Measurement, valuation and accounting of the water provisioning services in the Central Highlands of Victoria, Australia

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Abstract

The ecosystem services of water provisioning from the Central Highlands of Victoria, Australia, were measured and valued using the System of Environment-Economic Accounting Experimental Ecosystem Accounting (SEEA-EEA). The area provides most of the water used by the city of Melbourne and there is conflict between native forest logging and other land uses. Estimates of the water provisioning service were made for the period 1990 to 2015 using published information on the water supply industry, models of surface water run-off and the replacement cost method. In 2015, the volume of the water provisioning service was 306 ML and the value was AUD$75 million.

Replacement cost was used to estimate the value of the water provisioning service because: (1) valuation using the resource rent approach preferred by SEEA-EEA is problematic owing to government price control; (2) insufficient information exists to apply a production function; and (3) physical infrastructure was built to replace lost, or expected to be lost, water provisioning services. The data on water provisioning was included in a broader accounting exercise to provide information to help resolve land use conflict.

Questions for the London Group

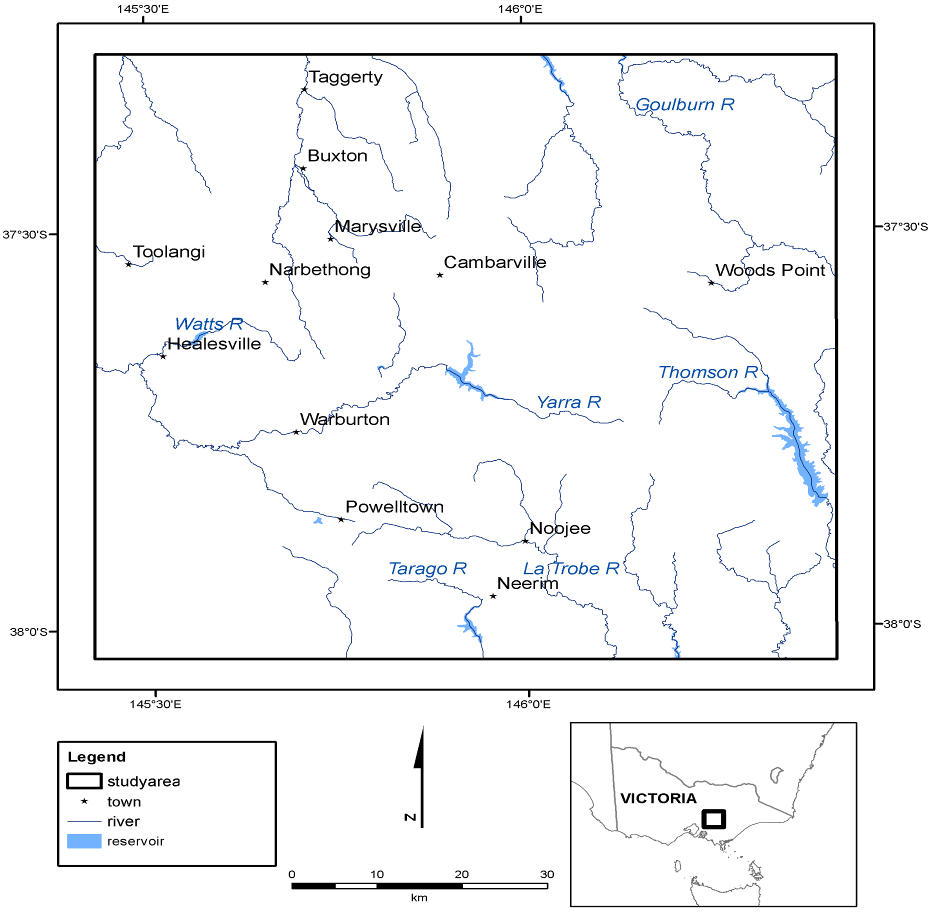
- Do you agree with the water provisioning service being defined as the flow into the reservoirs operated by the water suppliers? This flow is mainly run-off but also includes some direct precipitation on the reservoir.
- Do you agree with the water provisioning service being recorded at the time it flows into the reservoirs operated by the water suppliers? The alternative would be to record it at the time the water product is supplied (and the time the water delivered to users).
- For valuation, the replace cost method as recommended by Edens and Graveland (2014) was used. Two effective replacements cost options were identified and the lower valuation was used. Could an average replacement cost or ranges be used where there are multiple replacement options?

1. Introduction

The Central Highlands study area is in south-eastern Australia in the state of Victoria (Figure 1). It contains a range of landscapes including human settlements, agricultural land, forests and waterways; and is used for a variety of activities, including timber production, agricultural production, water supply and recreation. It is also home to many species, including the endemic and critically endangered Leadbeater's Possum. The study was undertaken as part of a broader project (Keith et al. 2017) aiming to provide comprehensive information on the condition and economic benefits obtained from current and past land use using the System of Environmental-Economic Accounting (SEEA) (UN 2014a, UN 2014b).

There is significant land use conflict in the study area, in particular between native forest logging and biodiversity conservation. The area is within the region covered by the Central Highlands Regional Forest Agreement, a land-use planning document that is due for re-negotiation within 2 years and includes the areas proposed for addition to the national park network (GFNP 2016).

Figure 1. Location of the Central Highlands study area, Victoria, Australia



1.1 System of Environmental-Economic Accounting (SEEA)

The SEEA provided the conceptual basis for estimation of the water provision service in the Central Highlands. The SEEA is contained in two complementary documents of the international community: SEEA Central Framework (UN 2014a) and SEEA Experimental Ecosystem Accounting (UN 2014b). Together they describe an integrated accounting structure covering component accounts (for example, land, water, carbon and biodiversity), as well as accounts for ecosystem extent, condition and services.

SEEA Experimental Ecosystem Accounting (UN 2014b) accounts for the composition and condition of ecosystems as well as the ecosystems services that support human well-being. Ecosystem accounting is based on a model of stocks and flows. In this model, ecosystem assets (which are spatially defined areas, in this study within the Central Highlands) provide a flow of services which in combination with human inputs (labour, capital, etc.), produce benefits that are used by a range of beneficiaries (for example, people, businesses or government). In ecosystem accounting, all areas, regardless of the level of human modification, are included as ecosystems. For example, crops, pastures and built-up areas are included as ecosystems in ecosystem accounts.

The SEEA has been recommended for use by the Australian Government (BoM 2013a) and is used by a variety of agencies including the Australian Bureau of Statistics (ABS) (e.g. ABS 2016a) and the Government of Victoria (e.g. Eigenraam *et al.* 2013; Varcoe *et al.* 2015). The Bureau of Meteorology (BoM) uses a system of water accounting (e.g. BoM 2014) that can be related to SEEA (Vardon *et al.* 2012), while the Wentworth Group of Concerned Scientists has also developed a process and metrics for producing indicators (e.g. Sbrocchi 2015).

A number of environmental or ecosystem accounts already cover all or part of the Central Highlands region or the economic users of the region. These include: Land Accounts Victoria, Experimental Estimates (ABS 2013); Water Accounts, Australia (e.g. ABS 2015); National Water Account – Melbourne (e.g. BoM 2014); State Tourism Satellite Accounts (e.g. TRA 2015); Value of Tourism to Victoria's Regions (Tourism Victoria 2015); Victorian Experimental Ecosystem Accounts (Eigenraam *et al.* 2013); Valuing Victoria's Parks (Varcoe *et al.* 2015); Melbourne Water Annual Reports; and VicForests Annual Reports. None of these accounts has spatial boundaries that align directly with the study. In particular, the National Water Account (Melbourne Region) (BoM 2016) and the ABS Water Account, Australia (ABS 2015) were not able to be used for this reason.

1.2 Water provisioning service

The physical estimate of the water provisioning service was determined to be equal to the runoff or water yield from the study area that flowed into the reservoirs operated by Melbourne Water. The service was deemed to be used by Melbourne Water at the time when it enters the reservoir and not when water leaves the reservoir and is supplied to customers. This treatment distinguishes the ecosystem service from the benefit, with the ecosystem service of water provision being the inflow to the reservoir and recorded in the time period of the inflow, while the benefit is the final good of water supplied to customers which may occur at a different time and is unlikely to be equal to the inflow.

1.3 Water supply

The study area contains the majority of the catchment areas for the ten water storage reservoirs of the Melbourne Water Corporation that supply water to the city of Melbourne. Some water from the Central Highlands catchments is used for rural water supply in surrounding regions. Melbourne Water is owned by the Victorian Government. They manage the reservoirs and supply water to water retailers: City West Water, South East Water and Yarra Valley Water (Melbourne Water 2015). These water retailers then supply residential and commercial customers in Melbourne and the surrounding areas.

Table 1 provides information on characteristics of the reservoirs within the study region. The water supply catchments of Melbourne Water cover an area of 157,000 ha but only 115,149 ha is within the study area. Some 8,931 ha are dedicated specifically to protection of water storages and part of the area has been logged or is available for timber harvest. Ten reservoirs are operated by Melbourne Water, with five of these reservoirs within the study area but the others are downstream and fed by the same catchments. Total reservoir capacity is 1,812 GL.

Table 1. Characteristics of the reservoirs within the Central Highlands study region

Reservoir	Capacity (GL)	Catchment area (ha)	Area logged (ha)	Area available but not logged (ha)	River supply
Thomson	1068	47,558	6,743	15,837	Thomson R.
Upper Yarra	200	34,047	217	432	Upper Yarra R.
Tarago	37	11,498	2,792	3,779	Tarago R.
Maroondah	22	10,191	24	28	Watts R.
O'Shannassy	3	11,888	73	57	O'Shannassy R.

Reservoir capacity refers to total water storage capacity. Approximately 2.5% of the capacity is 'dead storage', that is unavailable for use at the bottom of a reservoir.

2. Data sources and methods

A range of economic and environmental data were used to estimate the volume and value of the water provision service obtained from the region. The value of the service (V) is equal to the volume of the service supplied (Q) multiplied by the price per unit of the services (P) or:

$$V = P * Q$$

The estimates of the volume and value of water provisioning service were compiled into environmental accounts using the SEEA (UN 2014a, 2014b). Two distinct types of accounts were produced: (1) a physical asset account and (2) an account for the use of the ecosystem service of water provisioning. Only the ecosystem service was valued and the scope of the water asset account was limited to the water stored in reservoirs within the study area operated by Melbourne Water.

The runoff and precipitation that flows into the reservoirs operated by Melbourne Water is taken to be the volume of the water provisioning service. This inflow to the reservoirs is variable and different from the volume of water supplied by Melbourne Water out of the reservoirs to its customers. The ecosystem service of water provisioning is used by Melbourne Water as input to the production of water supplied and used in the economy.

2.1 Physical estimate of water accounts

2.1.1 Water provisioning service

Physical information was compiled from a variety of sources. These data were sometimes the result of direct measurement but often involved the use of hydrological models.

Data describing the characteristics of the ten reservoirs were obtained from the Melbourne Water website. Changes in the water stored in reservoirs represents the balance between all inflows and outflows, including supply to users. Inflows of water were runoff, rainfall directly onto the reservoir and transfers in from other storage facilities. Outflows of water include evaporation from reservoirs and supply of water from reservoirs to consumers in Melbourne, releases of water for environmental flows and irrigation, and a small amount for hydroelectricity generation.

Water yield or runoff was calculated spatially across the study area at a grid resolution of 0.01 degrees (~1 km^2 scale) and aggregated for each of the five reservoirs within the study area. These data provided information about the spatial distribution of water inflow and the change each year in response to climate variability, land cover change, and disturbance history. Applying the response of water yield to forest age allowed some understanding of the causes of change in yield over time in relation to forest management and disturbance events.

Water yield was estimated for each year using a spatially explicit continental water balance model calculated monthly across our study area (Guo *et al.* 2002, eMAST 2016). Actual evapotranspiration was calculated on a monthly time step from precipitation and pan evaporation . Runoff was calculated as the water in excess of the soil water field capacity of the catchment. The model was calibrated for the ecohydrological region (Stein *et al.* 2009) against gauged streamflow data (n = 347 flow gauges) (Peel *et al.* 2000, BoM 2013b). These gauging stations were selected to be in catchments with minimal disturbance, but there may have been some forest harvesting or fire in the past that would have resulted in a range of forest ages. Runoff for each grid cell upstream of the reservoir was accumulated to give a volume inflow to each reservoir. The spatial analysis covered a range of scales. The runoff estimates were derived at a grid resolution of 0.01 degrees, and the catchment delineation and flow routing were undertaken at 9 second resolution (approximately 270m). The forest age polygons were gridded at 0.0001 degrees resolution to minimise the information lost from the polygon boundaries. The runoff depth was resampled to the finer resolution, converted to a volume and adjusted for forest age (where applicable), then aggregated to 9 second resolution for routing (Stein *et al.* 2014).

The pattern of annual variability in the water balance model is driven by climate variability, in particular, precipitation and evapotranspiration. However, actual water yield is also influenced by the condition of the vegetation in the catchment, in particular, the age of the forest. Evapotranspiration depends on leaf area index and leaf conductance, which vary with forest age and thereby determine the shape of the water yield response curve (Vertessy *et al.* 2001). Forest age was determined from the last stand-replacing disturbance event, which refers to high severity fire or clearfell logging for montane ash forest and rainforest, and clearfell logging for mixed species forest. Change in water yield is shown as a proportion of the pre-disturbance amount (Figure 2). An increase in water yield occurs for the first 1 to 3 years after stand-replacing disturbance in all forest types. In montane ash forest and rainforest, a decrease then occurs with the greatest reduction between ages of 13 – 49 years and peaking at 25 years. Maximum reduction from a pre-disturbance 1939 regrowth forest is 29%, and from an old growth forest is 48%. Water yield is not fully restored for at least 80 years if a forest is regrowth at the time it is disturbed, and 200 years if a forest is old growth at the time it is disturbed.

Figure 2. Reduction in water yield in montane ash forest estimated as a proportion of the pre-disturbance amount in regrowth and old growth forest

Source: Kuczera (1987) for old growth model

The water yield calculated from the water balance model was derived for a constant vegetation condition, thus producing a baseline yield. This baseline yield was compared with the yield when forest age, and the change in age, were taken into account. The difference in water yield with and without disturbance events, and disaggregated into fire and logging events, provided information about the attribution or cause of the change in water yield.

Details of calculations of the water yield function with forest age taken into account are provided in the full report[1].

2.1.2 Water supply

The water supplied by Melbourne Water includes drinking water, environmental releases, irrigation entitlements, and extra allocations (Table 2). Minimum environmental flows are specified in the Environmental Bulk Entitlement for each river. There are additional regulations concerning minimum quantities of downstream flows, both daily and seasonal. These rights to water may be suspended, reduced, increased or changed after water shortage has been declared (Victorian *Water Act 1989* Section 33AAA(2), DEPI1989). Surface water allocations are made for high reliability and low reliability water shares. Water is diverted from rivers under licensed water access entitlements as non-allocated surface water to users, for irrigation, stock and domestic water use, commercial and industrial purposes. Take and use licences specify a maximum entitlement volume, but this does not represent a surface water liability.

Table 2. Sources of water releases from reservoirs within the Central Highlands

Reservoir	Water supply (GL)	Source of Entitlement
Thomson	639 (2012)	Supply to Melbourne Water via pipe to Upper Yarra reservoir (share of inflow)
	25.1	Victorian Environmental Water Holder, 15.1 GL for controlled daily flows + 10 GL additional allocation
	45 + 6% of inflow	Southern Rural Water for Thomson-Macalister Rivers irrigation district
Tarago	4.8	Gippsland Water for urban water supply
	3 or 10.3% of inflows	Tarago & Bunyip Rivers Environmental Entitlement
Yarra	17	Yarra River Environmental Entitlement

2.2 Valuation of the water provisioning service

The water supplied into the economy is the end result of a combination of fixed capital (reservoirs, water mains, pumps, etc.), labour and other inputs, as well as ecosystem services. The annual reports of Melbourne Water (e.g. Melbourne Water 2015), provided the information on the volume of water supplied, the revenue received from water supply and the costs of producing the water (e.g. wages and salaries, consumption of fixed capital other running costs).

The value of the water supplied is not equal to the value of the water provisioning service. This is because the values of the fixed capital, labour and other inputs need to be deducted. The regulation of the price of water in Victoria (see Melbourne Water 2008) presents another complication for valuation that is discussed later. A further complication is that the water supplied to the economy uses the additional ecosystem service of water filtration but separate estimates of this have not been made.

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[1] http://www.nespthreatenedspecies.edu.au/Ecosystem%20Complete%20Report_V5_highest%20quality.pdf

Data derived from the Melbourne Water business accounts were used to generate an initial estimate of the value of the ecosystem service of water provisioning and the value added by the company, aligned with the concepts of Gross Value Added in national accounting.

Three methods for calculating the value of the water provisioning service were considered: (1) resource rent, (2) production function and (3) replacement cost. All are outlined in general in the SEEA Experimental Ecosystem Accounting (UN2014a).

The resource rent method was not used owing to the constrained nature of the water market in Victoria, where prices are regulated by the Essential Services Commission, and the lack of suitable data in the Annual Reports of Melbourne Water about the value of the water supply infrastructure and the costs associated with water supply. While the reports contain some information about these costs, the data are presented as the combined values of water supply and sewerage operations, whereas separate information about these two activities is required for resource rent calculations. Similarly, in the Australian System of National Accounts information about the water supply industry is included with the sewerage industry. In addition, previous calculations of resource rent in Australia by Comisari *et al.* (2011), and in the Netherlands by Edens and Graveland (2014), have found negative rents.

Lack of data also was the reason for rejecting the production function approach. In the case of water from the Central Highlands, the water provisioning services are used by Melbourne Water. However, the revenue received for the supply of water is price constrained. The benefits of the price constraint are passed on to the consumers of the water supplied by Melbourne Water. This is firstly the water retailers and secondly the users of the water from these retailers. The production function approach would require detailed information on the water retailers and the subsequent water consumers in Melbourne. This is not just the price of the water received but the value and all other inputs to the production activities of business.

Because of these practical data constraints, the replacement cost method was used to value the water provisioning services, broadly following the method of Edens and Graveland (2014). The replacement cost method assumes: (1) that if lost, the service would be replaced, and (2) that the consumption pattern would be unaffected by any increase in cost.

Three options for the replacement cost of water were investigated: (1) transfer of water from other regions; (2) use of desalination; and (3) use of recycled water.

2.2.1 Cost of transfer of water from other regions

Water can be traded between regions in Victoria, with the price of water allocations varying over time and between locations. Between 2010-11 and 2013-14, the price ranged from $30 to $100 per ML (DELWP 2015). The purchase of water from other regions (for example, from northern Victoria) and its transport to supply Melbourne is possible, although subject to regulatory approval. Melbourne Water could transport water to its distribution network (and hence customers) via an existing pipeline, the 70 km long Yea-Sugarloaf pipeline, which can transport up to 75 GL yr^{-1} and was completed in 2010 at a cost of $750 million

(Melbourne Water 2010). Assuming a 75 year asset life for the pipeline and a simple linear depreciation (that is, \$10 million per annum), the capital cost is \$133 ML^{-1}.

However, operation of the pipeline is energy intensive and this adds significantly to the costs of energy for water supply. Energy cost is typically the biggest cost in water systems (World Bank 2012). Energy use by Melbourne Water increased by 222,000 GJ between 2008-09 and 2009-10 due to the operation of the Yea-Sugarloaf pipeline, as well as the energy requirements of another pumping station and a wastewater treatment plant (Melbourne Water 2010, p. 26). Assuming the pipeline used one-third of the additional energy, this is 74,000 GJ to transport 16.7 GL (Melbourne Water 2010 p. 26). In 2009-10, Melbourne Water's total energy use was 1,638,000 GJ and energy expenditure was \$20.2 million (Melbourne Water 2010 p. 27). This represents an energy cost of \$55 per ML transported. The total cost of replacing water would thus be around \$218 per ML in 2009-10 based on the sum of: \$30 per ML for purchase of water allocation (using the lowest value), \$133 per ML for the estimated capital cost of the pipeline, and \$55 for the energy cost.

2.2.2 Use of desalination

The cost of desalination was determined from the information available on the Wonthaggi Desalination Plant that was built to supply water to Melbourne in case of the failure of other water sources. The price was \$1.37 per kilolitre (\$1370 per ML) in 2009 (Department of Treasury and Finance 2009), based on the assumption of the plant operating at full capacity for 27.75 years.

The Wonthaggi Desalinisation Plant has the capacity to supply 150 GL yr^{-1} when required. Construction of the plant cost \$3.5 billion and was built between 2009 and 2012. The net present cost of financing, building and operating the plant over 30 years is \$5.7 billion (assuming water orders of 150 GL yr^{-1}). It is unclear if this cost also includes the cost of pipes and pumping to transport the water produced via desalination to the existing distribution network.

2.2.3 Use of recycled water

The recycling and treatment of wastewater from the sewerage and stormwater systems and its supply to water users already occurs in Melbourne. The volume of treated wastewater available for supply by Melbourne Water in 2014-15 was 295 GL yr^{-1}, and has increased steadily from 43.8 GL in 2005-06 (volume excludes environmental flows) (Melbourne Water 2009). This treated wastewater cannot be used for drinking and as such is not yet an equivalent product to most of the water supplied by Melbourne Water that is used by households and businesses.

Treated wastewater could, however, be used for some purposes, such as irrigation of sports fields and industrial processing. Unfortunately, the costs associated with production of recycled water are not easy to determine from accounts of Melbourne Water owing to the value of capital assets for water supply and sewerage being presented together. Also, this water, because it is of a different quality, cannot be transported via the existing water supply network. The price for treated water charged by Melbourne Water provides a guide:

in 2006-07 revenue from recycled water was $2.0 million for the supply of 61 GL (Melbourne Water 2009 pp. 30-31) or $33 per ML. Given that recycled water is not an equivalent product and cannot be used as a replacement for all water currently supplied by Melbourne Water, this value was not used to estimate the replacement cost for the water provisioning service generated by the Central Highlands. This value might however, be useful for the estimate of the value of the ecosystem service of water filtration.

2.2.4 Comparison of values

The prices for water transfer and desalination determined for the reference years were applied to all other years, adjusting the average annual price for inflation using the Australian Consumer Price Index Inflation Calculator (ABS 2016b). No attempt was made to adjust the estimate for changes in technology. The implicit assumption is that the costs of water transfers and desalination and water recycling have remained constant over the time period, which while unlikely to be true, should be indicative of trend.

Water filtration services are also an input to production of water by Melbourne Water. Fires are known to impact water quality, requiring additional treatment costs and remediation activities in the region (for example, p8 of Melbourne Water 2010) and elsewhere (for example, in the ACT, see ACTEW 2003). However, these services were not estimated separately.

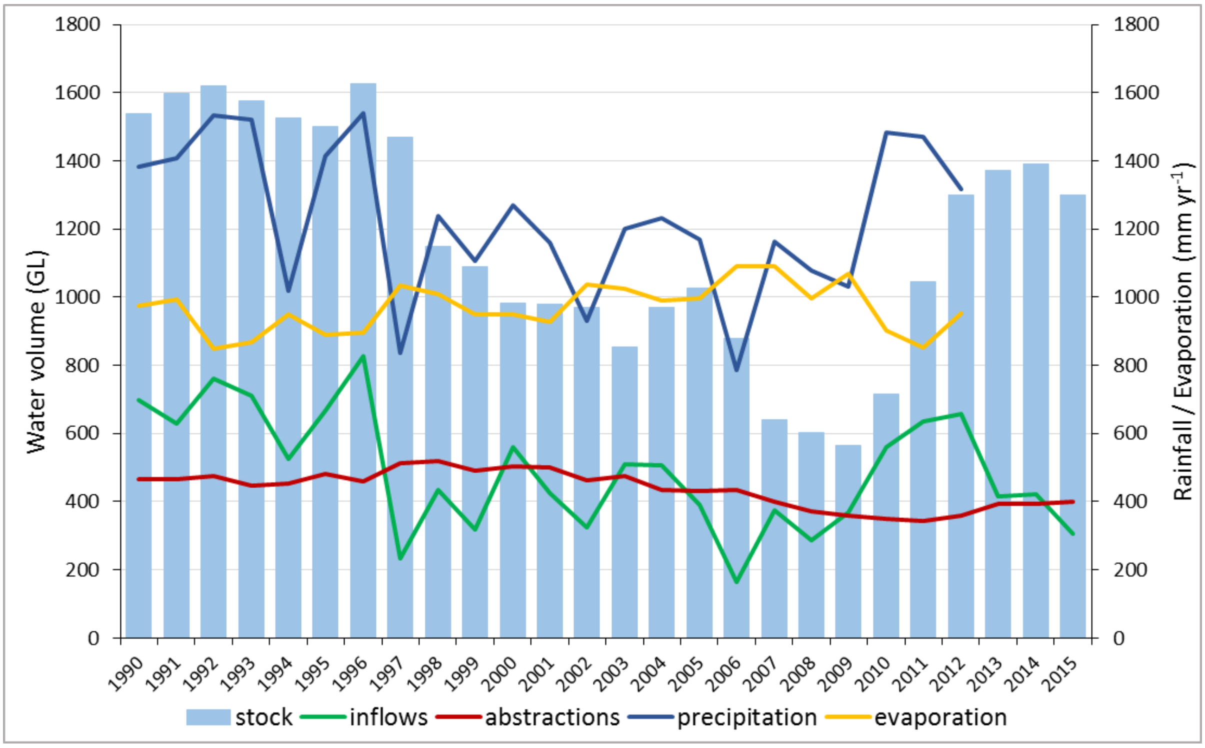
3. Results

Inflow to the reservoirs, mainly surface water runoff from the forested catchments, closely follows the pattern of rainfall (Figure 3). However, runoff is also influenced by season of rainfall and antecedent soil water content. Figure 3 shows the time series of water stocks in the reservoirs of Melbourne Water as well as, inflows from precipitation and runoff, and reductions due to abstraction and evaporation. The water stock or storage volume (GL) represents the average over the year for the combined ten Melbourne Water reservoirs. Inflow represents the annual inflow (GL yr^{-1}) to the reservoirs.

Water abstraction is reasonably constant and does not display the same variability as the inflow (Figure 3). Supply and consumption of water is influenced by human population size, which has been increasing over time, and efficiency of water use, which has been improving. Overall, there is a trend of decreasing water consumption, which is also seen in state wide estimates by the ABS (ABS 2015). The Millennium Drought from 2001-2009 (Van Dijk et al 2013), can be seen as a reduction in inflow (Figure 3) and also resulted in decreasing water use due to water restrictions, greater water use efficiency and investment in alternative water projects. Water abstraction per person is now 23% lower than pre-drought levels. However, water abstraction has increased slightly in the last four years, partly attributed to a growing population, although levels are still lower than pre-drought conditions (Melbourne Water 2016).

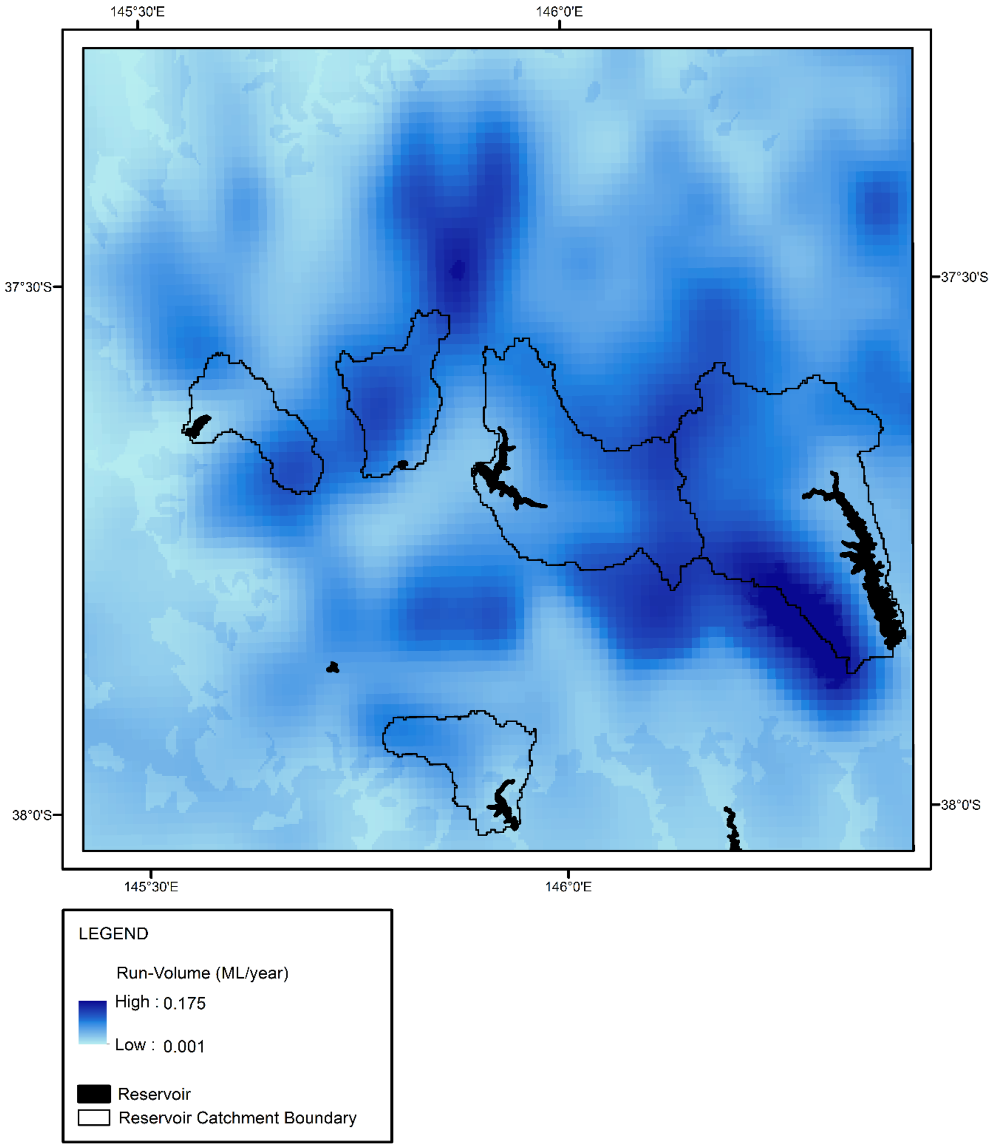
Water runoff (water yield) from the catchments is summarised by land cover type in Table 3 and by forest type and age in Table 4. The results are shown for the calculation of runoff using the pre-disturbance vegetation condition of the 75-year old regrowth forest as this is considered the most realistic scenario for this region because the majority of the forest was burnt in 1939. Water yield in each of the land cover and age classes depends on the area of land in each class, the precipitation and evaporation in that area, and the effect of the land cover on runoff. (Figure 4)

Figure 3. Time series of precipitation, water storage (stock), inflow (runoff), evaporation and supply (abstraction) for the Melbourne Water reservoirs and catchments within the study area. Rainfall and evaporation are the annual average of the eMast (eMast 2016) 0.01 degree raster cell values of pan evaporation and rainfall within the study area.



Summary information on the operations of Melbourne Water is shown as a set of accounts (Table 5). These include standard business accounting measures plus the use of ecosystem services by value and volume. The revenue, costs and profit (loss) reported and industry value added calculated are for all Melbourne Water activities, which include water supply and sewerage operations. To separate water and sewerage operations, it was assumed that the industry value added of water supply was proportional to the revenue of water supply compared to total revenue. The volume of water supplied decreased between 2000 and 2015, while the revenue received increased steeply since 2008, with revenue increasing by 500% since 2008 (Figure 5). The increase in revenue from 2013 to 2014 was associated with the unit price rise of water to cover the cost of the Wonthaggi Desalination Plant.

Figure 4. Spatial distribution of modelled runoff in 2012 calculated assuming a constant age of the forest. Shown is the volume of runoff from each 0.01 degree grid cell



The total revenue received by Melbourne Water from water supply activities was $876 million in 2015 and the value of the ecosystem service of water provisioning was $75 million (Table 5). The gross value added (or contribution to GDP) of water supply by Melbourne Water was estimated to be $134 million in 2015, or $1160 ha^{-1} (based on the catchment area within the study area of 115,149 ha).

The replacement value of the water provisioning service is always lower than the water revenue and this difference increases from 2009 (Figure 6), when revenue began to increase sharply and the construction of the desalination plant was commenced. The replacement option with the lowest cost is water transfer (Table 6) although it is not known if the amount of water could be supplied by transfer from other regions given current infrastructure can transport just 75 GL per annum.

Table 3. Water provisioning service of water yield (ML yr^{-1}) for the whole study area classified by land cover, using an average annual total for each 5-year period

Land cover	1985-89	1990-04	1995-99	2000-04	2005-09	2010-12
Bare	33,522	38,820	28,870	21,435	13,019	42,066
Swamp	61	59	48	47	38	61
Built-up area	40,237	47,497	36,572	25,923	14,052	52,559
Crop	1,964	1,945	1,497	1,142	510	2,321
Crop/ pasture/ grassland	19,729	23,408	17,973	12,635	6,822	25,711
Pasture / grassland	81,576	88,391	67,224	48,903	24,376	97,546
Horticulture	8,755	10,289	7,946	5,506	2,752	11,271
Pine plantation	30,794	34,382	25,282	18,987	11,129	37,258
Eucalypt plantation	61,455	72,314	54,654	38,892	21,848	79,598
Shrub & heath	24,470	25,108	19,669	17,505	13,077	26,668
Riparian shrubs	26,189	26,687	20,912	18,250	13,079	28,507
Woodland	12,712	15,260	11,949	8,184	4,357	17,273
Montane woodland	140,066	137,990	103,426	96,688	72,876	144,984
Open mixed forest	594,173	643,267	440,591	353,956	228,955	675,159
Wet mixed forest	904,808	1,000,743	708,858	550,497	387,057	1,062,748
Alpine Ash	500,190	502,009	378,299	349,860	268,102	624,202
Mountain Ash	750,495	807,288	606,153	511,585	377,444	969,954
Rainforest	41,651	42,162	32,632	29,381	22,159	54,648
Unknown	15,125	17,707	11,746	8,856	5,803	18,282
Total	**3,287,971**	**3,535,325**	**2,574,300**	**2,118,232**	**1,487,455**	**3,970,818**

Figure 5. Volume and value of water supplied to Melbourne Water

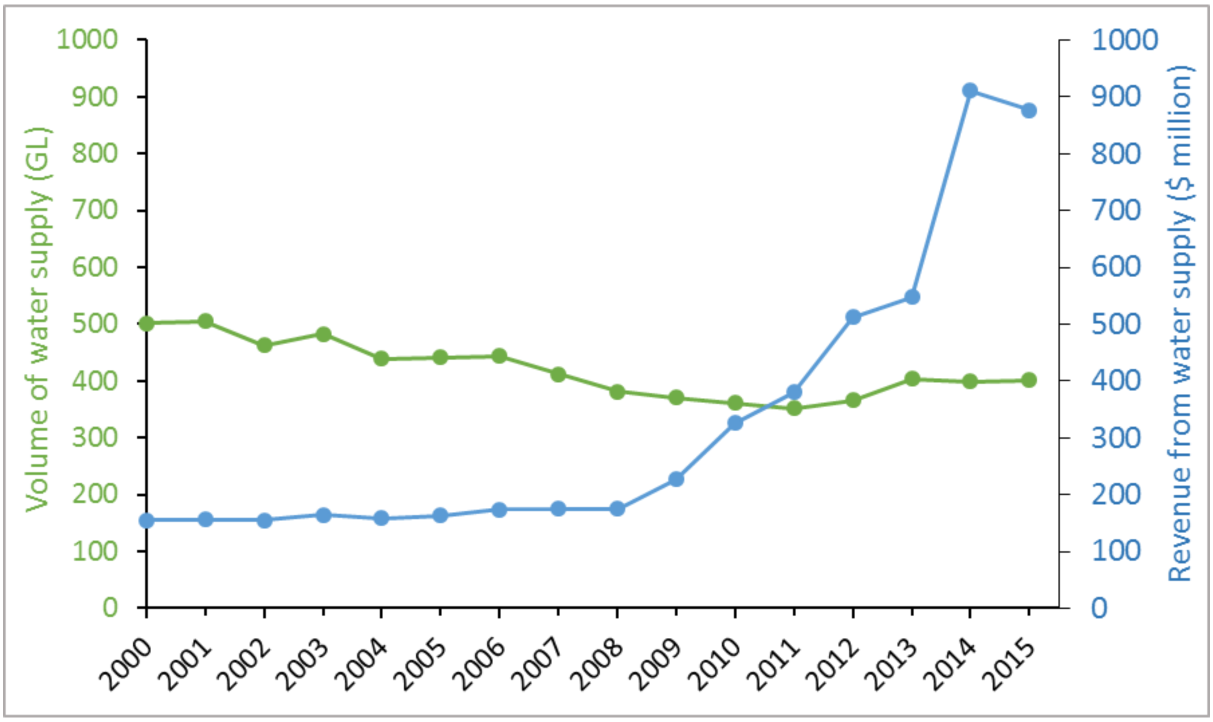


Table 4. Water provisioning service (ML yr^{-1}) classified by land cover and forest age-class, using an average annual total for each 5-year period

Land cover	Age (yrs)	1985-89	1990-04	1995-99	2000-04	2005-09	2010-12
Woodland	< 4	33	0	0	0	0	7
	4 - 12	141	95	26	0	0	0
	13 - 24	255	319	156	59	18	0
	25 - 49	4	83	161	198	140	567
	50 - 75	0	0	0	0	0	59
	> 75	12,277	14,764	11,613	7,924	4,198	16,643
Montane woodland	< 4	43	7	6	0	1	5
	4 - 12	1,031	108	37	10	2	2
	13 - 24	3,325	2,142	947	280	32	35
	25 - 49	400	2,387	2,392	2,758	2,110	4,950
	50 - 75	0	0	0	0	0	130
	> 75	135,199	133,290	100,221	93,677	70,726	139,848
Open mixed forest	< 4	1,295	731	1,466	1,168	468	1,328
	4 - 12	16,871	5,527	1,944	2,214	1,764	4,808
	13 - 24	22,567	30,798	18,504	5,568	1,353	5,266
	25 - 49	1,881	7,256	11,281	19,498	15,305	45,323
	50 - 75	0	0	0	0	0	2,148
	> 75	550,576	588,821	402,709	325,542	207,264	600,685
Wet mixed forest	< 4	7,279	4,306	2,285	2,441	1,247	3,132
	4 - 12	41,843	26,671	9,701	5,045	3,887	9,555
	13 - 24	56,303	65,693	43,699	21,360	7,245	14,554
	25 - 49	6,953	29,362	35,952	47,669	41,071	124,040
	50 - 75	0	0	0	0	0	12,903
	> 75	823,536	897,512	628,624	501,257	343,739	922,919
Alpine Ash	< 4	6,615	14,680	7,067	6,869	21,395	149,592
	4 - 12	20,141	16,372	16,669	16,051	10,353	69,521
	13 - 24	24,711	20,615	15,634	13,086	10,056	18,391
	25 - 49	344,560	15,590	16,486	20,820	18,002	32,729
	50 - 75	103,614	435,983	323,560	293,583	208,498	358,755
Mountain Ash	< 4	54,170	28,639	20,363	18,721	12,916	183,508
	4 - 12	62,304	108,543	51,995	36,042	28,494	60,543
	13 - 24	14,152	21,862	52,077	56,182	37,535	61,781
	25 - 49	474,494	8,487	9,486	12,397	22,760	92,555
	50 - 75	155,761	655,563	476,287	391,858	279,811	580,527
	> 75	649	791	635	444	251	919
Rainforest	< 4	748	5	6	0	0	13,673
	4 - 12	973	1,543	281	7	2	0
	13 - 24	300	232	846	820	318	13
	25 - 49	29,762	116	169	205	418	1,586
	50 - 75	9,867	40,274	31,320	28,350	21,421	39,382

The volume of the water provisioning services generated from the study area that flow as runoff into the reservoirs operated by Melbourne Water, has an inconsistent relationship with the volume of water supplied to customers from these reservoirs. Thus in some years the water provisioning service exceeds the amount of water supplied (for example, 2010 to 2012). The very function of reservoirs is to hold water for when it is needed. Also, when water is in short supply, such as during drought, a key response is to impose water restrictions (such as, no watering of gardens).

Figure 6. Value of water provisioning service used and revenue from water supply

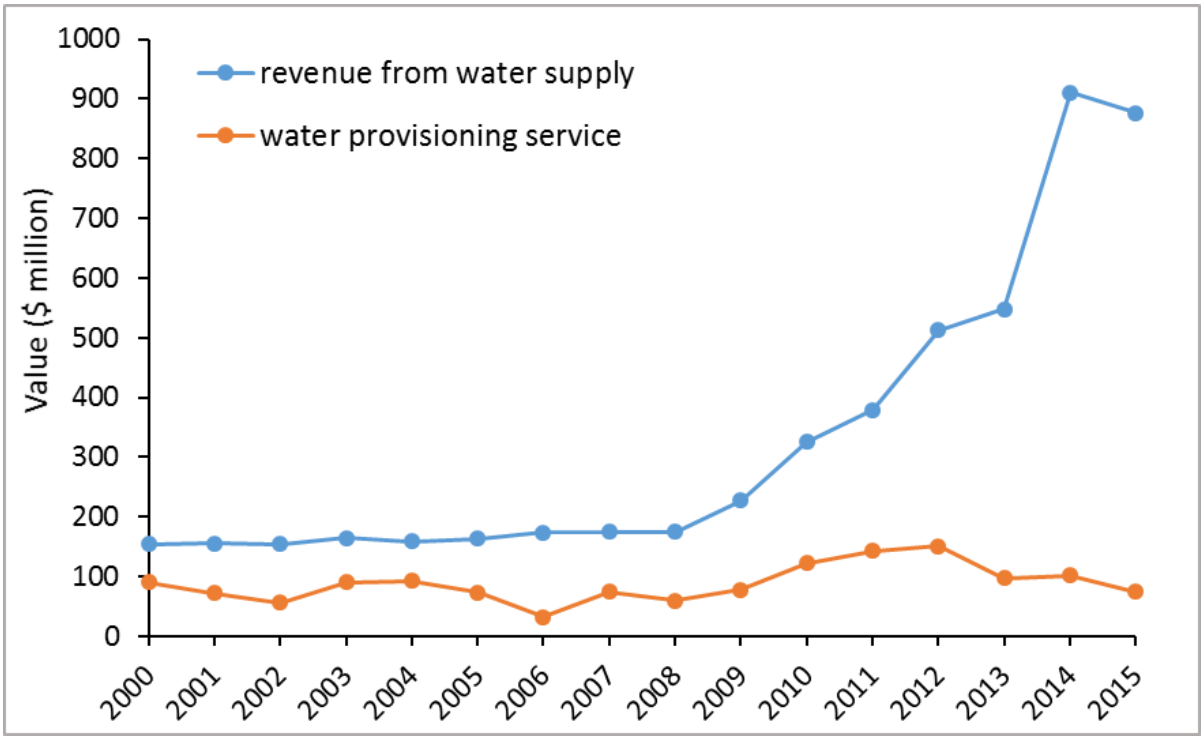


Table 5 Accounts for the volume and value of water supply and water provisioning service by Melbourne Water, and the financial accounts that include all Melbourne Water activities. Values are calculated for the replacement option with the lowest cost (water transfer) (Table 6)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Revenue and other income	478	461	480	511	504	528	593	588	600	732	858	997	1240	1258	1717	1750
Expenses	281	332	350	361	380	402	424	455	533	604	672	839	970	1298	1627	1634
Profit/(loss)after tax ($m)	197	129	130	150	123	126	169	134	68	128	186	158	270	-40	90	116
Wages, employee benefits ($m)	34	34	34	37	40	42	47	51	61	65	73	75	104	87	101	106
Estimated IVA ($m)	239	210	220	256	219	230	274	228	154	239	311	289	476	25	233	267
Total assets ($m)	2852	2954	2995	3051	3132	3263	3769	3969	4436	5421	8948	9755	10034	14498	14339	14440
Total liabilities ($m)	1685	1657	1667	1670	1723	1770	1929	2083	2449	3419	4930	5380	5495	10117	9856	9715
Net assets ($m)	1167	1297	1328	1381	1409	1494	1804	1886	1987	2002	4018	4375	4539	4381	4483	4725
Number of employees (FTE)	481	488	498	512	501	537	614	645	729	807	828	841	*834	832	812	899
Water supply																
Volume supplied (ML)	501720	505140	462322	483000	438796	440982	444365	411747	381097	371170	361363	351761	365559	404260	399489	401849
Revenue from supply ($m)	155	156	154	165	159	164	174	175	176	227	326	380	512	548	911	876
Water provision services																
Volume used (ML)	560063	426363	324202	508840	507961	389269	163240	374236	287465	368941	559363	633776	658286	415665	420935	306258
Value used ($m)	162	169	174	179	183	188	195	199	208	212	218	225	229	235	241	244
Water in storage																
Volume (ML)	980307	968937	854388	968892	1027661	877597	641161	603321	563608	716752	1045479	1299733	1371971	1388928	1300186	

*Depreciation and amortisation are added to profit (loss) before tax and wages and employee benefits. Assumes no taxes or subsides on products.

**Annual Report unclear whether FTE or total number

Table 6 Estimates of the value of the water provisioning services at replacement cost

	Water provisioning service	**Replacement option (unit price)**		**Replacement option (total value = unit price x volume)**	
	Physical volume	Water transfer	Desalination	Water transfer	Desalination
	ML	$ ML^{-1}	$ ML^{-1}	$ Million	$ Million
Year					
1990	697,519	130	841	91	587
1991	628,053	134	868	84	545
1992	759,890	136	877	103	666
1993	711,745	138	893	98	636
1994	526,585	141	910	74	479
1995	666,737	147	953	98	635
1996	826,375	151	977	125	807
1997	231,941	152	980	35	227
1998	432,954	153	988	66	428
1999	316,984	155	1,003	49	318
2000	560,063	162	1,047	91	586
2001	426,363	169	1,093	72	466
2002	324,202	174	1,127	56	365
2003	508,840	179	1,158	91	589
2004	507,961	183	1,184	93	601
2005	389,269	188	1,216	73	473
2006	163,240	195	1,260	32	206
2007	374,236	199	1,289	74	482
2008	287,465	208	1,345	60	387
2009	368,941	212	1,370	78	505
2010	559,363	218	1,409	122	788
2011	633,776	225	1,456	143	923
2012	658,286	229	1,482	151	976
2013	415,665	235	1,518	98	631
2014	420,935	241	1,556	101	655
2015	306,258	244	1,580	75	484

Figure 7. Volume of the water provisioning service and the water supplied

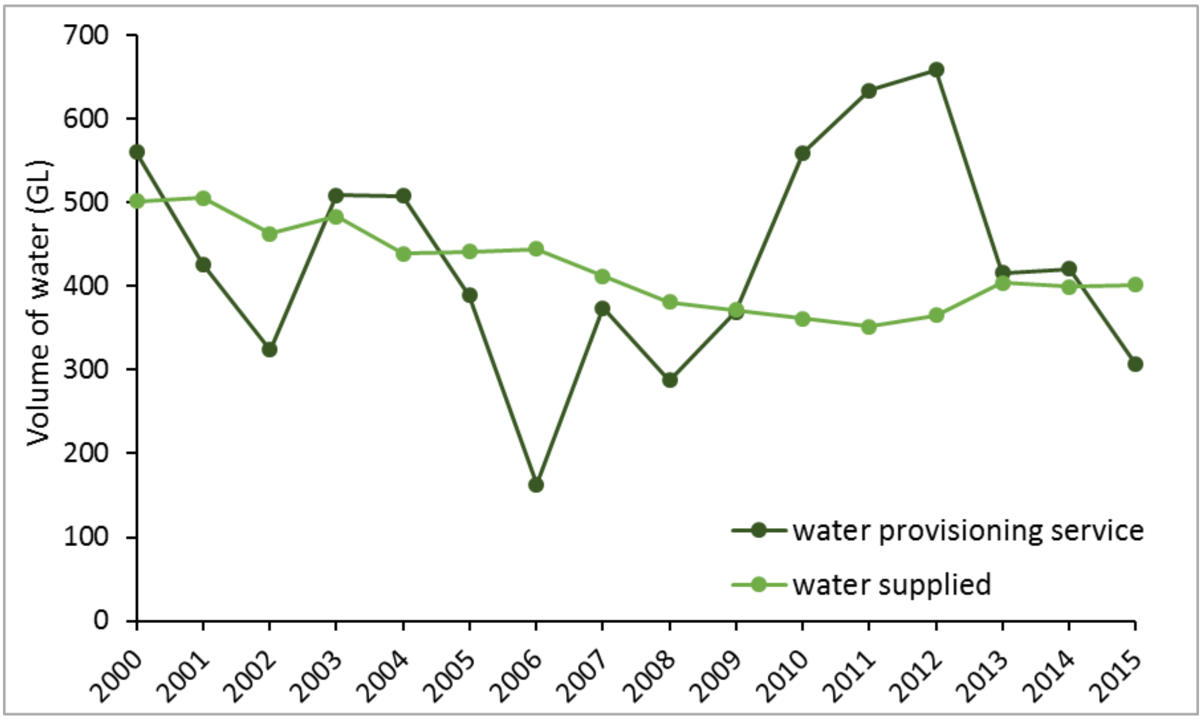
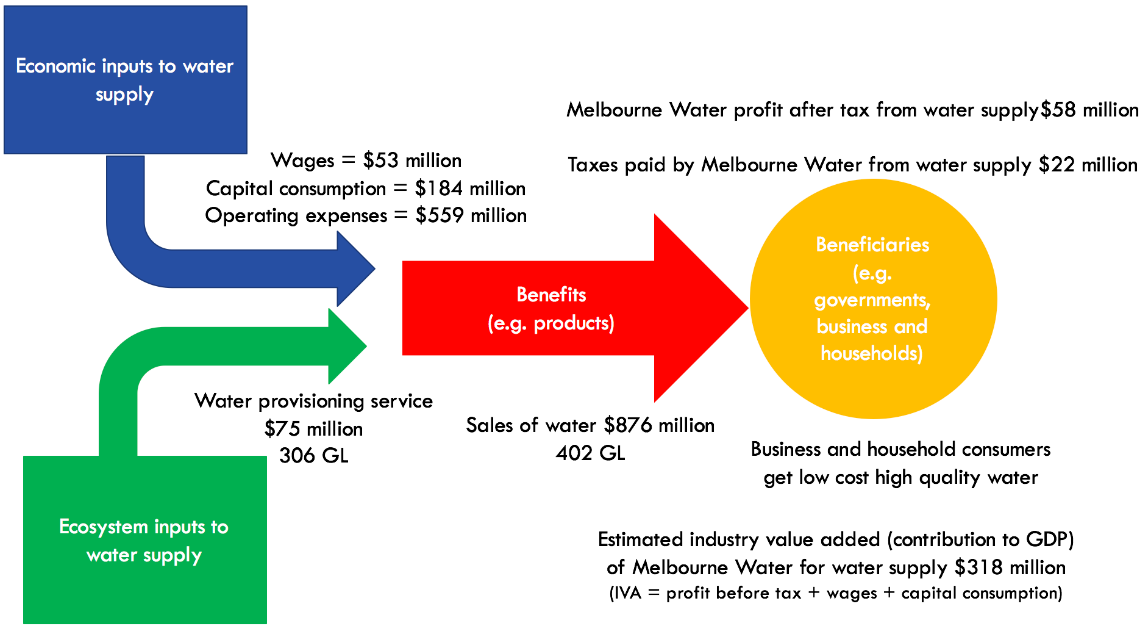


Figure 8. Use of ecosystem services, cost of water production and industry value added by Melbourne Water 2014-15



Discussion

Estimates of the volume and value of the ecosystem service of water supply were produced with existing data and methods and summarised in Figure 8. Readily available physical information and models were able to estimate the physical volume of the service (306 GL in 2015) and using the lowest cost replacement cost method a value of $75 million was ascribed to these services. If the high replacement cost option of water desalination is used then the value would be $484 million.

In this study, the replacement cost value for ecosystem services was the cost of transfer from other regions which was the lowest available (treated wastewater is not an equivalent product). Melbourne Water actually opted for a higher replacement cost option of desalination, so a case can be made for using this value. A common comment on the replacement cost method is that it is unknown if the service would be replaced, and if it was replaced, would the same volume of service be used. In the case of Melbourne Water we do know that they would replace it as they have built and paid for infrastructure to do this up to 150 GL per annum. Average water use for the period was relatively stable fluctuating are 400 GL and it is doubtful that Melbourne would be left without water for any length of time.

The results have highlighted the importance of the ecosystem service of water provision to Melbourne Water, the direct user of the ecosystem service as well as those supplied with the water. Some of the native forest area that provides the water provision service is available for harvest and the logging that occurs in the catchments supplies about a quarter of the timber volumes from the study area. In the short term of 1 to 3 years, logging increases run-off but increases sediment loads and thus decreases water quality. In the long-term run-off is decreased for many decades.

The harvesting of forest on an approximately 80-year cycle means that most regrowth forests across the landscape have high water demand, reducing the level of water provisioning services.

The demand for water is likely to grow with the population and economic activity of Melbourne. With increasing demand, fluctuating inflows and costly infrastructure in place to provide water at times of stress, it would seem likely that using the native forest for water supply would provide greater overall economic, social and environment benefits than forestry.

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