Water Values: Use, LCA, and Water Footprinting

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Executive summary

This report overviews perspectives of water valuation, current water consumption in Australia and the use of water in selected mineral processing and metal production sectors. This information is used to update the economic value associated with water use by mining, mineral processing agricultural and other sectors.

The report begins with a review of water valuation. The United Nations is the peak global agency driving water reform and their World Water Assessment initiatives has lead to action by international government, industry and not for profit organisations. The review finds that a moral imperative and water ethic rather than economic opportunities drives water valuing.

In Australia the agriculture sector has reduced water use from 69% (14,989 GL) of the national water use to 54% (7,175GL) over the past decade (2000 to 2010). Over the same time period, the cost of water used by agriculture has increased from about $0.01 per kL to $0.14 per kL and the value of associated with water used by agriculture in 2010 was estimated to be $6.50 per kL.

The proportion of water used by Australian mining sector has increased from 1.4% (321 GL) in 2000 to 4% in 2010 (540GL). In absolute terms the water used by mining has increased by almost 70%. The cost of the water used by mining has increased from about $0.01 per kL to $1.82 per kL and the value of associated with water used by mining and metal production in 2010 was estimated to be between $161 and $199 per kL.

The report advocates for water valuation approaches that integrate economic efficiency, cost-benefit and maintain diversity locally, regionally and into the future. The report also recommends alignment, and where possible, adoption of the water footprint principles, requirements and guidelines being developed by the International Organisation for Standardization (ISO).

1 Introduction

In 2006, Norgate and Lovel [2006] used life cycle assessment to assess the variation in direct water use (consumption) for a range of metal production and processing routes. Since then there has been significant refinement of the LCA of water capability at CSIRO and a growing international interest in the water planning, management and use.

This report presents information and data collected via a desk based literature review. The first section of the report overviews perspectives of water valuations, the dominant national and international agencies that are focussing attention on water-related issues and some of the issues faced.

The second section of the report overviews changes in water use and economics since Norgate and Lovel [2006] and presents water use data for a range of industrial sectors. The water use and value added by agriculture and mining and mineral processing are examined in more detail and this information is used to update the economic value associated with water use by mining, mineral processing agriculture and other sectors originally presented in Norgate and Lovel 2006.

In undertaking this review it was apparent that there is significant difference in accounting methods used for water use and uncertainty of the drivers for prioritising water use. The third and final section of this report presents different frameworks and tools that have been developed for managing water, introduces the ISO/DIS 14046 which is being developed by the International Organisation for Standardization and provides a high level overview of 6 core principles that could be used to develop an integrated framework for water valuation, appraisal and management.

The research has been conducted as part the Minerals Down Under Australian Mineral Futures Theme Project Code R-3370-1 - Environmental Life Cycle Assesment.

1.1 Water values.

It is widely accepted that water is an essential resource [Euzen and Morehouse 2011] and a foundation for human health [Secretariat of UN-Water, 2005]. Access to water creates opportunity, wealth and power. [Wateau 2011, Euzen and Morehouse 2011. The "Water Ethic" proposes that "A thing is right if it preserves or enhances the ability of the water within the ecosystem to sustain life; and wrong if it decreases that ability" [Armstrong 2006].

In the literature, water management is frequently viewed as a moral imperative rather than an economic opportunity. The moral argument arises from the critical role water plays in sustaining life. Millions of people die each year from disease related to water supply, sanitation and hygiene. Most of these people (99%) die in developing countries and it has been estimated that improving water supply, sanitation, hygiene and management will prevent 10% of the global disease burden (WHO 2008).

In 2005 the United Nations General Assembly concluded that people were missing out on the foundations for human progress because rivers are drying up, groundwater tables are falling and water-based ecosystems are being rapidly degraded [Watkins 2006; Secretariat of UN-Water, 2005]. The assembly noted that water is essential for life, crucial for sustainable development and indispensable for human health and well-being. They conclude "the world is running down one of its most precious natural resources and running up an unsustainable ecological debt that will be inherited by future generations" [Watkins 2006]. They proclaimed the years 2005 to 2015 would be the International Decade for Action on 'Water for Life' [Secretariat of UN-Water 2005].

The 4th edition of the UN World Water Development Report suggests that water underpins all aspects of development, and that a coordinated approach to managing and allocating water is critical and that water usage needs to be an intrinsic element in decision-making across the whole development spectrum [WWAP 2012]. A greater focus on water-related issues is the main goal of the 'Water for Life' Decade and the achievement of internationally agreed upon water-related goals contained in Agenda 21 [UNEP 1992], the United Nations Millennium Development Goals [UNGA, 2000] and the Johannesburg Plan of Implementation [UNCED 2002].

Governments and the United Nations are promoting efforts to meet international commitments that include halving the proportion of people without access to safe drinking water by 2015, stopping unsustainable exploitation of water resources, developing integrated water resource management and water efficiency plans (by 2005) and halving the proportion of people who do not have access to basic sanitation by 2015 (Secretariat of UN-Water, 2005). Appendix 1 overviews eight reasons for the world to act on water and sanitation [Watkins 2006].

Increasing national and international attention has shifted the management of water from a local level to a national and international priority [Wateau 2011]. The Sixth Session of the Commission on Sustainable Development (1998) promoted the need for regular, global assessments of the status of freshwater resources and member organizations of UN-Water initiated a United Nations system-wide continuing assessment process. Founded in 2000, the flagship programme of United Nations - Water, the World Water Assessment Programme coordinates the production of the triennial United Nations World Water Development Report on the status of global freshwater resources and the progress achieved in reaching the Millennium Development Goals related to water [WWAP 2012].

In the ten years since the water for life declaration, the global water crisis continues to threaten security, stability and environmental sustainability, particularly in developing nations and there is recognition that best practice water management requires the best possible understanding of all relevant systems and an integrated approach. The Integrated Water Resources Management (IWRM) is a process developed by the United Nations to coordinate development and management of water, land and related resources while maximising equitable economic and social benefit without compromising the sustainability of vital ecosystems and the environment [UNESCO 2012].

Conceptual framework and techniques are being developed and used to assess and compare projects and a number of countries and the European Commission have introduced legal provisions requiring impact and cost benefit assessments of major policies and regulations [OECD 2006]. In 2012 the World Business Council for Sustainable Development advocated the following five business drivers for valuing water[1]:

1) Enhance decision-making
2) Maintain and enhance revenues
3) Reduce costs
4) Manage risks
5) Enhance reputation

[1] More details are provided in Appendix 2

1.2 Australian Government response to uncertain water supply.

The Australian Governments' committed to the National Water Initiative (NWI) in 2004 and developed the "Water for the Future" initiative to provide national leadership. The NWI empowered Government Departments and Authorities to reform water management, manage water scarcity by prioritises action on climate change, wise water use, and supporting health rivers. The Australian Government committed $12.9 billion to supporting "Water for the Future" and securing Australia's water supply [AGDEWHA 2010].Table 1 overviews the roles and responsibilities of the relevant departments and authorities.

Table 1 Australian Government agencies involved in water reform and their role in water management (adapted from AGDEWHA 2010).

Responsible institution	Key function
The Department of the Environment, Water, Heritage and the Arts	Implements Water for the Future
The National Water Commission	Assists government with National Water Initiative implementation and advises COAG and the Australian Government on national water issues
The Murray–Darling Basin Authority	An independent authority responsible for planning the integrated management of the Murray–Darling Basin's water resources.
The Bureau of Meteorology	Responsibility for collection of water information functions critical to enhancing the understanding of Australia's water resources.
The Australian Competition and Consumer Commission (ACCC)	Advise Government and the Murray–Darling Basin Authority, on rules relating to water trading in the Murray–Darling Basin and monitors compliance with and enforcing water market and water charge rules.

1.3 Definitional uncertainty

1.3.1 WATER USE AND CONSUMPTION

Different approaches to data collection and use have lead to ambiguity and uncertainty of definitions associated with water use. For example, LCA practitioners define “water use” as the total input of freshwater into a product system and “water consumption” as the amount of water that becomes unavailable due to evaporation or product integration [Berger 2010]. In contrast, the Australian Bureau of Statistics (ABS) defines “water use” as the sum of water distributed, self–extracted water use and reuse water[2]. This definition differs from the LCA water consumption definition in that it is a gross measure, rather than netting out the volumes of water used in–stream, supplied to other users or supplied to the environment as 'environmental flows'. The ABS define water consumption as the sum of distributed water use, self–extracted water use and reuse water use less water supplied to other users and less in–stream [ABS 2012]. Consequently, care and clarity is required when comparing data from different sources. Appendix 3 contains AB**S** definitions of water sources and use. In this report we have attempted to use “water use” for ABS data and “water consumption” for LCA derived data.

1.3.2 DIRECT AND INDIRECT WATER CONSUMPTION

Direct water use of most businesses is generally lower than the supply chain water use and ignoring the supply chain can obscure effective opportunities to reduce water use [Hoekstra etal 2011]. For example, inclusion of indirect water (water consumed off-site during the production of materials and energy used in a process) [Northey and Haque 2013a; 2013b] showed that indirect water use can be a significant proportion of the water used, particularly for hydrometallurgical processes involving reagents such as sulphuric acid and sodium cyanide.

1.3.3 WATER SCARCITY

Water scarcity is a measure of inadequate access to water for human and environmental uses. There are a variety of methods of calculating water scarcity and different methods can lead to different and sometimes contradictory measures of scarcity [White 2012]. Currently there is no uniformly accepted definition of water scarcity and different measurements capture different aspects of the pressures on water resources (Table 2).

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[2] Reuse water is drainage, waste or storm water that has been used again without first being discharged to the environment. It may have been treated to some extent and excludes "on–site" recycling.

Table 2 Water scarcity definitions (adapted from White 2012, Molden 2007, and Sullivan 2003)

Scarcity measure	Approach	Limits
Water Stress Index	Based on a calculation of the amount of renewable freshwater in a country that is available for each person each year	Water stress <1,700 m^3 Water scarcity <1,000 m^3 Absolute water scarcity < 500 m^3
Water Criticality	Based on the proportion of total annual water that is withdrawn from the available water resources	Water scarcity 20 – 40% Severely water scarce < 40%
Economic Scarcity (Molden,. 2007)	Based on estimates of the proportion of water withdrawn for human purposes and evaluates if future water demands can be met by investments in infrastructure and efficiency.	Little or no water scarcity:< 25% Physically scarce: >75% Economic scarce: Water is available but needs investment or efficiencies to be made available.
Water Poverty Index (Sullivan, 2003)	Based on calculations of the weighted average of resources, access, capacity, use and environment.	Highest score – best situation Lowest score – worst situation

1.3.4 CONTEXT MATTERS

Water issues and responses shift with time and place. A substantial study seeking to understand water demand (Foran and Poldy 2002) concluded that Australia's future is not threatened by the availability of water. Their 50 year scenario planning study concluded that the most critical water management issues were "side effects" associated with water use, particularly irrigation and river salinity, depletion of inland fisheries, economic and social vitality in regional areas, heavy metal and pesticide contamination and conflict with other social values (eg beauty and amenity) (Young 2001 and Foran 2002).

Foran and Poldy's work preceded 12 years of low rainfall and despite a 2002 conclusion that Australia would not be threatened by water scarcity, New South Wales, Queensland and South Australia, Victoria and Western Australia have all constructed desalination plants to secure water supply in the past 10 years. The construction of desalination plants in Australian capital cities suggests significant concern about fresh water supply in Australia and is an example of overcoming economic scarcity by investment in desalination.

In 2013 the Bureau of Meteorology concluded that a drying and warming climate, increasing groundwater extraction, expanding farm dams, urban growth and the consequent increase in water demand, increasing environmental flows, irrigation supply demands, expanding plantations and bushfire recovery are all factors affecting water security in Australia [BOM 2013] .

2 Water Use

2.1 International Costs and Tariffs

Water utilities typically aim to minimise tariffs while recovering some of the operating and capital cost (eg the cost of building, operating and maintaining drinking-water and wastewater systems) [Zetland and Gasson 2012]. Global Water Intelligence (GWI) attributes global variations in water tariffs to three factors: water service costs (ie labour rates, the age and condition of infrastructure, the rate of infrastructure maintenance and replacement), local policies and scarcity. The GWI study suggests local policies frequently subsidises the price of water to below cost which in turn, leads to unsustainable use and inequitable provision of water [GWI 2012]. These issues are said to be most acute in developing countries struggling to provide clean water to all people [Zetland and Gasson 2012]. The United Nations Development Programme has also found that water scarcity can be created through political processes and institutions that systematically exclude some people and disadvantage the poor, even in spite of sufficient water for domestic agriculture and industry [Watkins 2006].

Water tariffs were calculated in the GWI study of 308 cities in 102 countries [GWI 2012]. Tariffs for selected countries are presented in Table 3. The study uses results from a phone, email and internet surveys of water and wastewater tariffs to calculate water tariff's (ie the sum of variable and fixed waters costs (and sales tax) and the variable and fixed waste water costs (and sales tax)) . The average tariff was US$2.03/$m^3$.

Table 3 Water tariff for selected countries [adapted from GWI 2012]

	Tariff (US$/m^3)		
Country	Combined	Water	Wastewater
Denmark	8.83	4.32	4.52
Australia	5.78	3.14	2.65
Germany	5.36	3.33	2.02
France	4.56	3.24	1.31
United Kingdom	4.27	2.07	2.19
Czech Republic	3.63	1.86	1.78
Canada	3.14	1.95	1.19
Poland	3.12	1.44	1.68
United States	2.98	1.29	1.69
Japan	2.56	1.48	1.08
Portugal	2.27	1.62	0.65
Spain	2.13	1.47	0.66
Turkey	2.14	1.38	0.76
Italy	1.81	0.94	0.87
Russia	1.00	0.61	0.39
South Korea	0.76	0.56	0.20
Mexico	0.69	0.65	0.04
China	0.46	0.34	0.12
India	0.15	0.14	0.01

In contrast to Norgate and Lovel [Norgate 2006] the GWI study suggests that Australian water price (US$ 5.78 m^3) is almost 3 times the global average (US$ 2.03 m^3). Five Australian capital cities were included in the GWI study (Table 3). Sydney was the capital with the most expensive water tariff (US$6.62/m^3) and was the 5th most expensive in the study, followed by Brisbane (US$6.46/m^3) and 9th most expensive in the study, Melbourne (US$6.12/m^3), Adelaide (US$5.59/m^3) and Perth(US$4.01/m^3).

2.2 Water use in Australia.

2.2.1 ECONOMIC USE OF WATER IN AUSTRALIA

The Australian Bureau of Statistic's Water Account Australia provides data and commentary on the physical and monetary supply and use of water in key industries (Agriculture, Water supply, sewerage and drainage) and households. The data has been developed using the System of Environmental–Economic Accounts (SEEA) and the SEEA–Water (SEEA) [ABS 2012, Secretariat of UN-Water 2010]. The ABS calculates "Water consumption" as being the sum of distributed water use plus self–extracted water use plus reuse water use minus in–stream water use minus distributed water supplied to other users minus water supplied to the environment as 'environmental flows'.

The total water extracted from the environment and used within the Australian economy in 2010–11 was 71,796 GL. Each year, about 90% of this water was "in stream use", mainly for hydroelectricity generation. About 10% of the total water extracted was used by all other industries and householders. In 2010-2011, 13,337 GL was used by these sectors [ABS 2012].

Figure 1 overviews water use for selected years since 2000. In 2010-2011, the agriculture industry used 54% of the water (7,175 GL), households used 13%, water supply used 12%, and the mining sector used 4% (540 GL). Since 2000 the proportion of water used by agriculture has reduced from 69% to 54% while the proportion of water used by mining has increased from 1.6% to 4%.

Table 4 summarises the total water use in Australia and water use by agriculture and mining in these years. The summary suggests that total water consumption has reduced by almost 9000 GL, from a high of 22268 GL in 2000-01 to 13337 GL in 2010-11 and that the majority of this reduction is associated with a 9545 GL reduction in agricultural use. Water use by mining has increased from 321 GL in 2000-01 to 540 GL in 2010-11 [ABS 2012] but it remains significantly lower than the water used by agriculture.

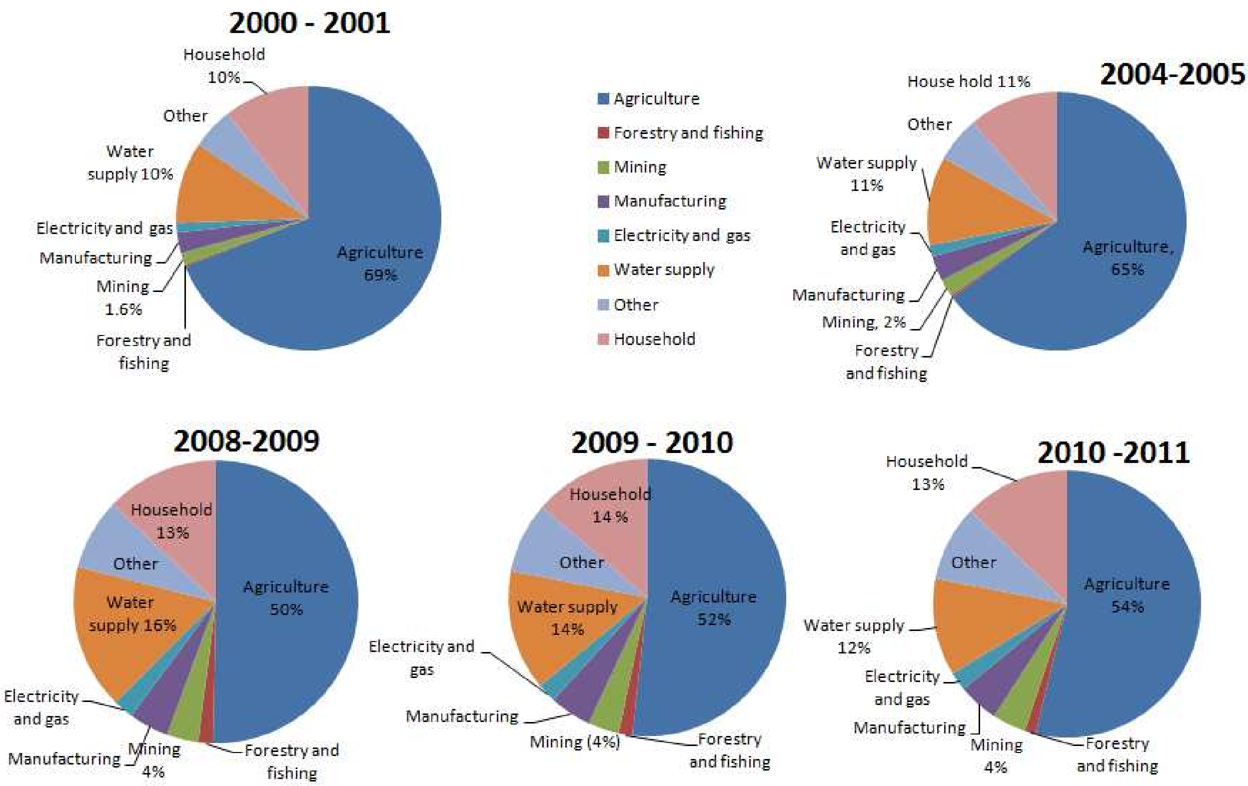

Figure 1 Water use by sector for selected years (adapted from ABS 2006, 2012)

Table 4 Total water use in Australia and water use by Agriculture and Mining.

Year	Total use (GL)	Agriculture (GL)	Mining (GL)
2010-11	13337	7175	540
2009-10	13515	6987	489
2008-09	14061	7077	506
2004-05	18767	12191	413
2000-2001	21703	14989	321

Mining has had the largest increase in water price since 2005 ($0.01 per kL to $1.82 per kL). Over the same time the price of water used in agriculture has increased from $0.01 per kL to $0.14, manufacturing has increased from about $0.58 per kL to $1.12 per kL and domestic use costs have increased from $1.00 per kL to $2.44 per kL [Norgate and Lovel 2006, ABS 2013]. ABS domestic water price does not include service charges and is not directly comparable to the GWI water tariff.

2.2.2 WATER USE IN AGRICULTURE

In 2010-2011, approximately 53 % (405.5 M Ha) of land in Australia is agricultural holdings and less than 1% of this land is irrigated (~2 M Ha). Rice (100%), cotton (100%) and grapes (90%) are the crops with the largest proportion of irrigated production area. Table 5 (Figure 3) summarises industry gross value, water use[3] and gross value added per GL of water over the 3 financial years spanning 2008 and 2011 [ABS 2012].

In 2010-2011 the ABS concluded that cotton growing was the agricultural activity that used the greatest amount of water (1,882 GL or 25% of agricultural activities). Rice used 10% (766 GL), dairy cattle grazing 8% (627 GL), fruit and nuts 7% (550 GL) and sugar cane growing 6% (459 GL) [ABS 2012].

The cost of irrigation water traded on the temporary water market is negatively correlated with water allocations (Figure 2). Agricultural production and production methods changes associated with higher prices include conserving water by changing irrigation technology, precision agriculture, water harvesting, shifting water applications to more water-efficient crops, drought tolerant crop breeding strategies and changing crop mix to higher valued crops[Gardner, 1983, Molden et al, 2010]. Gardner suggests that increasing water costs are also offset by substitute of other inputs, additional labour and more intensive use of land and capital.

For most of the period between 2000 and 2011 the dominant agricultural zones of Australian were affected by the “Millennium drought”. Beginning in about 1997, the decline in rainfall and runoff caused by the Millennium drought resulted in decreased water availability and contributed to widespread crop failures, halving of the national sheep population and a collapse of rice and cotton production [Herberger 2012].The millennium drought saw the lowest inflows on record in the Murray-Darling Basin in 2006. Kirby et al (Kirby 2012) calculated that water used by irrigation in 2008-9 was 33 % of the 2000-01 value. They found a significant reduction in water used in rice, cotton, meat (pasture) and dairy production, an increase in productivity per unit of water in all commodities and an increase in water trading increased after 2006.

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[3] The ABS data does not consider rainfall used in agriculture or make allowances for runoff or aquifer recharge (ie water that is not embodied in product or evaporated during agricultural production).

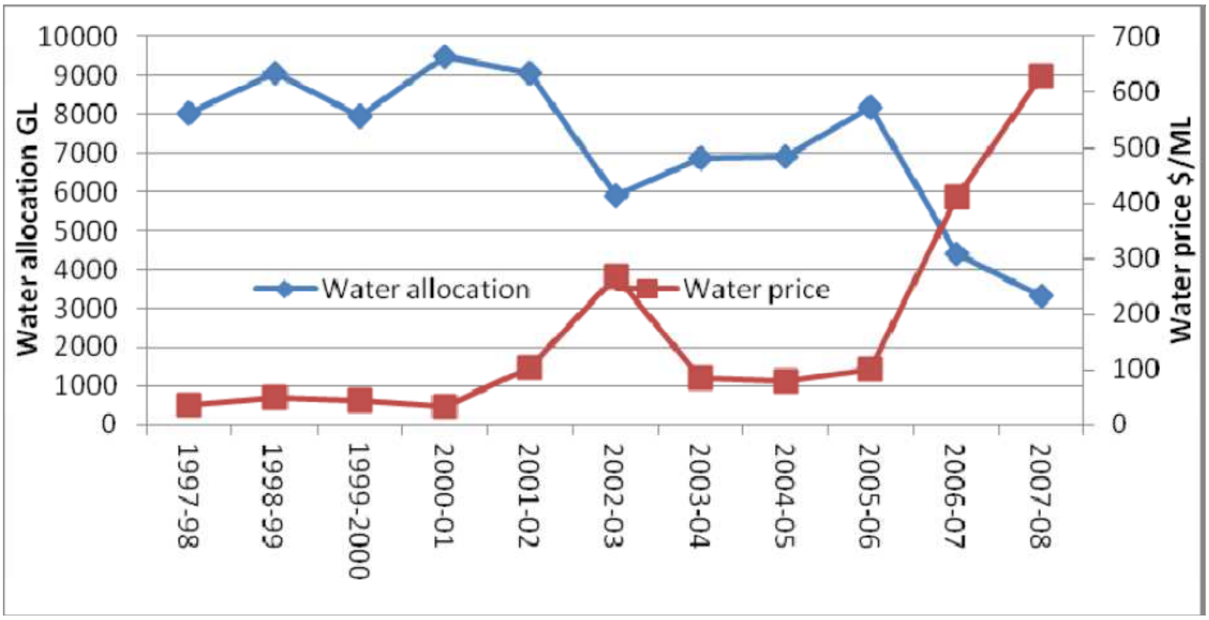

Figure 2 Historical water allocation and temporary water price [Qureshi et al 2012]

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Table 5 Economic value per GL of water used for various sectors. Adapted from ABS 2012

	2008-09			2009-10			2010-11		
Industry sector	Industry gross value added	Water used	Industry gross value added per GL of water used	Industry gross value added	Water used	Industry gross value added per GL of water used	Industry gross value added	Water used	Industry gross value added per GL of water used
	$m	GL	$m/GL	$m	GL	$m/GL	$m	GL	$m/GL
Agriculture, Forestry & Fishing									
Agriculture	24,479	7,077	3	23,977	6,987	3	27,727	7,175	4
Aquaculture, Forestry, Fishing	4,548	237	19	4,439	217	20	4,429	175	25
Total Agriculture, Forestry & Fishing	29,027	7,314	4	28,416	7,204	4	32,156	7,350	4
Mining									
Coal mining	43,570	100	435	21,202	76	280	23,397	89	264
Oil & gas extraction	28,707	37	774	23,027	34	686	27,242	42	651
Other mining	35,912	323	111	42,884	336	128	71,909	362	199
Exploration & mining support services	6,577	46	144	8,072	44	182	8,561	48	179
Total mining	114,766	506	227	95,185	489	195	131,109	540	243
Selected Manufacturing									
Petroleum, coal, chemical & associ..	16,655	66	251	17,455	78	225	17,913	70	258
Non-metallic, mineral products	5,129	30	173	4,924	33	150	4,970	31	161
Metal products	25,848	151	171	22,795	140	163	22,202	138	161
Total manufacturing	110,035	641	172	107,782	659	164	107,808	651	166
Electricity & gas	18,331	325	56	19,162	298	64	21,331	298	72

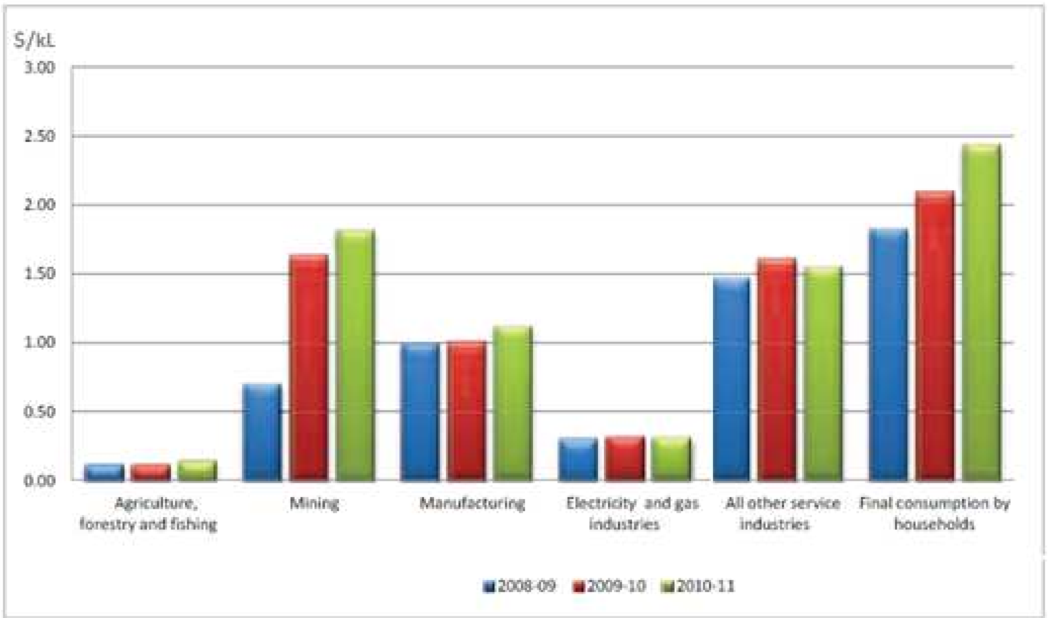

Figure 3 Average price per kL of distributed and reused water [adapted from ABS 2013].

Table 6 updates the economic value per GL of water used for agriculture in Australia that was originally prepared by Norgate and Lovel [2006]. Since this report there has been an increase in the value of product per m3 of water. The updated review highlights a significant increase in the value of products per m3 water consumed in dry land farming systems that produce wheat and grain and beef cattle

Table 6 Economic value per GL of water used for various agricultural sectors. Expanded from Norgate and Lovel 2006.

Industry sector	A$/m^3 water consumed							
	Irrigation and dry land farming		Irrigation Only			Farmweb website	Urban ecology website	Foran & Poldy (2002)
	2011 - 2012	2010 - 2011	2010 - 2011	2009 - 2010	2008 - 2009			
Agriculture								
Rice	0.22		0.23	0.36	0.34	0.19	0.13	0.13
Wheat & grain (+ seed 2008-2011)	17.0		0.56	0.25	0.38			4.08
Beef cattle		19.8	1.50	1.22	0.98		2.6	1.23
Dairy cattle & milk		6.3	3.42	2.10	2.88		1.47	0.68
Sugar cane	1.69		0.81	0.99	0.71	0.42	0.81	0.81
Cotton	1.2		0.83	0.78	0.70	0.61	0.63	0.63
Fruit & vegetables	5.1		4.92	3.58	3.69	1.6	9.7	2.64
Total agriculture		6.5						

2.2.3 WATER CONSUMED IN MINING AND METAL PRODUCTION

Between 2000 and 2010 the proportion of water used by the Australian mining sector has increased from 1.4% (321 GL) in 2000 to 4% in 2010 (540 GL) [Figure 1 and ABS 2012]. In absolute terms the water used by mining has increased by almost 70%. The cost of the water used by mining has increased from about $0.01 per kL [Norgate and Lovel 2006] to $1.82 per kL [ABS 2013] and the value of associated with water used by mining has increased from $83 per kL [Norgate and Lovel 2006] to between $161 and $199 per kL (Table 5) .

Northey and Haque (2013a; 2013b) examined various production processes for copper, gold and nickel to quantify the direct and indirect water consumption (Table 7). Direct water is physically consumed at the mine site, mineral processing or metal production facility. Indirect water is consumed off-site during the production of materials and energy that is required by these facilities. The direct and indirect water is combined to calculate the “total” water consumption. Consideration of the total water used can significantly change the amount of water used and the economic value added per m^3 of water consumed (Table 7). For example direct water consumption for copper is 30% higher for pyrometallurgical processes than for hydrometallurgical processes while the total water consumption for copper is about 50% lower for pyrometallurgical processes than for hydrometallurgical processes.

Table 7 Economic value per m3 of water consumption for copper, gold and nickel production. Consumption data from Northey and Haque (2013a; 2013b).

		Consumption (m^3 / t metal)			Value (US$ / m^3)	
Metal	Process	Direct	Indirect	Total	Direct	Total
Copper	Pyrometallurgy	91	37	128	88	63
	Hydrometallurgy	70	198	267	114	30
Gold	Non-refractory ore	244,701	69,732	314,433	245	191
	Refractory ore	284,235	149,112	433,347	211	138
Nickel	Pyrometallurgy	68	35	102	259	173
	Hydrometallurgy	303	1,409	1,712	58	10

2012 Prices: US$ 363 per lb Cu, $ 1700 per ounce Au, U$ 17600 per tonne Ni (USGS, 2013)

Ore Grades: 0.75% Cu, 3.5 g Au/t, 1.3% Ni.

There are several critical process variables that also affect the economic value generated by water consumed during primary metal production. One major factor is the ore grade (i.e. metal concentration) of the material being mined. A lower ore grade requires more material to be mined and processed per tonne of metal product and increasing the amount of material processed increases water consumption. The relationship between economic value achieved per m^3 of water and ore grade is shown in Figure 4.

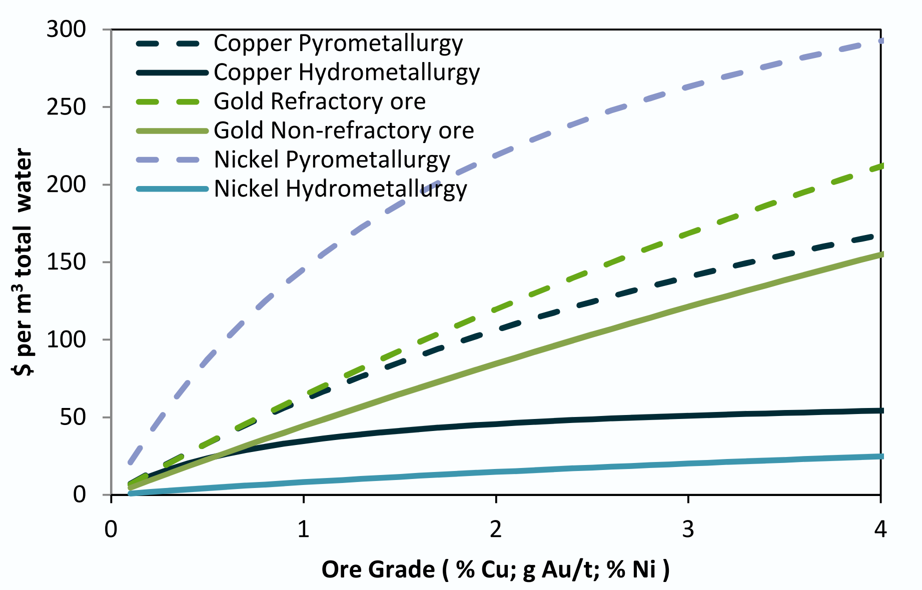

Figure 4 Economic value per m^3 of total (direct+indirect) water use vs ore grades.

The value of production associated with direct and indirect water use by the mining industry is compared with previous estimates by Norgate and Lovel (2006) in Table 8. The estimates of the value added for copper and nickel production by Northey and Haque (2013a; 2013b) are lower than that estimated by Norgate and Lovel (2006) (Table 8). A significant proportion of the variation is due to differences in assumed ore grades (0.75% Cu compared with 2% to 3% Cu and 1.3% Ni compared with 1% to 2.3% Ni). In addition, Northey and Haque (2013a,b) also considered a wider range of materials and energy that contributes to indirect water consumption and changes in metal prices may also increased (or decrease) the value per m^3 estimates for these metals.

Table 8 Comparison of the value per m3 of water consumed during metal production between the results of this study and Norgate and Lovel (2006).

Metal	Process	This study		Norgate and Lovel (2006)	
		m^3/t metal	\$ / m^3	m^3/t metal	\$/ m^3
Aluminium	Bayer/Hall-Heroult		60#	35.9	68
Copper	Pyrometallurgy	128	63	25.9	158
	Hydrometallurgy	267	30	38.0	105
Gold	Non-refractory ore	314,433	191	252,087	80
	Refractory ore	433,347	138		
Iron/steel	Blast furnace and basic oxygen furnace		258#	2.9	125
Lead	Blast furnace		159#	12.6	95
	Imperial smelting process		92#	21.7	55
Nickel	Pyrometallurgy	102	173	79.0	250
	Hydrometallurgy	1,712	10	377	52
Stainless	EAF (ferronickel feed)		41#	74.0	25
steel	EAF (nickel feed)		228#	13.4	139
Titanium	Becher/Kroll processes		107#	110	216^
Zinc	Imperial smelting process		89#	21.2	66
	Electrolytic processes		72#	26.3	53

In the absence of revised consumption data, this figure has been estimated using Norgate and Lovel's (2006) consumption data and 2012 metal prices (USGS, 2013).

^ This value is from Table 3 of Norgate and Lovel (2006). Table 4 of that study has a different value of \$ 68 per m^3.

3 Frameworks for Managing water

The international focus on water has lead to the development of a variety of methods that promote, encourage and measure sustainable water management (Table 10). In Australia, the effort has also been guided by the Intergovernmental Agreement on a National Water Initiative [National Water Commission 2006] that committed governments to improve water resource management in Australia. The NWI aims to enhance the security and commercial certainty of water rights and protect water resources and their dependent ecosystems. The NWI outlines a framework for water resource management that combines water access entitlements and water allocation plans for water systems. Currently, Clause 34 of the NWI recognises special circumstances in the Minerals and Petroleum sectors[4] that may warrant specific management arrangements outside the scope of the NWI. However, the Commission has expressed concerns that exemptions have been applied as the norm rather than the exception [National Water Commission 2011] and they are promoting and seeking to integrate the mining sector into water planning and entitlements regimes during the 2014 NWI review.

Currently a range of frameworks have been developed and used to assess water used in mining and mineral processing in Australia. For example, The Water Accounting Framework (WAF), is a joint initiative of Minerals Council of Australia and University of Queensland Centre for Water in the Minerals Industry [MCA and SMI, 2012]. WAF is developing into a reporting standard for industry that enables comparisons between companies and transparent communication of water performance. The model reports inputs and outputs by source/destination and quality, and reports the water use and reuse efficiency in activities internal to operations [Danoucaras N. 2013]. While this framework aims to provide a consistent methodology for the calculation and reporting of water flows within the Australian minerals industry, there are significant differences between this standard and other reporting standards in use. For example the WAF excludes rainfall from the totals used to calculate water recycling and reuse (MCA and SMI, 2012) while the Global Reporting Initiative (GRI) guidance accounts includes rainfall. Neither the WAF nor GRI consider indirect water consumption associated with materials and energy produced by third parties and used within the operation.

In other sectors, increasing sophistication of analysis and refining of the analysis boundaries has lead to significant variations in water use associated with production. For example the "Water footprint" per kg of wheat barley and oats in the Northern Statistical Division (SD) was calculated by Ridoutt to about 500 times lower than the national average (Table 9) [Ridoutt 2009]. Ridoutt suggests the use of national climatic data (which averages across highly variable climate zones) and the use of virtual water content of a crop without consideration of the type of water being used and the local water scarcity have both contributed to the large variation in results. Similarly, without assessing and considering the broader impacts of water use on the broader social and environmental systems it is not feasible to compare production and economic value attributed to water use between the Agricultural and Mining sectors.

[4] These factors include isolation, relatively short project duration, water quality issues, and obligations to remediate and offset impacts [Hamstead, 2012].

Table 9 The Australian-equivalent water footprints of wheat, barley and oats produced in the Northern SD of New South Wales in 2005/06 (Ridoutt and Poulton 2009), and the Australian Average (Chapagain and Hoekstra 2004)

Water Footprint	Wheat (L per kg)	Barley (L per kg)	Oats (L per kg)
Nothern SD	3.14	2.19	3.69
Australian Average	1,588	1,425	1,533

Recently, the International Organisation for Standardization (ISO), an international standard-setting body that promotes worldwide proprietary, industrial and commercial standards began developing water footprint principles, requirements and guidelines based on life cycle assessment [ISO/DIS 14046]. The initiative has been developing for several years and has recently been approved for publication, with publication expected in July 2014 [Ridoutt 2013].

The ISO/DIS 14046 is expected to establish clarity over equivalence and adherence to a standard which prescribes that comparisons will only be valid when they are made across equivalent systems. Acceptance and adherence to the ISO standard/guidelines is anticipated to provide certainty of definitions and consistency in assessing and reporting of water inventories and water footprint results. It is anticipated that adherence to the ISO standards will enable more objective comparison between and across sectors. It is recommended that CPSE Process Development and Evaluation Team consider adopting the principles, practices and guidelines described in ISO/DIS 14046, as it develops expertise and metrics for water accounting within the mining, mineral processing, metal production, and recycling industries.

Table 10 Examples of international tools, guidelines and directives that promote sustainable water management [adapted from UNGC (2010)].

Initiative	Overview	More details
Alliance for Water Stewardship	Using water footprinting to quantify water use, discharge, and impacts,	www.allianceforwaterstewardship.org
Berlin Rules on Water Resources	Provide non binding guidelines for appropriate transboundary management of water supply and quality	www.allianceforwaterstewardship.org
CDP Water Disclosure	Assists companies demonstrate water management and effectiveness through a framework that collect companies' water related information and policies	:www.cdproject.net/water-disclosure
European Union Water Framework Directive	A legally binding policy of the European Union that provides steps and protocol for the management and protection of water resources and includes frameworks for improving river basin management, coastal marine environments, water supply, water-related human health issues, and water quality. For companies operating in EU member states it is essential for ensuring that engagement efforts align with policy goals. For companies operating in other countries—particularly those without a comprehensive and effectively implementing water policy framework—the directive serves as a useful model	http://ec.europa.eu/environment/water/water-framework/index_en.html
Charting Our Water Future:	The report identifies cost-effective supply- and demand-side measures that conserve water and enables the development of a "water-marginal cost curve" that supports decision-making and technology evaluation.	www.mckinsey.com/clientservice/water/charting_our_water_future.aspx
The Ruggie Framework for Business and Human Rights	The framework provides a conceptual and policy framework on the private sector's role in human rights. The human right to water is one of the most controversial and important emerging issues related to water resources management and the framework provides guidance and helps companies and governments acknowledge and establish their roles and develop effective strategies.	www.reports-and-materials.org/Ruggie-report-7-Apr-2008.pdf http://www2.ohchr.org/english/bodies/hrcouncil/docs/11session/A.HRC.11.13.pdf
UN Millennium Development Goals	The eight goals have become the most widely recognized framework for assessing success of international development. Each of these broad goals is composed of numerous specific targets and access to safe drinking water and sanitation services is one of the targets for environmental sustainability. The MDGs enable institutions to assess how each of their actions effect development.	www.un.org/millenniumgoals
Water Footprint Network	Water footprinting combines direct and indirect freshwater water. The method can be applied to individuals, communities, businesses or nations.	www.waterfootprint.org/
Global Water Tool	The global water tool enables water consumption and efficiency to be calculated and compared on a country and across watersheds, It is used to assist in identifying water risks and create Global Reporting Initiative (GRI) indicators, inventories, risk and performance metrics.	www.wbcsd.org/web/watertool.htm

Turner et al (2004) has proposed an integrated framework for water valuation, appraisal and management to improve allocation, manage trade-offs between economic growth and water resource degradation and depletion, while increasing the decision making transparency. Turners approach is based around 6 core principles that are summarised below.

1. Economic efficiency and cost-benefit analysis.

The value of water is related to the cost of obtaining the water plus the opportunity cost that is created by the provision of the water. Turner suggests consideration of costs and benefits of water use as is feasible.

2. Integrated analysis.

Water allocation impacts socially, culturally, politically, economically and all these perspectives are relevant when considering the value of water.

3. An extended spatial and temporal perspective.

The volume and quality of water supplies and the functions that they provide can be determined by the rate of abstraction, recharge and the hydrological system. Sustaining water resources requires consideration across extended geographical perspective over long, intergenerational, time scale. The geographical perspective can include catchment scale surface water processes, aquifer scale ground water processes their interactions with each other as well as other drivers that impact on water resources

4. Functional diversity maintenance.

Maintenance of functional diversity is a key component of a sustainable water resource because it contributes to the stability of the associated ecosystems and to the capacity of the ecosystems to recover from stresses and shocks.

5. Long term planning and precaution.

Sustaining water resources requires consideration of long time scale. The quantity of water available for use should not exceed run-off and water quality should not decline with use. Typically the volume and quality of water supplies and the functions that they provide are determined by the rate of abstraction, recharge and the hydrological system.

6. Inclusion.

Interactive, participatory and inclusive approaches help focus deliberations on real world problems, and enable solutions to be developed from the combined knowledge and experiences of decision-makers, experts, interest groups and the lay public.

Turners work concludes the value of water is based on linkages between water resource structures, processes and the goods and services that they provide. This contrasts the simplistic economic value per m^3 that is frequently used to suggest one form of water usage is more valuable than another.

4 Summary

This study suggests that the international inter-government panels and international groups proactive support for the development of water auditing and footprinting is driven by a moral imperative rather than economic necessity.

Over the past 15 years a range of United Nations initiatives have led to a widely held view that an integrated approach to managing and allocating water is critical and that water usage needs to be an intrinsic element in decision-making across the whole development spectrum.

The World Business Council for Sustainable Development advocates that valuing water can enhance decision-making, supports revenue, reduce costs, manage risks and enhance reputation and it is anticipated that water valuation and allocation will increasingly integrate broad cost benefit analysis that have been developed across a groundwater-wide ecosystem.

In Australia water used by the agriculture sector has reduced water use from 69% (14,989 GL) of the national water use to 54% (7,175GL) over the past decade (2000 to 2010). Over the same time period, the cost of water used by agriculture has increased from about $0.01 per kL to $0.14 per kL and the value of associated with water used by agriculture in 2010 was estimated to be $6.50 per kL.

The proportion of water used by Australian mining sector has increased from 1.4% (321 GL) in 2000 to 4% in 2010 (540GL). In absolute terms the water used by mining has increased by almost 70%. The cost of the water used by mining has increased from about $0.01 per kL to $1.82 per kL and the value of associated with water used by mining and metal production in 2010 was estimated to be between $161 and $199 per kL.

The water use and valuation tools currently under development have been criticised for failing to provide a universal, open, transparent and comprehensible measure of water use. Some of these issues may be overcome by adherence to the ISO Environmental management – Water footprint – Principles, requirements and guidelines that is under development although comparative studies will require matching functional units and equivalence of systems being compared and it is recommended that CPSE Process Development and Evaluation Team considers adopting the principles practices and guidelines described in ISO/DIS 14046, Environmental management for future development of water footprinting for the Mining and Mineral processing sectors. Furthermore it is recommended that the group pursues opportunities to develop water valuation in the holistic, integrated manner overviewed by Turner and the group work towards practices that will enable comparisons between and across sectors.

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Appendix A

Water and the millennium goals

Developed by Watkins, K. (2006).

The Millennium Development Goals are the world's time-bound targets for overcoming extreme poverty and extending human freedom. Representing something more than a set of quantitative benchmarks to be attained by 2015, they encapsulate a broad vision of shared development priorities. That vision is rooted in the simple idea that extreme poverty and gross disparities of opportunity are not inescapable features of the human condition but a curable affliction whose continuation diminishes us all and threatens our collective security and prosperity.

The multifaceted targets set under the Millennium Development Goals cut across a vast array of interlinked dimensions of development, ranging from the reduction of extreme poverty to gender equality to health, education and the environment. Each dimension is linked through a complex web of interactions. Sustained progress in any one area depends critically on advances across all the other areas. A lack of progress in any one area can hold back improvements across a broad front. Water and sanitation powerfully demonstrate the linkages. Without accelerated progress in these areas many countries will miss the Millennium Development Goals. Apart from consigning millions of the world's poorest people to lives of avoidable poverty, poor health and diminished opportunities, such an outcome would perpetuate deep inequalities within and between countries. While there is more to human development than the Millennium Development Goals, the targets set provide a useful frame of reference for understanding the linkages between progress in different areas—and the critical importance of progress in water and sanitation.

Millennium Development Goal	Why governments should act	How governments should act

Goal 1 Eradicate extreme poverty and hunger	• The absence of clean water and adequate sanitation is a major cause of poverty and malnutrition:
	  • One in five people in the developing world—1.1 billion in all—lacks access to an improved water source.
	  • One in two people—2.6 billion in all—lacks access to adequate sanitation.
	  • Diseases and productivity losses linked to water and sanitation in developing countries amount to 2% of GDP, rising to 5% in Sub-Saharan Africa—more than the region gets in aid.
	  • In many of the poorest countries only 25% of the poorest households have access to piped water in their homes, compared with 85% of the richest.
	  • The poorest households pay as much as 10 times more for water as wealthy households.
	• Water is a vital productive input for the smallholder farmers who account for more than half of the world's population living on less than $1 a day.
	• Mounting pressure to reallocate water from agriculture to industry threatens to increase rural poverty.
		• Bringing water and sanitation into the mainstream of national and international strategies for achieving the Millennium Development Goals requires policies aimed at:
		  • Making access to water a human right and legislating for the progressive implementation of that right by ensuring that all people have access to at least 20 litres of clean water a day.
		  • Increasing public investment in extending the water network in urban areas and expanding provision in rural areas.
		  • Introducing "lifeline tariffs", cross-subsidies and investments in standpipes to ensure that nobody is denied access to water because of poverty, with a target ceiling of 3% for the share of household income spent on water.
		  • Regulating water utilities to improve efficiency, enhance equity and ensure accountability to the poor.
		• Introducing public policies that combine sustainability with equity in the development of water resources for agriculture.
		• Supporting the development and adoption of pro-poor irrigation technologies.

Goal 2 Achieve universal primary education	• Collecting water and carrying it over long distances keep millions of girls out of school, consigning them to a future of illiteracy and restricted choice. • Water-related diseases such as diarrhoea and parasitic infections cost 443 million school days each year—equivalent to an entire school year for all seven-year-old children in Ethiopia—and diminish learning potential. • Inadequate water and sanitation provision in schools in many countries is a threat to child health. • The absence of adequate sanitation and water in schools is a major reason that girls drop out. • Parasitic infection transmitted through water and poor sanitation retards learning potential for more than 150 million children.	• Linking targets and strategies for achieving universal primary education to strategies for ensuring that every school has adequate water and sanitation provision, with separate facilities for girls. • Making sanitation and hygiene parts of the school curriculum, equipping children with the knowledge they need to reduce health risks and enabling them to become agents of change in their communities. • Establishing public health programmes in schools and communities that prevent and treat water-related infectious diseases.

Millennium Development Goal	Why governments should act	How governments should act
Goal 3 Promote gender equality and empower women	• Deprivation in water and sanitation perpetuates gender inequality and disempowers women. • Women bear the brunt of responsibility for collecting water, often spending up to 4 hours a day walking, waiting in queues and carrying water. This is a major source of time poverty. • The time women spend caring for children made ill by waterborne diseases diminishes their opportunity to engage in productive work. • Inadequate sanitation is experienced by millions of women as a loss of dignity and source of insecurity. • Women account for the bulk of food production in many countries but experience restricted rights to water.	• Putting gender equity in water and sanitation at the centre of national poverty reduction strategies. • Enacting legislation that requires female representation on water committees and other bodies. • Supporting sanitation campaigns that give women a greater voice in shaping public investment decisions and household spending. • Reforming property rights and the rules governing irrigation and other water user associations to ensure that women enjoy equal rights.
Goal 4 Reduce child mortality	• Dirty water and poor sanitation account for the vast majority of the 1.8 million child deaths each year from diarrhoea—almost 5,000 every day—making it the second largest cause of child mortality. • Access to clean water and sanitation can reduce the risk of a child dying by as much as 50%. • Diarrhoea caused by unclean water is one of the world's greatest killers, claiming the lives of five times as many children as HIV/AIDS. • Clean water and sanitation are among the most powerful preventative measures for child mortality: achieving the Millennium Development Goal for water and sanitation at even the most basic level of provision would save more than 1 million lives in the next decade; universal provision would raise the number of lives saved to 2 million. • Waterborne diseases reinforce deep and socially unjust disparities, with children in poor households facing a risk of death some three to four times greater than children in rich households.	• Treating child deaths from water and sanitation as a national emergency—and as a violation of basic human rights. • Using international aid to strengthen basic healthcare provision in preventing and treating diarrhoea. • Establishing explicit linkages between targets for lowering child mortality and targets for expanding access to water and sanitation. • Prioritizing the needs of the poorest households in public investment and service provision strategies for water and sanitation. • Ensuring that Poverty Reduction Strategy Papers recognize the link between water and sanitation and child mortality. • Publishing annual estimates of child deaths caused by water and sanitation problems.
Goal 5 Improve maternal health	• The provision of water and sanitation reduces the incidence of diseases and afflictions—such as anaemia, vitamin deficiency and trachoma—that undermine maternal health and contribute to maternal mortality.	• Treating water and sanitation provision as a key component in strategies for gender equality. • Empowering women to shape decisions on water and sanitation at the household, local and national levels.
Goal 6 Combat HIV/AIDS, malaria and other diseases	• Inadequate access to water and sanitation restricts opportunities for hygiene and exposes people with HIV/AIDS to increased risks of infection. • HIV-infected mothers require clean water to make formula milk. • Achieving the Millennium Development Goal target for water and sanitation would reduce the costs to health systems of treating water-related infectious diseases by $1.7 billion, increasing the resources available for HIV/AIDS treatment. • Poor sanitation and drainage contribute to malaria, which claims some 1.3 million lives a year, 90% of them children under the age of five.	• Integrating water and sanitation into national and global strategies for tackling malaria and improving living conditions of HIV/AIDS patients. • Ensuring that households caring for people with HIV/AIDS have access to at least 50 litres of free water. • Investing in the drainage and sanitation facilities that reduce the presence of flies and mosquitoes.

(continued on next page)

Eight reasons for the world to act on water and sanitation—links to the Millennium Development Goals (continued)

Millennium Development Goal	Why governments should act	How governments should act
Goal 7 Ensure environmental sustainability *Halve the proportion of people without sustainable access to safe drinking water and basic sanitation*	• The goal of halving the proportion of people without access to water and sanitation will be missed on current trends by 234 million people for water and 430 million people for sanitation. • Sub-Saharan Africa will need to increase new connections for sanitation from 7 million a year for the past decade to 28 million a year by 2015. • Slow progress in water and sanitation will hold back advances in other areas.	• Putting in place practical measures that translate Millennium Development Goal commitments into practical actions. • Providing national and international political leadership to overcome the twin deficits in water and sanitation. • Supplementing the Millennium Development Goal target with the target of halving water and sanitation coverage disparities between the richest and poorest 20%. • Empowering independent regulators to hold service providers to account for delivering efficient and affordable services to the poor.
Reverse the loss of environmental resources	• The unsustainable exploitation of water resources represents a growing threat to human development, generating an unsustainable ecological debt that will be transferred to future generations. • The number of people living in water-stressed countries will increase from about 700 million today to more than 3 billion by 2025. • Over 1.4 billion people currently live in river basins where the use of water exceeds minimum recharge levels, leading to the desiccation of rivers and depletion of groundwater. • Water insecurity linked to climate change threatens to increase malnutrition by 75–125 million people by 2080, with staple food production in many Sub-Saharan African countries falling by more than 25%. • Groundwater depletion poses a grave threat to agricultural systems, food security and livelihoods across Asia and the Middle East.	• Treating water as a precious natural resource, rather than an expendable commodity to be exploited without reference to environmental sustainability. • Reforming national accounts to reflect the real economic losses associated with the depletion of water resources. • Introducing integrated water resources management policies that constrain water use within the limits of environmental sustainability, factoring in the needs of the environment. • Institutionalizing policies that create incentives for conserving water and eliminating perverse subsidies that encourage unsustainable water-use patterns. • Strengthening the provisions of the Kyoto Protocol to limit carbon emissions in line with stabilization targets of 450 parts per million, bolstering clean technology transfer mechanisms and bringing all countries under a stronger multilateral framework for emission reductions in 2012. • Developing national adaptation strategies for dealing with the impact of climate change—and increasing aid for adaptation.
Goal 8 Develop a global partnership for development	• There is no effective global partnership for water and sanitation, and successive high-level conferences have failed to create the momentum needed to push water and sanitation in the international agenda. • Many national governments are failing to put in place the policies and financing needed to accelerate progress. • Water and sanitation is weakly integrated into Poverty Reduction Strategy Papers. • Many countries with high child death rates caused by diarrhoea are spending less than 0.5% of GDP on water and sanitation, a fraction of what they are allocating to military budgets. • Rich countries have failed to prioritize water and sanitation in international aid partnerships, and spending on development assistance for the sector has been falling in real terms, now representing only 4% of total aid flows. • International aid to agriculture has fallen by a third since the early 1990s, from 12% to 3.5% of total aid.	• Putting in place a global plan of action to galvanize political action, placing water and sanitation on to the agenda of the Group of Eight, mobilizing resources and supporting nationally owned planning processes. • Developing nationally owned plans that link the Millennium Development Goal target for water and sanitation to clear medium-term financing provisions and to practical policies for overcoming inequality. • Empowering local governments and local communities through decentralization, capacity development and adequate financing, with at least 1% of GDP allocated to water and sanitation through public spending. • Increasing aid for water by \$3.6–\$4 billion annually by 2010, with an additional \$2 billion allocated to Sub-Saharan Africa. • Increasing aid for agriculture from \$3 billion to \$10 billion annually by 2010, with a strengthened focus on water security.

Appendix B

The business case for valuing water

The business case for undertaking water valuation

(WBCSD, 2012)

1) Enhance decision-making

Undertaking water-related valuation tends to enhance decision-making in the following ways:

- **Improve sustainable decision-making** All water-related valuation studies improve the sustainability of decisions made by companies. When undertaken comprehensively, valuation ensures that broad environmental, social and economic issues and trade-offs are considered, integrated and made more comparable.
- **Inform mindsets, behavior and actions** The process of undertaking water-related valuation studies enhances the awareness of internal company staff and stakeholders at all levels in relation to the different values businesses and stakeholders generate and hold, and the impacts and benefits that company activities and decisions may have.
- **Enhance collaboration** Undertaking water-related valuation studies often involves bringing together different experts from within a company to share views and information, which can improve business results.

2) Maintain and enhance revenues

Water-related valuation can help ensure that revenues are maintained and enhanced:

- **Maintain license to operate** Water-related valuation can help highlight the role businesses play for society and local communities, and demonstrate how responsible companies are being with their operations, thereby maintaining a license to operate and maintaining their revenues.
- **Evaluate new revenue streams** Studies that involve valuing water-related ecosystem services, particularly when evaluating an individual’s willingness to pay for improvements, can help evaluate the potential nature and scale of new revenue streams, such as payments for ecosystem services.
- **Improve pricing** Valuation studies, particularly questionnaires on the willingness to pay, are ideal for providing businesses and governments with relevant information to inform pricing. This may relate either to the pricing of water services or company products with a strong association with water.
- **Justify demand for products** In certain situations valuation can be used to help justify expenditures on certain activities or the need for certain products, for example by demonstrating environmental and social values that are not obvious.
- **Focus product development**Water-related valuation can be used to help improve product development, for example by designing specifically to reduce the water needed to make or use a product, or determining the potential value of different costs and benefits associated with using a product.

3) Reduce costs

Water-related valuation can help reduce company costs:

- **Justify infrastructure investments** Valuation can play a key role in helping to justify investments in infrastructure, including the use of natural or green infrastructure as an alternative to man-made interventions. This may not only reduce costs, but may also lead to additional societal benefits.
- **Enhance investment planning** Water-related valuation can help inform investment planning, in particular by helping to compare trade-offs, but also by revealing cost savings and externality benefits.
- **Improve operational efficiency** Valuation can help identify and quantify cost savings from improved operational efficiency throughout the value chain. For example, this may be in terms of water use or associated energy use by applying alternative and innovative processes.
- **Inform social and environmental liabilities and insurance premiums** Companies can undertake valuation to help eliminate potentially harmful outcomes and to ensure that any necessary compensation payments or associated insurance premiums are set at an appropriate and fair level, which may save money.

4) Manage risks

Water-related valuation is ideal to help evaluate and manage a broad range of risks:

- **Secure supplies** Water-related valuation can be used to highlight where the security of water supply may be compromised due to over-use or from ecosystem degradation, and to justify existing or alternative water resource allocation arrangements or enhanced watershed management and the optimal societal use of water.
- **Assess risks** Linked to securing supplies, valuation can be used to assess and manage a broader range of potential water-related risks, such as price rises, new environmental markets, droughts and floods.
- **Maintain license to operate** The use of valuation can help identify and manage risks, thereby maintaining a company's license to operate.

5) Enhance reputation

Water-related valuation can be used to help enhance brand value and reputation, which in turn can lead to increased revenues, reduced costs and potentially an increased share price:

- **Enhance transparency** Valuation enables the provision of greater transparency to shareholders and stakeholders in relation to the actual impacts a company is causing, therefore engendering greater trust.
- **Demonstrate shared value** Valuation offers a means of evaluating and potentially demonstrating that a company is creating shared value (i.e. generating net societal value to stakeholders in addition to generating financial value for shareholders).
- **Demonstrate leadership in sustainability** Given the embryonic status of environmental valuation within a business context and its potential to enhance sustainability, companies that embrace and help mainstream water valuation will be seen as sustainability leaders.

Appendix C

ABS definitions of water use

Self–extracted water occurs when water is extracted directly from the environment (i.e. rivers, lakes, groundwater and other bodies) for use by industry and households alike. Self–extracted water is supplied by the environment free of charge in general. It is the source for distributed and reuse water.

Most of the self–extracted water in Australia is used in–stream for electricity production and is returned to the environment (e.g. the river) as regulated discharge water. Some water that is extracted directly from the environment is distributed via water providers to industry and households, at which time it becomes distributed water.

Distributed water is supplied to industry and households through a natural (e.g. river) or man–made network (e.g. pipelines or open channels), where an economic transaction has occurred for the exchange of this water. It is sourced from self–extracted water.

Reuse water is water that is made available for use again without firstly being discharged to the environment (e.g. treated effluent, drainage, waste or storm water). It may occur as waste water from production processes as well as collected storm water. Reuse water may have been treated to some extent and it is ultimately sourced from self–extracted water. It excludes "on–site" recycling.

Regulated discharge water is water that has been sourced from self–extracted water, used and is returned to the environment. However its state may have been altered (e.g. temperature, quality) during this process or the return not matches the natural flow of the body that existed prior to its use (e.g. stored for a period of time). This type of water is primarily seen in the water supply, electricity generation, mining and manufacturing industries.

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