,633	0	5	6,176	29
Furniture & other manufacturing	0	2,149	0	9	1,641	17
Electricity supply	108	4,937	22	28	1,301	36
Gas supply		362		2	514	2
Water supply	787	1,856	**424**	**436**	981	**427**
Building & construction	6	15,874	0	5	14,947	71
Trade & repairs	17	35,998	0	10	19,599	**202**
Hotels, cafes, restaurants & accommodation	14	7,264	2	36	5,551	**193**
Transport	9	17,880	1	3	7,210	22
Communication	5	8,674	1	4	2,561	11
Banking, finance, property & insurance	6	33,808	0	1	19,627	26
Technical services	4	8,025	0	11	2,470	28
Business services	8	16,342	0	11	784	9
Government administration	11	5,284	2	3	6,337	30
Defence	4	570	7	7	1,588	9
Education	18	6,869	3	4	6,610	25
GPs, hospitals, vets &community health	10	10,279	1	3	8,980	31
Cinema, radio, news, television & entertainment	16	1,416	11	16	947	13
Libraries, museums, galleries, music & arts	7	384	17	25	359	9
Parks, gardens & zoos	2	113	18	24	156	4
Gambling	7	1,284	5	11	855	9
Sport and recreation	20	2,027	10	29	1,498	43
Personal services	38	1,926	20	26	1,602	42
Community services & organisations, police, correction & fire brigade	93	4,124	23	22	3,948	83
Waste disposal	0	80	3	7	72	1
All	4,910	283,086			141,419	3,449

Tab. 7: Victoria’s virtual water Cycle (cont.)

Victoria's Virtual Water Cycle - Breakdown of Victoria's final demand

Sector	Private final cons. ($m)	Virtual water (GL)	Governm't final cons. ($m)	Virtual water (GL)	Private gross fixed capital exp. ($m)	Virtual water (GL)	Publ.Ent. gross fixed capital exp. ($m)	Virtual water (GL)	Gov't gross fixed capital exp. ($m)	Virtual water (GL)	Increases in stocks ($m)	Virtual water (GL)	Imports ($m)	Virtual water (GL)	Total final demand in Victoria	Total virtual water
Sheep and wool	7	2	0	0	31	8	0	0	0	0	65	17	0	0	104	27
Grains			0	0	0	0	0	0	0	0	50	13	0	0	50	13
Rice			0	0	0	0	0	0	0	0	0	0			0	0
Oilseeds and legumes			0	0	0	0	0	0	0	0	9	2	0	0	9	2
Beef cattle	8	2	0	0	105	28	0	0	0	0	1	0			114	30
Dairy cattle & milk	1	0	0	0	171	142	0	0	0	0	85	73			257	216
Pigs, poultry & eggs	80	22	0	0	0	0	0	0	0	0	156	46	0	0	237	68
Fruit	291	76	0	0	0	0	0	0	0	0	27	7	11	3	329	86
Vegetables	381	83	0	0	0	0	0	0	0	0	4	1	23	5	408	88
Sugar cane																
Cotton																
Other agriculture	112	31	21	0	3	0	0	0	0	0	176	29	473	128	785	188
Forestry	4	0	39	1	3	0	0	0	1	0	3	0	1	0	51	1
Fishing	247	11	23	0	1	0	0	0	0	0	21	0	596	10	887	22
Coal mining	7	0	0	0	0	0	0	0	0	0	28	2	3	0	38	2
Oil & gas extraction	70	0	9	0	7	0	6	0	2	0	3	0	7	0	103	0
Iron ores																
Non-ferrous metal ores	0	0	1	0	6	0	8	0	2	0	1	0	1	0	19	0
Mineral sands																
Stone, gravel & sand	0	0	0	0	2	0	0	0	0	0	359	5	0	0	362	5
Limestone, clay, salt & phosphate rock	0	0	0	0	1	0	0	0	0	0	8	0	0	0	9	0
Mineral exploration			44	0	12	0	1	0	0	0	0	0			58	0
Meat	937	181	0	0	2	0	2	0	1	0	121	13	5	1	1,068	195
Dairy products	866	429	0	0	1	1	2	1	1	0	1	1	50	26	921	457
Vegetable products	404	30	0	0	2	0	2	0	1	0	25	2	85	6	519	39
Fruit products	214	16	0	0	1	0	1	0	0	0	15	1	39	3	270	20
Oils & fats	132	5	0	0	0	0	0	0	0	0	5	0	45	2	181	7
Rice products	62	62	0	0	0	0	0	0	0	0	1	1	5	5	68	69
Flour	38	1	0	0	0	0	0	0	0	0	17	1	3	0	58	3
Fodder and feed	0	0	0	0	0	0	0	0	0	0	2	0	0	0	3	0
Breakfast cereals and pasta	150	11	0	0	0	0	0	0	0	0	16	1	18	1	185	12
Pies, cakes and biscuits	310	24	0	0	0	0	0	0	0	0	61	5	40	3	411	32
Bread	335	9	0	0	0	0	0	0	0	0	0	0	8	0	344	9
Confectionary	192	34	0	0	0	0	0	0	0	0	0	0	47	8	238	42
Sugar	74	13	0	0	7	5	6	5	2	2	112	60	0	0	203	84
Seafood	59	1	0	0	0	0	0	0	0	0	4	0	190	3	253	4
Other food products	505	27	0	0	2	0	2	0	1	0	41	2	60	3	613	33
Animal food	128	29	0	0	1	0	1	0	0	0	13	4	8	2	151	35
Soft drinks	539	39	0	0	0	0	0	0	0	0	32	2	33	2	604	43
Beer and malt	415	25	0	0	3	0	5	0	1	0	3	0	16	1	444	27
Spirits	44	5	0	0	0	0	0	0	0	0	66	8	62	7	172	20
Wine	232	38	0	0	1	0	1	0	0	0	68	22	4	1	308	62
Tobacco	206	6	0	0	0	0	0	0	0	0	0	0	93	3	299	9
Wool scouring	12	3	0	0	0	0	0	0	0	0	0	0	7	2	19	4
Human-made fibres	17	1	0	0	0	0	0	0	0	0	2	0	25	1	44	2
Cotton fabrics	18	6	0	0	0	0	0	0	0	0	0	0	11	4	29	10
Wool fabrics	6	1	0	0	0	0	0	0	0	0	0	0	5	1	11	2
Textile products	179	3	0	0	4	0	6	0	7	0	39	0	86	1	321	5
Knitting mill products	126	6	0	0	0	0	0	0	0	0	23	1	54	3	204	10
Clothing	852	10	0	0	0	0	0	0	0	0	33	0	471	6	1,356	17
Footwear & leather	142	2	0	0	1	0	0	0	0	0	7	0	129	2	279	5
Sawmill products	0	0	0	0	0	0	0	0	0	0	22	0	0	0	23	0
Pulp & paper	20	0	0	0	0	0	0	0	0	0	0	0	10	0	30	0
Wood products	9	0	0	0	1	0	1	0	0	0	112	1	12	0	135	2

Tab. 8: Breakdown of Victoria’s virtual water Cycle (cont.)

Paper products	99	1	0	0	2	0	1	0	0	0	238	3	24	0	364	5
Printing & stationery	79	1	7	0	0	0	0	0	0	0	24	0	19	0	129	1
Publishing	153	1	1	0	68	1	5	0	4	0	42	0	193	1	465	3
Newspapers, books & periodicals	447	3	1	0	2	0	0	0	0	0	5	0	39	0	494	3
Petrol & diesel	608	2	0	0	0	0	0	0	0	0	0	0	39	0	648	2
Gas oil, fuel oil	0	0	0	0	0	0	0	0	0	0	43	0	18	0	62	0
Kerosene, LPG, bitumen & other refinery products	52	0	0	0	0	0	0	0	0	0	264	1	7	0	324	1
Basic chemicals	18	0	0	0	2	0	1	0	0	0	2	0	3	0	27	0
Medicinal goods	287	3	304	3	1	0	1	0	0	0	60	1	250	3	903	9
Soap & detergents	142	3	0	0	1	0	1	0	0	0	69	1	24	0	238	4
Cosmetics & toiletry products	165	3	2	0	0	0	0	0	0	0	7	0	109	2	283	5
Explosives, munitons, inks, glue & other chemical products	21	0	0	0	0	0	0	0	0	0	52	1	1	0	74	1
Tyres & other rubber products	22	0	0	0	2	0	1	0	0	0	105	1	32	0	162	1
Plastic products	94	1	0	0	30	0	2	0	1	0	69	1	49	0	245	2
Fertilisers	91	1	0	0	1	0	0	0	0	0	25	0	72	0	189	1
Glass products	6	0	0	0	2	0	2	0	0	0	4	0	3	0	17	0
Ceramic products	9	0	0	0	2	0	2	0	0	0	4	0	18	0	35	0
Cement, lime, plaster & concrete	0	0	0	0	1	0	1	0	0	0	97	1	0	0	101	1
Working stone, glass fibre and other non-metal mineral products	0	0	0	0	1	0	0	0	0	0	131	1	12	0	145	1
Basic iron & steel	0	0	0	0	37	0	11	0	11	0	72	0	5	0	137	1
Basic non-ferrous metals	2	0	2	0	56	0	54	0	15	0	343	0	15	0	488	0
Structural and fabricated metal products	75	1	0	0	118	1	9	0	25	0	182	1	72	0	481	3
Transport equipment	1,692	8	1	0	833	4	96	0	75	0	84	0	2,731	12	5,512	25
Appliances & other equipment	613	4	0	0	745	4	40	0	29	0	352	2	4,396	20	6,176	29
Furniture & other manufacturing	633	5	0	0	201	2	14	0	46	0	133	2	612	8	1,641	17
Electricity supply	1,187	33	7	0	36	1	46	1	25	1	0	0			1,301	36
Gas supply	513	2	0	0	1	0	0	0	0	0	0	0	0	0	514	2
Water supply	909	396	41	18	12	5	15	6	4	2	0	0			981	427
Building & construction	0	0	725	3	10,842	52	1,684	8	1,685	8	11	0	0	0	14,947	71
Trade & repairs	16,715	182	5	0	2,129	14	53	0	128	1	523	4	45	1	19,599	202
Hotels, cafes, restaurants & accommodation	5,421	190	1	0	0	0	0	0	0	0	0	0	128	2	5,551	193
Transport	3,276	10	1,347	5	241	1	24	0	35	0	23	0	2,264	6	7,210	22
Communication	1,911	8	38	0	232	1	273	1	78	0	0	0	29	0	2,561	11
Banking, finance, property & insurance	18,250	19	10	0	1,123	7	1	0	3	0	167	0	73	0	19,627	26
Technical services	101	1	476	5	1,436	16	126	1	297	3	0	0	34	0	2,470	28
Business services	416	4	235	3	127	1	0	0	0	0	0	0	6	0	784	9
Government administration	198	1	6,091	29	46	0	0	0	2	0	0	0	0	0	6,337	30
Defence			1,588	9	0	0	0	0	0	0	0	0	0	0	1,588	9
Education	1,891	7	4,620	17	15	0	1	0	3	0	0	0	80	0	6,610	25
GPs, hospitals, vets &community health	2,670	10	6,269	21	4	0	0	0	1	0	0	0	35	0	8,980	31
Cinema, radio, news, television & entertainment	385	7	147	2	19	0	0	0	18	0	0	0	378	3	947	13
Libraries, museums, galleries, music & arts	176	4	171	5	10	0	0	0	0	0	0	0	2	0	359	9
Parks, gardens & zoos	32	1	124	3	0	0	0	0	0	0	0	0	0	0	156	4
Gambling	825	9	8	0	0	0	0	0	0	0	0	0	23	0	855	9
Sport and recreation	1,393	40	87	3	0	0	0	0	0	0	0	0	18	1	1,498	43
Personal services	1,560	41	33	1	0	0	0	0	0	0	3	0	6	0	1,602	42
Community services & organisations, police, correction & fire brigade	2,133	49	1,814	34	0	0	0	0	0	0	1	0	0	0	3,948	83
Waste disposal	0	0	71	1	0	0	0	0	0	0	0	0	0	0	72	1
All	73,705	2,296	24,364	162	18,751	296	2,517	27	2,510	19	4,974	343	14,600	307	141,421	3,450

Tab. 8: Breakdown of Victoria's virtual water Cycle (cont.)

In the following, the most significant figures in Tabs. 4 and 5 will be explained, and all relevant data sources analysed. We will focus on the most important industries in terms of water intensity, and of total water use and embodiments. Note that many of the data source discrepancies and adjustment procedures described below apply also to industries with lower water intensities and/or use. In general, any discrepancies between the water intensities reported here and those reported in *Balancing Act* [28] may be due to either

- differences between States and Territories and the national average,
- changes in technology between 1994 and 1999, and
- inflation, and other price changes over this period.

5.4.1 Sheep, beef, grains, and other agriculture

Due to the nature of mixed broadacre farming, the ABS Water Accounts [29] list an aggregated water use of Victorian livestock, pasture and grains of 1,053 GL in 2000-01. The combined gross output of these industries in Victoria is about $3.6b [66].[11] Combining these two figures yields a common water intensity of about 250 L/$. No further distinction between livestock and grains can be made, with the exception of dairy cattle and rice. The total water intensities of these sectors are only marginally higher.

5.4.2 Dairy cattle and whole milk

The ABS Water Accounts [29] state an aggregated water use of Victorian dairy growing of 1,928 GL in 2000-01. The ABS agriculture survey [66] lists the gross output of the Victorian sector as about $2.4b. The Australian 1998-99 input-output tables [35] state $3.4b as the total output for the entire Australian industry. Combining all estimates yields a direct water intensity of about 800 L/$. *Balancing Act* reports 1,380 L/$ for the Australian dairy cattle industry in 1995.

The ‘Dairy cattle’ sector shows final demand as private gross fixed capital expenditure, not as private final consumption. The total amount of capital expenditure on output of the Australian dairy cattle and untreated milk industry amounts to about $500m. This demand represents mostly livestock for breeding. In the gravity model, about one third of this transaction becomes allocated to the State of Victoria, where most of the gross output of dairy cattle occurs.

5.4.3 Cotton

This sector includes cotton growing, ginning, and downstream supply of cotton seed and lint. The ABS Water Accounts allocate zero water use to cotton growing, but the Business Registers list 3 ([36], 1998) and 5 ([37], 2001) cotton growing establishments in Victoria. Nevertheless, this apparent output was not taken into consideration.

5.4.4 Rice growing

[11] The Victorian industry Fact Sheets [67] and the ABS agriculture survey [66] list an output of $1.1b (beef) and $700m (lambs) in purchasers prices. The gravity model arrives at solutions in basic prices of about $800m, and $500m, respectively. Amongst grains, the majority of output is wheat ($600m) and barley ($300m). Legumes output was about $55m, while oilseeds amounted to $130m [62].

The ABS agriculture survey [66] lists total turnover for Victorian rice growing for 1996-97 ($2.4m) and 2001-02 ($3.3m). Interpolating this to 1998-99 suggests a turnover of about $2.9m. However note that there exists a discrepancy between the ABS agriculture survey [48] and the commodity cards of the Australian input-output tables [49]: While the former source suggests the value of Australian-grown rice as about $270m (interpolated from 1996-97 and 2001-02 values), the latter source states a total supply worth $317m.[12]

The ABS Water Accounts [29] were not prepared for 1998-99, but for 2000-01, listing the water use of Victorian rice growing as 25.6 GL. Dividing this by gross State output yields a direct water intensity of about 8,700 L/$. This value corresponds well with the *Balancing Act* study [28]. For comparison, calculating the same intensity for NSW 2001 yields about 6,800 L/$ (2197 GL / $320m) [47, 48]. The total water intensities for both States are only marginally higher. *Balancing Act* reports a direct water intensity of 7,343 L/$ and a total water intensity of 8,408 L/$ for Australia in 1995.

5.4.5 *Vegetable and fruit growing*

The direct water intensities can be calculated straight from data in the ABS Water Accounts [29], the ABS agriculture survey [66], and the Victoria industry fact sheets [68, 69]. Total water intensities for these sectors are only marginally higher. Note that the sector 'fruit' does not include grapes for wine, because grapevines are identified separately in the ABS Water Accounts and allocated directly to the sector 'Wine'. In 2002, production of grapes for wine was almost as large as of all remaining fruit. *Balancing Act* reports combined water intensities of 300 L/$ (direct) and 360 L/$ (total) which is in reasonable agreement with the values listed in Tab. 7.

5.4.6 *Coal mining*

The ABS Water Accounts [29] state an aggregated water use of Victorian coal mining to be 22.1 GL. The ABS mining survey [70] does not distinguish Victorian coal mining from other mining, but states an overall mining turnover of about $3.5b for Victoria. The 2001 Australian Business Register [37] states a total of 18 coal mining establishment in Victoria, but lists only 11 of these in the lowest two turnover brackets spanning $0 - $100,000. It omits the remaining 7 establishments in the three highest turnover brackets. Balancing the entire Business Register to conform with all totals and sub-totals suggests a gross output of the Victorian coal mining industry of just under $1b. This figure has to be compared with 1998-99 gross output of brown coal for the whole of Australia, which is about $350m [49]. The gross output figure for Victorian coal mining is hence associated with a high uncertainty. Nevertheless, given the relatively low water use, it is not expected that this industry will have a major influence on Victoria's virtual water cycle.

5.4.7 *Oil and gas extraction*

In 1999, Victoria produced 11.6 GL of crude oil, 5,500 GL of natural gas, and 1.9 GL of LPG. However, the corresponding monetary figures are not available from ABS Statistics [71], and have to be estimated by reconciling national totals, and business locations by turnover range. The direct water intensity for Victorian oil and gas extraction is therefore associated with a high uncertainty. Once again, given the relatively low water use, it is not expected that this industry will have a major influence on Victoria's virtual water cycle.

[12] In contrast, the Australian Rice Growers website [63] states $800m in revenue, however this could refer to husked rice which – in ABS classifications – is a rice product.

5.4.8 Iron ore and mineral sands mining

Victorian iron ore and mineral sands industries are allocated zero water use because material flow statistics [70] state that neither iron ore nor mineral sands are mined in Victoria. However, 1998 registered business counts by ANZSIC4 classification state that there are 2 iron ore mining establishments [36] and 13 minerals sand mining establishments [37] in Victoria. In accordance with ABS practices, water use is distributed across sub-IOBIG mining industries according to mass extracted, so that Victorian iron ore and mineral sands are allocated zero water use. The registered businesses generating monetary output could be some branches of larger mining companies, but this was not followed up further.

5.4.9 Meat products

Most of the total water intensity of meat products is determined by the embodied water in beef cattle. The Australian input-output tables list $3.6b of input of 'beef cattle' into 'meat products', compared to gross output of 'meat products' of about $13.2b. This yields a livestock-to-product input coefficient of about 0.27. Multiplying this factor with the water intensity of 'beef cattle' (see above) yields a water intensity contribution for the 'meat products' sector of 110 L/$ just for this single supply chain. The total water intensity listed in *Balancing Act* for the nation in 1995 is higher at 330 L/$.

5.4.10 Dairy products

Gross output of dairy products manufactured in Victoria is just under $4.8b [65]. Most of the total water intensity of dairy products is determined by the embodied water in dairy cattle. The Australian input-output tables list $2.9b of input of 'dairy cattle & whole milk' into 'dairy products', compared to gross output of 'dairy products' of about $7.9b. This yields a livestock-to-product input coefficient of about 0.36. Multiplying this factor with the water intensity of 'dairy cattle and whole milk' (see above) yields a water intensity contribution for the 'dairy products' sector of 310 L/$ just for this single supply chain. Dairy products' total water intensity according to *Balancing Act* is marginally higher than the value calculated in this work.

5.4.11 Rice products

The output of the rice and other cereal products sector includes husked rice for further processing, rice meals and pellets (mostly intermediate demand), and rice flour and bran (mostly final demand). For confidentiality reasons, rice products are aggregated together with other worked cereal products. The gross output of 'flour mill and cereal products' sector in Victoria in 1998-99 (of which the rice products sector is a part) was about $800m [48].[13] After subtracting non-confidential commodities such as wheat flour and breakfast foods, we estimate the gross output of the remainder to be about $250m. At least $42m of this are husked rice and rice bran.

Most of the total water intensity of rice products is determined by the embodied water in grown rice. The Australian input-output tables list $646m of input of 'grains' into 'flour mill and cereal products', compared to gross output of 'flour mill and cereal products' of about $3.2b. This yields a

[13] For the whole nation, the Australian Rice Growers website [63] states $800m in revenue just for rice, $500m of which are export revenues.

grain-to-product input coefficient of about 0.2. Given that most of rice is grown in NSW and not in Victoria, the gravity model estimates that the rice and other cereal products sector in NSW produces the bulk of rice products (rice input coefficient of about 0.4), while in Victoria other cereal products dominate (rice input coefficient of about 0.12). This yields water intensities for the rice and other cereals sectors of about 2,700 L/$ (NSW) and about 1,000 L/$ (Victoria). Note that these figures are a result of the gravity model and as such associated with a high uncertainty.

5.4.12 Fodder, feed, and animal food

These sectors derive their inputs from by-products of human food products. The water intensities are thus a reflection of the water intensities of grazing and cropping industries, and the value-added of food manufacturing.

5.4.13 Confectionery

Most of the total water intensity of confectionery is determined by the embodied water in dairy products. The Australian input-output tables list $149m of input of ‘dairy products’ into ‘confectionery’, compared to gross output of ‘confectionery’ of about $1.46b. This yields a mother-to-daughter-product input coefficient of about 0.1. Multiplying this factor with the water intensity of ‘dairy products’ (see above) yields a water intensity contribution for the ‘confectionery’ sector of 40 L/$ just for this single supply chain. The next most important supply chains are raw and refined sugar, and sugar cane, at about 10 L/$ each. The water intensity listed in *Balancing Act* is only half that of the water intensity calculated here – around 90 L/$.

5.4.14 Sugar

Most of the total water intensity of sugar is determined by the embodied water in sugar cane. The Australian input-output tables list $1.3b of input of ‘other agriculture’ (mainly sugar cane) into ‘other food products’ (mainly raw and refined sugar), compared to gross output of ‘other food products’ of about $9.3b. This yields a crop-to-product input coefficient of about 0.14. Multiplying this factor with the water intensity of Queensland sugar cane (1,110 GL / $890m = 1,200 L/$) yields a water intensity contribution for the sugar of about 170 L/$ just for this single supply chain. In *Balancing Act*, sugar is aggregated within ‘Other food products’ so that a direct comparison is not possible.

5.4.15 Spirits

Even though the ABS manufacturing survey [48] lists the ANZSIC4 class ‘2184 Spirit mfg’, it does not list any data for 1999. According to the commodity cards [49] of the national input-output tables, the 1998-99 gross output of the ‘Whisky, brandy, rum, gin and fortified spirits; other distilled alcoholic beverages (incl liqueurs and mixed drinks)’ ANZSIC 4-digit industry sector was $211m. In contrast, the 1998 Business Register lists only 3 spirit manufacturing establishments of unknown size. The figures reported in Tabs. 7 and 8 are produced by the gravity model, which allocates about half of the Australian gross output to Victoria. As a consequence, direct water use and direct water intensities for this industry are associated with high uncertainties. *Balancing Act* reports a structural path analysis of water used in the combined Australian ‘Wine and Spirits’ industry, with about 70 L/$ embodied in rice for sake. In 2000, the Penrith (NSW) producer Sun

Masamune produced 800,000 litres of sake a year and had a turnover of $2.5m [72]. Victoria does not produce sake, so that the water intensity of spirits is lower at about 110 L/$.

5.4.16 Wine

The direct water intensity of Victorian wine can be calculated straight from data in the ABS Water Accounts [29] and the ABS agriculture [66] and manufacturing [48] surveys. Victorian wine growing consumed 288 GL in 2001, generating $300m (grapes for wine) and $600m (wine) of output, leading to a water intensity of about 320 L/$. In this report, the total water intensity is made up of an average of the primary product (wine grapes; 880 L/$) and wine for consumption (190 L/$). Final demand of wine grapes in Victoria is very low (about $10 million), while final demand of wine dominates the aggregate (about $300 million), which is the reason why for this aggregate, the total water intensity (219 L/$) is lower than the direct intensity (320 L/$). Note that the sector ‘fruit’ does not include grapes for wine, because grapevines are identified separately in the ABS Water Accounts and allocated directly to the sector ‘Wine’. In 2002, production of grapes for wine was almost as large as of all remaining fruit. In *Balancing Act*, wine and spirits are aggregated together, with a total water intensity of about 500 L/$, which is probably due to the higher proportion of rice used in the Australian average sectors.

5.4.17 Wool scouring and wool fabrics

Most of the total water intensity of wool products is determined by the embodied water in shorn wool. The gravity model yields a wool-to-product input coefficient of about 0.6. Multiplying this factor with the water intensity of ‘sheep and shorn wool’ (about 300 L/$) yields a water intensity contribution for the ‘cotton fabrics’ sector of about 180 L/$ just for this single supply chain, explaining virtually the entire water intensities of the commodities ‘wool scouring and wool fabrics’.

5.4.18 Cotton fabrics

Most of the total water intensity of cotton products is determined by the embodied water in grown cotton. The gravity model yields a crop-to-product input coefficient of about 0.2. Multiplying this factor with the water intensity of ‘cotton growing’ (about 2,051 GL / $900m ≈ 2,000 L/$, [47, 66]) yields a water intensity contribution for the ‘cotton fabrics’ sector of 300 L/$ just for this single supply chain. This explains a major part of the water intensity of the commodity ‘cotton fabrics’. In *Balancing Act*, both wool and cotton fabrics are aggregated within the ‘Fibres, yarn and fabrics sector’.

5.4.19 Electricity generation

The ABS Water Accounts state that in 2000-01 – after subtracting in-stream use – Victorian power stations use about 108 GL [29]. The ABS publication ‘Electricity, Gas, Water and Sewerage Operations, Australia, States and Territories - companion data’ [73] lists Victorian Gross State Output as $5.1b, and national gross output of electricity as about $24.4b. However, the 1998-99 national input-output tables [35] list the same quantity as $18.6b. In order to comply with the input-output tables, Victorian electricity output was scaled down to about $4.9b. This leads to a direct water intensity of about 22 L/$. The total water intensity is only marginally higher. Total final electricity demand in Australia is about $5b. The Household Expenditure Survey suggests that Victoria's part in this is about $1.3b.

Note that previous editions of the Australian 2000-01 Water Accounts reported the water use of the Victorian electricity industry to be around 1,500 GL. This figure was based on a reporting mistake from Victorian power stations that double-counted water repeatedly extracted from and re-inserted into cooling ponds. This is why a direct comparison with *Balancing Act* is not possible.

5.4.20 Gas supply

The Victorian gas supply industry is not allocated direct water use. This is because in the Australian Water Accounts, water use for this industry is lumped together with water used for electricity generation. While for other industries, water use was prorated according to gross monetary output, this procedure was deemed inappropriate for this pair of industries, because the electricity industry would use almost all water even though its share of gross output is less than 100%.

5.4.21 Water supply

According to the ABS, the water consumption of the water supply industry sector includes losses from seepages and evapotranspiration (where measured). For Victoria, 787 GL are recorded for the water consumption of the water supply industry [29]. Unfortunately, there is no data source that directly breaks down gross output of the water supply industry by State and Territory (References [73, 74] contain breakdowns for electricity, but not for gas and water). The 2001 Australian Business Register [37] lists 182 Victorian establishments engaged in water supply and sewage/drainage services, distributed across turnover ranges between $0 and $1m. The Register states a total of 200 establishments for Victoria, but the number of establishments in the two turnover brackets above $1m are not specified. Consulting industry data on the Victorian water supply industry suggests a gross output of the Victorian water supply industry of about $1.9b. This figure has to be compared with 1998-99 gross output for the whole of Australia, which is $6.4b. Combining water use and gross output suggests a direct water intensity of around 400 L/$. *Balancing Act* suggests about 330 L/$ for the nation in 1995. Note that in the input-output framework this water intensity applies to both water for final demand (residential consumption) as well as industrial and irrigation water. In reality however, most of evapotranspiration losses occur during transfers in open channels to agricultural users. The water intensity of residential water is hence significantly smaller than the average water intensity reported here.

5.4.22 Final demand

All final demand figures were derived from the 1998-99 Household Expenditure Survey (HES) undertaken by the ABS [34]. Note that the original expenditure data represent a survey and not a census: There exist significant discrepancies between the sum over all expenditure items from the survey, and the item 'Private Final Consumption' in the national input-output tables [35]. First, the HES commodity classification differs from the IOPC classification, but the former is fortunately more detailed. Second, the HES registers expenditures in purchasers' prices, which differ from the input-output tables' basic prices because of added margins and taxes. In order to force the Household Expenditure Survey data to comply with totals from the national input-output tables, a concordance matrix was estimated (using constrained optimisation techniques) that exactly maps Australian survey data into the national input-output data. This concordance matrix was subsequently applied to household expenditure data for Victoria.

Some of the final demand commodities are significant in terms of their water embodiment because of the magnitude of final consumption expenditure. Examples are ‘Meat’, ‘Dairy products’, ‘Building & construction’, ‘Trade & repairs’, ‘Hotels, cafes, restaurants & accommodation’, and ‘Community services & organisations, police, correction & fire brigade’.

Victorians spend about $15 per week and household on meat, and $11 per household and week on dairy product, which equates to about $1b on each product type per year for all of Victoria. The output of the sector ‘Trade and repairs’ comprises services of storing, and distributing goods from virtually all manufacturing sectors of the economy. This output does not comprise the value of the traded commodity, but only that of the trade service. Included in the retail sector are take-away food outlets, hence the relatively high water intensity compared to other service sectors. Similarly, the sector ‘Hotels, cafes, restaurants & accommodation’ contains food products, leading to a relatively high water intensity compared to other services. Victorians spend more than $50 per week and household on meals, alcohol on licensed premises and accommodation, which equates to about $5b per year for all of Victoria. Similarly, some service sectors have a relatively high water intensity, such as ‘parks, gardens, zoos’, ‘sports and recreation’, and ‘fire brigade’, presumably because of water used for lawn watering, and fire fighting.

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6 Appendix: Mathematical exposition of the project methodology

6.1 National Accounting

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. The Australian input-output tables are published annually or biannually 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 [3]. 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 [4] 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** (Figure below) 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.

The layout of the complete use table (Figure below) reflects the National Accounting Identity

$$\mathrm{GDP} + m = \mathrm{GNE} + e = \mathrm{GNT}, \qquad (1)$$

with the *Gross Domestic Product* (GDP) and imports (m) arranged in rows and the *Gross National Expenditure* (GNE) and exports (e) arranged in columns around a central square table of inter-industrial intermediate transactions (Fig. 1). Both sums add up to *Gross National Turnover* (GNT). In the input-output terminology, GDP + m is called *primary input*, or *value added* (v), and GNE + ex is called *final demand* (y). Adding *intermediate demand* (U) yields *total output*

$$x = U + v = U + y \ . \qquad (2)$$

Final demand consists of gross fixed capital expenditure (k), government and private domestic final consumption (c_{gv}, c_{pr}), changes in inventories (i) and exports (e), while primary inputs are wages and salaries (w), gross operating surplus (s), net taxes on products and production (t) and complementary and competing imports (m):

$$w + s + t + m = k + c_{gv} + c_{pr} + i + e \ . \tag{3}$$

Disaggregating Equation 2 into M commodities (expenditure side) and N industries (production side) yields

$$\{x'_i\}_{i=1,...,M} = \{\Sigma_j U_{ij}\}_{i=1,...,M} + \{y'_i\}_{i=1,...,M} \ \text{, and} \tag{4a}$$
$$\{x_j\}_{j=1,...,N} = \{\Sigma_i U_{ij}\}_{j=1,...,N} + \{v_j\}_{j=1,...,N} \ . \tag{4b}$$

Equations 4a and 4b are basically accounting equations, showing the production and usage balances of all commodities and industries in the economy. In the following, a prime (’) will denote a column vector, while unprimed variables are arranged in rows. Note that sums over commodities and industries must equal the scalar totals:

$$\Sigma_i x'_i = \Sigma_j x_j = x \quad \text{and} \quad \Sigma_i y'_i = \Sigma_j v_j = v = y \ . \tag{5}$$

Commodity and industry formulations can be converted into each other using the market share matrix **D**:

$$x'_i = \Sigma_j D_{ji} x_j \quad \text{and} \quad x_j = \Sigma_j D_{ji} x'_i \quad \Leftrightarrow \quad \boldsymbol{x}' = \mathbf{D}^t \boldsymbol{x}^t \quad \text{and} \quad \boldsymbol{x} = \boldsymbol{x}'^t \mathbf{D}^t \ ,^{14} \tag{6}$$

where industry totals are in a $1\times N$ row vector $\boldsymbol{x}$, commodity totals in a $M\times 1$ column vector $\boldsymbol{x}'$, and the superscript “t” denotes transposition.

[14] The market share matrix is normalised according to $\Sigma_i D_{ij} = 1$ and $\Sigma_j D^t_{ji} = 1$. Combining this normalisation with Equation 6, the sum requirement in Equation 5 can be seen as $\Sigma_i x'_i = \Sigma_j D^t_{ji} \Sigma_i x'_i = \Sigma_i \Sigma_j D_{ij} x_j = \Sigma_j x_j = x$.

Industries / Commodities	Agriculture, forestry and fishing	Mining	Food	Other manufac-turing	Utilities	Construc-tion	Trade	Transport and communication	Admini-stration, services
Agriculture, forestry and fishing Mining Food Other manufacturing Utilities (electricity, gas, water) Construction Trade (wholesale, retail) Transport and communication Administration and services	Use of commodities by industries in A$m								

Figure1: Structure of intermediate demand in the use table

	Intermediate demand	+ Private Final Consumption	+ Government Final Consumption	+ Private Gross Final Consumption	+ Public Enterprise Gross Final Consumption	+Government Gross Final Consumption	+ Changes in Inventories	+ Exports	= Total Supply	
INTERMEDIATE DEMAND	443,611	264,333	88,507	81,031	12,129	11,562	1,767	83,364	*986,308*	
+ Wages & salaries	226,904								***226,904***	
+ Operating surplus	191,809								***191,809***	**GDP**
+ Taxes on production	16,408			2,690					***19,098***	***473,463***
+ Taxes on products	12,973	17,970		2,948	73	90	133	1,461	***35,651***	
+ Imports, complem.	355	91		123		2	6		***579***	
= Australian Production	*892,062*	*282,395*	*88,507*	*86,793*	*12,202*	*11,655*	*1,907*	*84,825*	***1,460,351***	**GDP+M**
+ Imports, competing	94,246							2,828	***97,075***	***571,117***
= Total Use	*986,309*	***282,395***	***88,507***	***86,793***	***12,202***	***11,655***	***1,907***	***87,654***	***1,557,426***	
				GNE ***483,462***				**GNE+X**	***571,117***	**GNT**

Aggregate quantities in the 1994-95 Australian National Accounts (after [75]).
All figures in A$m, subtotals in italics, totals and aggregates in bold italics.
GNE = Gross National Expenditure, GDP = Gross Domestic Product, GNT = Gross National Turnover

6.2 Input-output theory - the Leontief model

The most commonly used input-output model assumes a market economy that is driven by demand. Accordingly, using Equation 4a, substituting $B_{ij} = U_{ij} / x_j$, and adopting matrix notation leads to

$$\{x'_i\}_{i=1,...,M} = \{\Sigma_j B_{ij} x_j\}_{i=1,...,M} + \{y'_i\}_{i=1,...,M} \quad \Leftrightarrow \quad \boldsymbol{x'} = \mathbf{B}\, \boldsymbol{x}^{\mathrm{t}} + \boldsymbol{y'} \ . \tag{7}$$

B is called a *direct requirements* matrix. As the use matrix **U**, it shows commodities in its rows and industries in its columns. In most generalised input-output applications, production technology is assumed to be a characteristic of industries, as opposed to commodities.'[15] Using Equation 6, Equation 7 can be transformed into industry formulation:

$$\boldsymbol{x'}^{\mathrm{t}}\, \mathbf{D}^{\mathrm{t}} = \boldsymbol{x}\, \mathbf{B}^{\mathrm{t}}\, \mathbf{D}^{\mathrm{t}} + \boldsymbol{y'}^{\mathrm{t}}\, \mathbf{D}^{\mathrm{t}} \quad \Leftrightarrow \quad \boldsymbol{x}^{\mathrm{t}} = \mathbf{A}\, \boldsymbol{x}^{\mathrm{t}} + \boldsymbol{y}^{\mathrm{t}} \ , \tag{8}$$

where $\mathbf{A} = \mathbf{DB}$ is an industry-by-industry direct requirements matrix. Its coefficients A_{ij} describe the intermediate demand of industries j=1,...,N of output from industries i=1,...,N per unit of total output of industry j. "Industry formulation" means that the whole accounting system is expressed in industry output terms, no matter the type of commodity. This is opposed to the "commodity formulation", which maps commodity-to-commodity flows. The industry formulation has an important practical advantage for generalised input-output models, since in many countries (and also in Australia), most auxiliary (for example social and environmental) statistics are in industry terms. **A** is the central element of the classical input-output relationship

$$\boldsymbol{x}^{\mathrm{t}} = (\, \mathbf{I} - \mathbf{A}\,)^{-1}\, \boldsymbol{y}^{\mathrm{t}} \ , \tag{9}$$

which follows directly out of solving Equation (8) for $\boldsymbol{x}$. **I** denotes the $N\times N$ unity matrix, and

$$\mathbf{L} = (\, \mathbf{I} - \mathbf{A}\,)^{-1} \tag{10}$$

is called the *total requirements* matrix or *Leontief inverse*. An element L_{ij} describes the total "content" or "embodiment" of output produced by industry i per unit of final demand from industry j. A *generalised* Leontief model features a $1\times N$ vector $\boldsymbol{Q}$ of *total factor multipliers*, that is total requirements of production factors per unit of final demand from N industry sectors. $\boldsymbol{Q}$ can be calculated from a $1\times N$ vector $\boldsymbol{q}$ containing (direct) sectoral production factor usage per unit of total output:

$$Q = q\, (\, \mathrm{I} - \mathrm{A}\,)^{-1} = q\, \mathrm{L}\ . \tag{11}$$

The total factor requirement Q (scalar) of a final demand bundle $\boldsymbol{y}$ can then be written as

$$\boldsymbol{Q} = Q\, y^{\mathbf{t}} = q\, \mathrm{L}\, y^{\mathbf{t}} = q\, x^{\mathbf{t}} \ . \tag{12}$$

These equations state that factor inputs $\boldsymbol{q}\mathbf{L}$ are required in order to satisfy a final demand bundle $\boldsymbol{y}$ (in monetary terms).

The technical approach taken in this work for generalisation of the standard input-output framework is to include water use $\boldsymbol{q}$ expressed in litres into the direct requirements matrices **A** and **A*** as additional rows below primary inputs. The Leontief inverse then contains total

[15] This condition is sometimes imposed because the available production factor data is in industry terms.

multipliers of these factors in the same rows. This procedure follows the solution of Leontief and Ford [21] to the problem of internal consistency[16].

The Leontief input-output system represents a situation that is characterised by (1) a linear relationship between inputs and output, or in other words, zero fixed costs and constant returns to scale, (2) no factor scarcity and perfectly quantity-elastic supply, (3) idle capacity, and (4) fixed prices that are unaffected by changes in final demand. This situation is dominated by consumers' demand, with producers adjusting to an optimal input structure reflected by the fixed requirements coefficients A_{ij}. Some of these assumptions are not restrictive for accounting purposes such as in TBL reporting, but only for modelling change.

6.3 Valuation

In the representation of Equation 2 in the Australian input-output tables, all quantities and intra-industrial transactions are valued in "farm or factory gate" prices, so-called *basic prices* (bp). These are also referred to as *net producer's prices*, because they differ from *producer's prices* (pp) by taxes on final demand t_f, so that

$$y_{(bp)} = y_{(pp)} - t_f \,. \tag{13}$$

Insertion of Equation 19 into Equation 3 yields

$$w + s + t + t_f + m = y_{(pp)} \,. \tag{14}$$

Note that t and t_f are not the only sources of tax earnings for the government, since the wages w contain income tax t_w. In contrast to the primary inputs, t_f is not paid by intermediate producers, but only by final purchasers, and must therefore not be treated with the input-output formalism.

Most input-output studies are carried out in terms of basic prices, because coefficients in basic prices valued in producers' prices can be subject to large fluctuation due to changes in taxation. As in the *Balancing Act* report, all intensities presented in this study therefore refer to basic prices.

6.4 Justification for choice of model

We chose an *input-output* model because it is the most simple model that allows looking at economic activity in a production life-cycle context. Moreover, input-output analysis is politically and ideologically neutral, and does not incorporate any specific behavioural conditions for the individual, companies or the state, except that an economy behave in a consistent manner. Finally, an input-output approach to TBL can be reproduced in every country, for almost any base year, by any institution, since input-output tables are generated and published in regular intervals by statistical bureaux around the world.

We chose a *static*, *short-term* model because the purpose of this TBL study is reporting and accounting for a particular base year, and not temporal modelling of structural change, or demographic, technological and policy scenarios. Using static input-output analysis, it is

[16] Early input-output models, such as by [76]) and [77]), incorporated pollution as outputs of industries, assembled in additional columns of the interindustry table, leading to incompatible units and summation problems across rows (see [15], p. 92). The solution of [21]) to reverse the position of environmental inputs and outputs (ie to assemble generated pollutants as inputs in rows) made this type of model operational.

impossible to precisely quantify changes in TBL factors, which would occur under real-economy shifts in demand or supply, or under corporate or government abatement policies. The difference between calculated TBL factor embodiments of two alternative scenarios would be equal to real TBL factor changes caused by the corresponding shift from the current to the alternative scenario only if during that shift (1) all commodity prices stayed constant, (2) there were no changes in technology, no input substitution, and hence no change in production factor intensities, (3) there were no constraints on production factors, such as a rigid labour supply, and (4) production costs were linear functions of production output (as inherently assumed in input-output analysis). The latter condition applies to production situations where there are no economies of scale, and where average costs equal variable costs, that is, fixed costs are zero. Since none of the above conditions is satisfied in practice, the difference in TBL factor embodiments is only *indicative* of the effect that real-economy demand or supply shifts, or corporate and government policies would have on TBL factors (compare [78], p 431).

Structural change, or demographic, technological and policy scenarios can be dealt with using other model types, such as general equilibrium models [79], marginal or dynamic input-output models [80], sequential interindustry models ([81-83]), or iterative physical models [84]. Some of these models feature an input-output model in their core. While this core is based only on neutral accounting identities, the model becomes analytical when assumptions are made about the behaviour of economic agents, which then enter into demand and production functions. In order to econometrically estimate these functions, a (sometimes prohibitively) large amount of data is needed, so that analytical models often operate at a high level of aggregation and/or borrow elasticities and other functional parameters from literature studies of previous years and different regions.

In any case, any analytical model relies on its assumptions about the functioning of the economy, and stands and falls together with their validity. This is not the case for static input-output systems that are applied to *ex-post* accounting, since interactions between economic agents are not modelled.