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Economics of Water Recovery in the Murray-Darling Basin, Australia

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Abstract

We review recent water reforms and the consequences of water recovery intended to increase stream flows in the Murray-Darling Basin (MDB), Australia. The MDB provides a natural experiment of water recovery for the environment that includes (*a*) the voluntary buy-back of water rights from willing sellers and (*b*) the subsidization of irrigation infrastructure. We find that (*a*) the actual increase in the volumes of water in terms of stream flows is much less than claimed by the Australian government; (*b*) subsidies to increase irrigation efficiency have reduced stream and groundwater return flows; (*c*) buy-backs are much more cost effective than subsidies; (*d*) many of the gains from water recovery have accrued as private benefits to irrigators; and (*e*) more than a decade after water recovery began, there is no observable basin-wide relationship between volumes of water recovered and flows at the mouth of the River Murray.

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1. INTRODUCTION

The supply of freshwater is highly variable, and in many locations, per capita availability is declining (WWAP 2015, 2016). While an increase in supply may be necessary, by itself it is not sufficient to meet the demand for water of an acceptable quality. Indeed, there is a "paradox of supply," whereby efforts to increase water supplies, but in the absence of demand-based approaches, may even magnify supply shocks on the poor and vulnerable, as well as on the environment (Damania et al. 2017).

A resolution of future water challenges requires reconciling a diminishing water supply per capita with the need to provide the following services: (*a*) provisioning, e.g., water directly used for drinking or irrigation; (*b*) regulation, e.g., water that reduces temperature extremes; (*c*) habitat, e.g., water that enables fish migration and spawning; and (*d*) cultural resources, e.g., water associated with ancestral practices, spiritual significance or language, and aesthetic appreciation. Given water's numerous attributes, a mix of water governance approaches is required that responds to water risks and especially unanticipated shocks of too much (floods) or too little (drought) water (Hanemann 2006).

Two key governance approaches to respond to water insecurity include demand-side management (e.g., education, regulations, planning processes, economic incentives, institutions) and supply augmentation (e.g., technology, infrastructure such as dams/weirs/desalination) (Grafton 2017b). Economic demand-side water management strategies include pricing to discourage overuse, providing rebates to encourage certain water-use behavior, and improving institutions that may include property rights over water (Damania et al. 2017).

Australia has been at the forefront in the development of water markets, especially in the Murray-Darling Basin (MDB), as a means to respond to inadequate water supplies (Grafton & Horne 2014, Grafton et al. 2015). Over the past 30 years in the MDB, successive Australian governments have developed the most sophisticated and extensive water markets in the world. These markets are a "cap and trade," whereby the Australian government sets the overall level of extractions by catchment within the MDB, and water rights holders are able to trade their rights, unbundled from land. Perversely, Australia is also a leader in nonmarket approaches to respond to water scarcity. In particular, the Australian government has allocated approximately AUD6 billion, as of 2018 and spent some AUD4 billion on subsidies to increase irrigation efficiency and infrastructure with the stated intent to assist irrigation communities and to increase stream flows in the MDB.

Water markets in the MDB have provided a means by which the Australian government has implemented the world's biggest buy-back of water rights. We define the acquisition of water entitlements for environmental purposes, be it by buy-backs or subsidies, as water recovery. The buy-backs involve the purchase of water rights that are called water entitlements. Water entitlements provide a permanent share of a consumptive pool of water to its holders and are defined in nominal volumes of water. The actual annual volume of water assigned to the water entitlement, called a water allocation, depends on its reliability, water storages, and expected inflows in the catchment where the entitlement is denominated.

Government buy-backs of water entitlements have been undertaken as a market- and compensation-based approach to reduce the overall cap on water extractions (also known as diversions) in the MDB so as to increase stream flows and associated environmental benefits. These buy-backs have been implemented through voluntary reverse auctions with irrigators. To date, the buy-back of water has cost ∼AUD2.5 billion, and no further buy-backs are expected.

After more than a decade of water recovery from buy-backs and irrigation subsidies (Grafton 2017a), it is timely to review progress and to provide insights into the costs, benefits, and their relative merits. We contend that insights from the "MDB policy experiment" provide valuable lessons elsewhere about the economic and environmental effects of water recovery.

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Figure 1

Map of the Murray-Darling Basin in southeastern Australia, illustrating the southern and northern basins. Major rivers are shown as blue lines. Adapted with permission from MDBA (2015). Abbreviations: ACT, Australian Capital Territory; NSW, New South Wales; QLD, Queensland; SA, South Australia; VIC, Victoria.

2. BACKGROUND

2.1. The Murray-Darling Basin

The MDB is Australia's largest and most regulated river system, as depicted in **Figure 1**. Located in southeastern Australia, it spans more than one million square kilometers and covers parts of four states and one territory. The MDB is separated into two regions: the northern basin (nMDB) and the southern basin (sMDB). The sMDB contains the majority of irrigated farmland in the MDB, is highly regulated, has many nationally and internationally significant environmental assets, and is hydrologically connected [which allows water trade to occur between South Australia, Victoria, and New South Wales (NSW)] (Wheeler et al. 2014a).

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Rainfall within the MDB is generally low but highly variable, with most having evapotranspired before being available as runoff. Surface water is used for irrigation, as well as urban, recreation, tourism, cultural, and environmental purposes. Irrigated agriculture has, typically, accounted for approximately 70% of water diversions and is responsible for ∼90% of the water consumed in the MDB (ABARES 2016).

2.2. History of Water Reform in the Murray-Darling Basin

Over the last 125 years, there have been a number of notable droughts in the MDB: the Federation Drought (1895–1902), World War II Drought (1937–1945), and the Millennium Drought (primarily between 2001–2002 and 2009–2010). Given the spatial and temporal water scarcity issues in the basin, water has commonly featured as a battleground across states since European settlement of Australia in 1778.

Prior to federation in Australia in 1901, there were six self-governing colonies (that adopted English riparian doctrine and common laws) that consequently became six states of the Commonwealth of Australia, along with a federal government. The same systems of government in states continued, and early constitutional recognition gave states the power to own and allocate water without recourse to the First Peoples of Australia (Aust. Gov. 2017a) who were dispossessed of much of the land and water resources that they previously used (NWC 2011, Tisdell 2014).

European settlement led to the need to coordinate water use and flows in the River Murray, especially as a result of the Federation Drought. This led to the first major transboundary water agreement in 1915 (the River Murray Waters Agreement) and the first national water institution (the River Murray Commission in 1917). **Table 1** provides a chronology of the various acts and regulations governing water in the MDB. Differing state water needs were also a cause of

Table 1 History of water institutions and reforms in the Murray-Darling Basin, Australia

Reform/institution	State(s) and description
Water Conservation and Distribution Act 1881	VIC; allowed trusts to borrow for irrigation
Irrigation Act 1886	VIC; developed from the Deakin Royal Commission review in 1884 and was a radical departure from existing laws on riparian rights. Private water riparian rights were abolished, and landowners could apply for a diversion license. The Lyne Royal Commission followed with similar recommendations in NSW, with other states following
Water Authorities Act and the Irrigation Act 1891	QLD; provided for construction and maintenance of dams and weirs
Australian Constitution 1901	Commonwealth; allowed for state negotiations over river resources
Water Act 1905	VIC; established the State Rivers and Water Supply Commission in 1906
Water Conservation and Utilization Act 1910	QLD; vested control of natural waters with the state
Water Act 1912	NSW; established water licenses/extraction requirements, some environmental flow protection, and the right for the government to purchase entitlements
River Murray Waters Act 1915	Commonwealth; first cross-boundary MDB arrangement after agreement by the Commonwealth, VIC, NSW, and SA in 1914; created the River Murray Commission in 1917 that controlled development and works on the River Murray up to 1988
Water Act 1926	QLD; granted water allocation powers, water license, and use rules
River Murray Waters Agreement Amendment 1934	Commonwealth; amended to rationalize river use from navigation to irrigation and allow constructions, e.g., Snowy Mountain Scheme in 1949

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Table 1 (*Continued*)

Reform/institution	State(s) and description
Water Act 1958	VIC; granted more control over surface water
Groundwater Act 1969	VIC; controlled groundwater development and use, driven by urban town scarcity that relied on groundwater
Environment Protection Act 1970	VIC; protected groundwater quality
National Parks and Wildlife Act 1974	NSW; protected wild rivers and water bodies
Water Resources Act 1976	SA; implemented more controls over surface waters
River Murray Waters Agreement Amendment 1982	Commonwealth; expanded scope to include water quality, environmental and recreational issues
Water (Amendment) Act 1983/1984/1986	NSW; initially allowed water transfer scheme with permanent water trade transfers allowed in 1986
MDB Ministerial Council 1985	Commonwealth, NSW, VIC, and SA met to discuss problems
Water Administration Act 1986	NSW; allowed for greater environmental allocations
Planning and Environment Act 1987	VIC; regulated groundwater land management impacts
MDB Agreement 1987	Amended/renamed River Murray Waters Agreement
Salinity and Drainage Strategy 1989	Commonwealth, NSW, VIC, and SA; ministerial agreement to undertake works and measures to reduce average salinity
Water Act 1989	VIC; introduced water trade and direct water allocation to environment
Water Act and Water Resources Act 1989	QLD; introduced transferable water entitlements within the same water area
Heritage River Act 1992	VIC; protected wild rivers
MDB Agreement 1992	Formalized rules for implementation of salinity and drainage strategy of 1989 and amended 1987 MDB agreement; established the MDBC to replace River Murray Commission
Native Title Act 1993	Commonwealth; recognized native title holders' rights to use water for domestic/personal purposes, but they had no right to negotiate
Catchment and Land Protection Act 1994	VIC; protected quality and quantity of water supplies in declared MDB catchments
COAG 1994	Commonwealth, states, and territories; introduced cap on surface-water extractions and agreed to unbundle water from land
National Heritage Trust of Australia Act 1997	Commonwealth; provided support for sustainable water management activities and funded the Murray-Darling 2001 program
Environmental Protection and Biodiversity Conservation Act 1999	Commonwealth; protected Australian wetlands under Ramsar Convention on Wetlands of International Importance and created the Environmental Protection and Biodiversity Conservation Regulations 2000
National Action Plan for Salinity and Water Quality 2000	Commonwealth; endorsed by COAG in 2000, plans to reduce MDB salinity
Water Management Act 2000	NSW; developed water sharing plans, water access licenses, monitoring, and enforcement
The Living Murray 2002	Six icon sites along the River Murray were selected across VIC, NSW, and SA to return to health through infrastructure expenditure and purchase of 500 GL of water
National Water Initiative 2004	Commonwealth and all states agreed to a national blueprint of reform (following COAG 1994) in regard to water plans, sustainable water use, trade, pricing, urban water, registers, water accounting, and some recognition of indigenous water access

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Table 1 (*Continued*)

Reform/institution	State(s) and description
National Water Commission Act 2004	Established the NWC, an independent statutory authority (abolished in 2014) that led the National Water Initiative
Natural Resource Management Act 2004	SA; amendments in 2009 for unbundling of water from land
Wild Rivers Act 2005	QLD; protected wild rivers and water bodies
National Plan for Water Security 2007	Commonwealth; AUD10 billion to be spent over 10 years on governance, modernizing irrigation, and addressing overallocation of water in the MDB
Water Act 2007	Commonwealth; removed trade barriers, introduced carryover, unbundled declared systems, dictated development of MDB Plan
Water for the Future 2008	Replaced National Plan for Water Security and increased funding to AUD12.9 billion
Water Amendment Act 2008	Commonwealth; created the MDBA that replaced the MDBC
Murray Lower–Darling Rivers Indigenous Nations 2008 and Northern Basin Aboriginal Nations 2010	Represent >75,000 indigenous MDB people across 46 Indigenous nations
The Basin Plan 2012	Commonwealth; to be reviewed and revised through 7-year implementation phase
Environmental Protection and Biodiversity Conservation Amendment Act–Water Trigger 2013	Commonwealth; assessed proposed coal seam gas and mining on water resources
Foreign Acquisitions and Takeovers Regulations 2015 and Amendment Act 2017	Commonwealth; foreign owners must register water entitlements with Australian Taxation Office
Water Amendment Act 2015	Commonwealth; surface-water purchases capped at 1,500 GL, added more flexibility with efficiency measures

Data from Taylor et al. (2017), Tisdell (2014), Wheeler (2014).
Abbreviations: COAG, Council of Australian Governments; GL, gigaliters; MDB, Murray-Darling Basin; MDBA, MDB Authority; MDBC, MDB Commission; NSW, New South Wales; NWC, National Water Commission; QLD, Queensland; SA, South Australia; VIC, Victoria.

disagreements between states: Victoria and NSW wanted water primarily for irrigation development, whereas South Australia needed it for transport priorities (Connell 2007, Tisdell 2014). South Australia's need for minimum river flows has continued, with later demands turning to more environmental purposes such as requiring enough water in the River Murray to keep the Murray Mouth open (Settre & Wheeler 2017).

To Australia's First Peoples, water is a part of everything in their culture, such as their dreaming stories, art, songs, and dance, and there is evidence that they have been managing water in the MDB for perhaps as long 40,000 years. Indeed, the Brewarrina fish traps (*Baiame's Ngunnhu*) on the Barwon River are possibly the oldest continuously used human water construction in the world (Bark et al. 2015). By comparison, European settlers typically viewed water as a resource to be used, manipulated, and harnessed for economic benefits. These two vastly different worlds have often clashed. Along with the legal fiction of terra nullius, there was also the myth of "aqua nullius" that rendered existing Indigenous water relationships invisible (Taylor et al. 2017).

Significant investment in MDB irrigation activities occurred between 1918 and the 1970s. Williams (2017) and others have described this period as the expansionary phase of water policy governance in Australia, with many major infrastructure projects funded and constructed. Total water storage increased substantially over this period, along with a growing number of irrigation trusts established to support water delivery to farmers (NWC 2011, Tisdell 2014).

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The severity and longevity of the Millennium Drought in the 2000s exposed the need to respond to water overallocation and environmental problems. An initial intervention to recover water for the environment was the Living Murray initiative, derived from a 2004 intergovernmental agreement that assigned AUD500 million to secure 500 gigaliters (GL) for MDB environmental water (Grafton & Hussey 2007). As part of this agreement, the National Water Initiative (NWI) also was created (COAG 2004). The NWI provided principles for national water reform and established the National Water Commission to support and audit the reform process (Stoeckl & Abrahams 2007).

At the height of the Millennium Drought, the Australian government promulgated the Water Act 2007 that involved substantial legislative, regulatory, and stakeholder water reform. The reforms included the creation of the Murray-Darling Basin Authority (MDBA) to replace the MDB Commission. In addition, the Commonwealth Environmental Water Holder (CEWH) and Commonwealth Environmental Water Office (CEWO) would be responsible for managing the water entitlements of the Australian government (Aust. Gov. 2017b). Importantly, the Water Act 2007 established the parameters for a basin plan with its key objects: "3d(i) to ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused"; and 3d(ii) "to protect, restore and provide for the ecological values and ecosystem services of the MDB." Such reallocations were consistent with economic modeling that indicated that a reallocation of some water from irrigation to the environment would increase societal economic benefits (Grafton et al. 2011) and was a response to perverse water sharing rules (Grafton et al. 2013).

The Water Act 2007 complemented the National Plan for Water Security in early 2007 and was renamed the Water for the Future (WFF) in 2008 (Connell & Grafton 2008, 2011a). The National Plan for Water Security initially allocated AUD10 billion over 10 years to support water reform, while the WFF allocated AUD12.9 billion for this purpose. Since 2002, the Australian government has spent or plans to spend more than AUD15 billion on water reform and irrigation efficiency improvements overall (Aust. Gov. 2014, p. 7).

The largest funding in WFF was for water infrastructure subsidies (AUD5.8 billion), followed by water entitlement purchases (AUD3.1 billion). The infrastructure subsidies are intended to deliver substantial and lasting returns for the environment and also to secure a long-term future for irrigation communities through the provision of grants for on- and off-farm irrigation water-use efficiency called the Sustainable Rural Water Use Infrastructure Program (SRWUIP). The purchase of water entitlements was intended to obtain water for the environment that represented "value for money" (Grafton 2010) delivered through voluntary sales of water entitlements to the Australian government through a series of rolling tenders. This scheme was called Restoring the Balance (RTB).

After the Water Act 2007, the MDBA was charged with delivering a sustainable basin-wide plan. The MDBA released the guide to the Basin Plan in 2010, which called for an average basin-wide reduction in current watercourse consumption diversions between 3,856 GL (that represented a 38% reduction in diversions in the sMDB) in a high uncertainty scenario in terms of achieving environmental water requirements and 6,983 GL (that represented a 68% reduction in diversions in the sMDB) to achieve a low uncertainty scenario (MDBA 2010, pp. 114–15). Using a 20% confidence interval around the high uncertainty estimate, the MDBA recommended in its guide to the proposed Basin Plan a reduction in diversions of between 3,000–4,000 GL annually (MDBA 2010).

Although environmentalists and some scientists (Wentworth Group 2010) stated that the Draft Basin Plan for water reallocation was inadequate, some irrigators and their communities were vehemently opposed to the proposed reductions in diversions, despite the fact that they were to be done voluntarily and with full compensation. Debates emerged about the effects of water recovery and the environmental benefits from increased stream flows (Crase et al. 2012) as well as about the

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community and farm impacts of permanent water sales, multiplier impacts, population losses, and legacy issues for remaining irrigators from higher irrigation infrastructure costs (Aust. Parliam. 2011, Connell & Grafton 2011b).

The Australian Parliament passed the Basin Plan into law in 2012, which included a series of plans, actions, and milestones until 2024. A key feature of the plan is the goal to reduce surface-water diversions in the MDB through the implementation of sustainable diversion limits (SDLs) that would reduce overall diversions by irrigators, when complete, on an average annual basis, by 2,750 GL based on a long-term average annual yield (LTAAY, which takes the security and reliability of water entitlements into consideration). Total water recovery of the 2,750 GL was to be achieved by July 1, 2019 (MDBA 2012). To ensure that the South Australian government did not proceed with its legal objections and to confirm secure passage of the legislation, 450 GL/year of additional water for the environment was to be secured through efficiency/supply and constraint infrastructure expenditures, bringing total water recovery to 3,200 GL/year. An additional AUD1.77 billion over 10 years from 2014 was committed for the extra 450 GL/year in water recovery, although the volume does not have to be fully delivered until 2024 (DAWR 2017). In 2015, an amendment to the Water Act 2007 limited the purchase of water entitlements to a total of 1,500 GL of LTAAY within the MDB (Hunt & Baldwin 2015). A full review of the plan is scheduled for 2026, with an interim evaluation in 2018.

The Australian government's responsibility is to set, monitor, and enforce water market rules and also undertake annual monitoring, evaluation, and enforcement of the Basin Plan. Actual monitoring and enforcement occur at the state level. The MDBA is also charged with (*a*) basin-wide planning and accreditation of state water plans, (*b*) determination of catchment-sustainable diversion limits, (*c*) determination of annual environmental water allocations, and (*d*) various environmental watering strategies. State governments have responsibility over (*a*) developing state water plans consistent with the Basin Plan, (*b*) determining state water allocations subject to water holdings and sustainable diversion limits, (*c*) determining state environmental flows, and (*d*) meeting interstate and federal flow regime obligations (Wheeler 2014).

As of September 30, 2017, surface-water recovery to achieve the Basin Plan was at 1,931 GL LTAAY (**Figure 2**). This represents approximately 70% of the 2,750 GL reduction in diversions (DEE 2017). Once previous state government purchases (from programs such as the Living Murray) are included, this increases to 77% of the target. The majority (64%) of the commonwealth water has been sourced through the RTB program, while 36% (i.e., 700 GL) has been sourced through infrastructure grants and subsidies.

In December 2017, the MDBA (2017c) proposed a sustainable diversion limit adjustment mechanism that would change how the 2,750 GL/year reduction in surface-water diversions would be implemented. This proposal reduces the water entitlements that would otherwise have been acquired by the Australian government for environmental purposes by 605 GL/year in the total plan. Instead, it affects what the MDBA claims to be an equivalent reduction in surface-water diversions through 36 water supply and two efficiency projects (rather than buy-back). As a result, the volume of surface water that would previously have been to be acquired as water entitlements for the environment is reduced by 22% to 2,145 GL/year by July 1, 2019. This has the effect of stopping any further buy-back of water entitlements. There has been much criticism of the effectiveness of these supply measures (e.g., see submissions to MDBA 2017c), with critics suggesting that 25 of the water supply projects do not satisfy Basin Plan requirements (Wentworth Group 2017).

Evaluation of Basin Plan outcomes occurred with an interim evaluation in 2017, with another major five-year statutory evaluation report due in 2020 and a ten-year review of the Basin Plan due in 2026.

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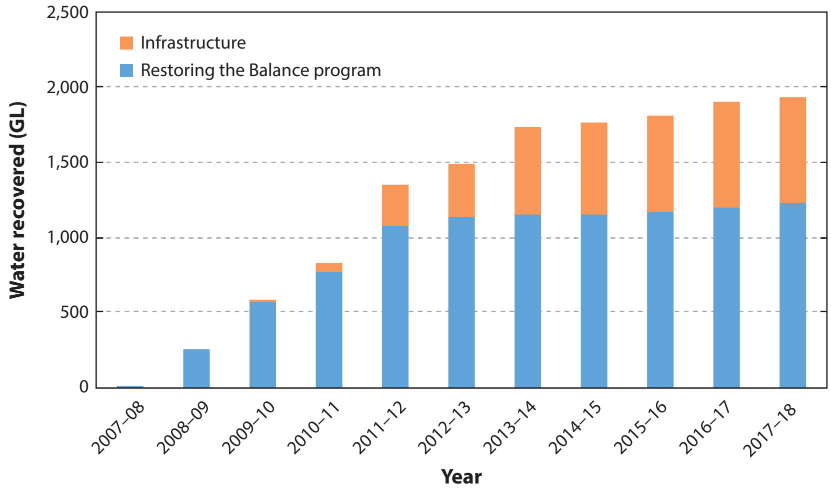

Figure 2

Volume of environmental water entitlements [in gigaliters (GL)] recovered by the Commonwealth of Australia, by scheme, as of September 30, 2017, expressed in long-term average annual yield (LTAAY). Created from data provided by the Commonwealth Department of Agriculture and Water Resources.

2.3. Water Markets

Water markets in the MDB originated with the development of volumetric water allocations defined as 3 megaliters (ML) per hectare (or one-acre foot) for properties with irrigation infrastructure. By the 1980s, trading was allowed within irrigation districts, and over time, trade has been permitted in terms of actual water entitlements and then across districts (Martin 2005). The MDB Agreement in 1992 led to a range of fundamental water reforms, upon which all current major water policy and institutions evolved, including the unbundling of land and water entitlements that was agreed to in the 1994 Council of Australian Governments (COAG) agreement and later implemented in 1997 (Young 2013).

The water entitlement market involves trade of water access entitlements in the form of a consumptive share of the water resources within a water resource plan area. The water allocations market involves the trade of seasonal allocations or physical volumes of water attached to a water entitlement (Connell & Grafton 2011a). Most of the water traded is between irrigators, many of whom use water markets as a risk management strategy (Nauges et al. 2016). Irrigators were initially more accepting of water allocation trades than water entitlement trades (Bjornlund 2002, Bjornlund et al. 2011), but today, there is widespread acceptance of trade in both water allocations and water entitlements.

Figure 3 highlights how water market trade has increased over time in the sMDB, with water allocation trade adopted the earliest, and water entitlement trade increasing substantially after the Millennium Drought. By 2015–2016, it was estimated that most irrigators in the sMDB have used water markets, and this has grown from estimates last recorded in 2010 (Wheeler et al. 2014a). Approximately half of all irrigators in the sMDB had made at least one water entitlement trade, whereas 78% had conducted at least one water allocation trade.

The sMDB includes the vast majority of water trade. By 2014–2015, the sMDB represented 88%, and the entire MDB represented 96% of the Australian water allocation market trade. Much of this water trade is in regulated surface-water allocations released from dam storages. In terms

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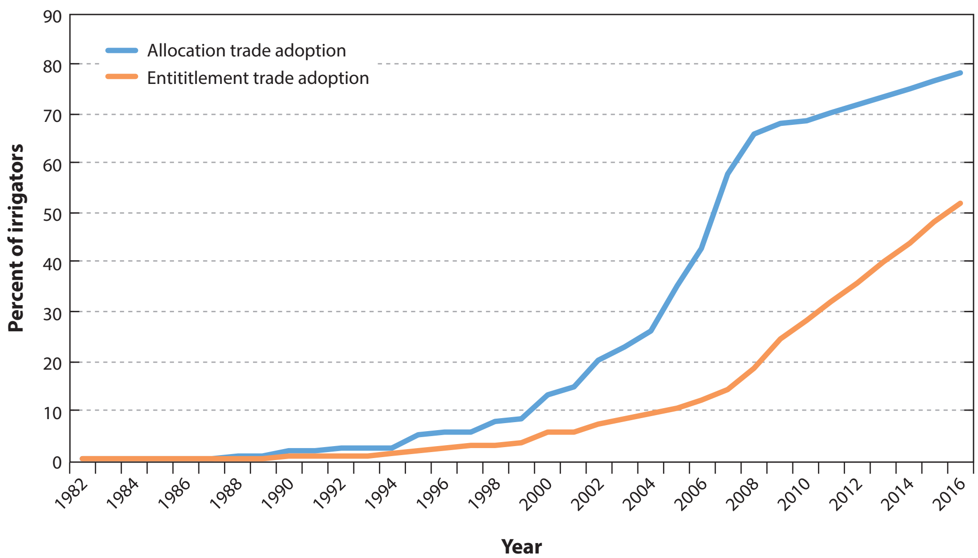

Figure 3

Percent of irrigators in the southern Murray-Darling Basin, Australia, that have used the water allocation and water entitlement markets at least once by 2015–2016. Figure created using current and historical University of Adelaide irrigator survey data.

of the water entitlement trade across Australia in 2014–2015, only 44% occurred in the sMDB (78% in the total MDB). Some 15% of water entitlement trade is in groundwater. In 2014–2015, the sMDB-regulated surface-water trade had a turnover of AUD970 million (ABARES 2016). In 2015–2016, the overall value of water entitlements in the MDB was approximately AUD13 billion (Product. Comm. 2017).

While the MDB's water markets (water entitlements and water allocations) historically have predominantly been used by irrigators following the unbundling of water from land (and the Australian government buy-back program), there have been new market participants for water entitlements. These include water companies, environmental water holders (EWHs), and investors (e.g., superannuation companies). Much of the change in ownership has occurred because of transfers of water entitlements from irrigators to the Australian government since 2007. For instance, in 2015, 26% of Northern Victoria high-security water entitlements were owned by the CEWH, water corporations (e.g., Victorian urban and rural water corporations) represented 3% of ownership, and water entitlements not linked to land ownership were 7% of the total (Cummins Assoc. 2016).

Given the concerns associated with water entitlements not tied to land ownership and also the unease about the amount of foreign ownership of land and water resources in Australia, legislation was amended. Since July 1, 2017, foreign persons (as defined in the Foreign Acquisitions and Takeovers Act 1975 and the Foreign Acquisitions and Takeovers Regulation 2015) have to register their water entitlement holdings and contractual water rights with the Australian Taxation Office.

In 2014, the Australian Competition and Consumer Commission, an independent commonwealth statutory authority whose role is to enforce the Competition and Consumer Act 2010, enforced rules that prevent restrictions on trade by individual market participants. Previous to this development, state governments determined how water entitlements were allocated or traded and could restrict undesirable trades. For example, in Victoria, when trading was first allowed within and between districts and from a district to land on a river, trade outside of specified areas

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was limited each year to 2% of the nominal volume of available water entitlements in the area, but this limit was increased to 4% in 2005 and subsequently removed in 2014 (Grafton & Horne 2014).

Despite the removal of state restrictions on trade promoted by the Australian government, the federal parliament itself imposed a cap on the purchases of water entitlements for environmental purposes in 2015 (Hunt & Baldwin 2015), and such purchases were halted in 2017 (MDBA 2017c). The reason for this constraint has been to respond to the preference by some irrigators and lobby groups that water recovery should be focused on subsidies for irrigation infrastructure rather than voluntary sale of water entitlements by reverse auctions. This is despite research showing that irrigators only marginally prefer infrastructure expenditure above market-based options and that buy-back has far higher support from irrigators than current policy recognizes (Loch et al. 2014).

3. COSTS AND BENEFITS OF THE WATER FOR THE FUTURE PROGRAM

The WFF program that was established in 2008 contains two key components: the SRWUIP that involves multiple actions, and in particular, subsidies for upgrades to irrigation infrastructure; and the RTB program, described separately, that involves the voluntary sale of water entitlements to the Australian government.

3.1. Sustainable Rural Water Use and Infrastructure Program

The water savings from investments in irrigation efficiency infrastructure in the SWRUIP on farms are meant to be shared 50/50 between the farmer and the environment. Some irrigation efficiency (usually defined as the ratio of the amount of water consumed by the crop to the amount of water supplied by irrigation) can be as low as 40% for water delivered to farmers' fields (e.g., via flood irrigation) versus as high as 90% or more with drip irrigation on laser-leveled fields.

A key stated purpose and the goal of increased irrigation efficiency are to save the water that was previously lost for nonbeneficial consumptive use to increase the amount of water available for other purposes such as stream flows or other consumptive use such as in industry. But, this savings at a farm level ignores the return flows back into the system (Perry et al. 2009), either as surface-water runoff or groundwater seepage, and that can increase stream flows.

At present, there are no comprehensive estimates of the effect on return flows of either SRWUIP or RTB, yet this information is absolutely critical to judge their effectiveness on changes in stream flows. For instance, estimates of end-of-system flows, with and without irrigation, as calculated by CSIRO (2008) and as summarized in Grafton et al. (2014), indicate that, based on the historical climate, the end-of-system flows in the MDB without irrigation would have been approximately 12,200 GL/year, on average. By contrast, with irrigation and for the same period, the end-of-system flows are measured to be 4,700 GL/year, on average. The difference between these two volumes is 7,500 GL/year, whereas average surface-water diversions are estimated by CSIRO to be ~10,000 GL/year.

Using global irrigation numbers, Jägermehr et al. (2015) estimate that return flows on a worldwide basis comprise approximately 49% of withdrawals for irrigation. Further, they estimate that if water extractions were to remain unchanged, then a shift from surface to sprinkler irrigation would reduce return flows by 30%, a shift from sprinkler to drip irrigation would reduce return flows by 60%, and a shift from surface to drip irrigation would reduce return flows by about 75%. These global estimates highlight the importance of measuring the effects of return flows when undertaking irrigation subsidies with the intended objective of increasing stream flows.

The relevance of return flows to water recovery is that, at the very least, wherever return flows represent a substantial proportion of water losses, subsidies for irrigation upgrades to increase

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irrigation efficiency so as to increase stream flows are not cost effective (Qureshi et al. 2010). Depending on the proportion of the water saved that is evaporated or was previously return flows, the potential also exists for irrigation infrastructure subsidies to result in the opposite of what is intended and to actually reduce stream flows.

A report commissioned by the MDBA compares measured end-of-channel or discharge flows (excluding groundwater seepage or other surface return flows) in 1993–1994 and 2008–2009, the latter being a period of severe drought. The report observes that end-of-channel flows in 2008–2009 were just three per cent of what they were in 1993–1994 and states that "...it is considered unlikely that return flows will increase again to levels experienced prior to 1997–1998 (a predrought year). This is because since that time significant changes in irrigation practice have occurred to more water-use efficient operations, and there has been substantial investment in infrastructure modernisation..." (URS Aust. 2010, p. xiii).

Other criticisms of the SRWUIP include the fact that it may be creating on-farm technological lock-in by encouraging permanent crop plantings; it may also increase electricity costs and thus place irrigators at higher risk during droughts (Adamson et al. 2017). Another potential issue, highlighted by Wheeler et al. (2018), is that in 2015–2016, horticultural farmers' electricity prices were their second highest psychological stress factor. This is explained in part by the fact that irrigators who are the most technologically efficient in terms of water-use and irrigation infrastructure also have the highest electricity usage (Mushtaq et al. 2015).

Owing partly to criticisms from South Australian irrigators who had already substantially modernized infrastructure, some SRWUIP programs are beginning to include alternative ways, other than irrigation infrastructure, to spend on productive on-farm investments (e.g., allowing for diversification of crops, expansion of dormant and currently unproductive land, tree netting) in return for water entitlements.

3.2. Restoring the Balance Program

The most common fear of water markets and programs such as the RTB is that water transfers can impose substantial social and economic spillover costs. These costs include the reduction in local spending, employment, and public services because of a decrease in the water diverted in rural communities. These issues are generally the most pertinent for water entitlement trade (Bjornlund et al. 2011). Nevertheless, not all irrigators sell all of their water entitlements. As of 2012, only 30% of sellers to the RTB program sold all of their water entitlements and left farming. Approximately 60% of irrigators sold some of the water entitlements and kept farming, and 10% sold all of their water entitlements and kept farming by substituting with groundwater, water allocation purchases, or to dryland production (Wheeler & Cheesman 2013).

A beneficial outcome of the sale of water entitlements for environmental purposes is that many irrigators have sold at least some water entitlements to repay debt and interest payments or to reinvest for future farm productivity. Where irrigators held surplus water entitlements, there is not necessarily a corresponding reduction in farm outputs. Indeed, Wheeler & Cheesman (2013) found that, as of 2012, of those who sold permanent water to the RTB program, 75% of the irrigators had surplus water. This study also found that of those who had partially sold water entitlements, only 16% decreased their irrigation area. For those who sold all water and kept farming, 40% reduced their irrigation area.

Other economic studies on the impact of MDB water markets have previously found that water trade increased the regional domestic product by AUD4.3 billion (NWC 2011). Studies that have evaluated reductions in irrigation diversion limits predict relatively small impacts on irrigated production and related employment (e.g., Adamson 2012, Dixon et al. 2011, Grafton & Jiang

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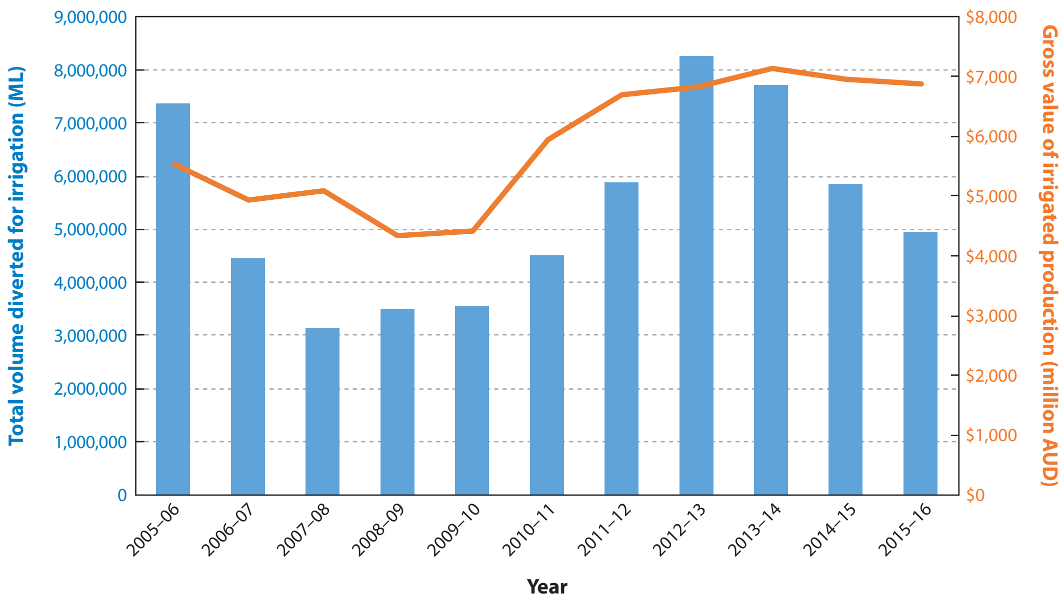

Figure 4

Water-use [in megaliters (ML)] and irrigated production value (in millions of AUD) in the Murray-Darling Basin, Australia, from 2005–2006 to 2015–2016. Data from the Australian Bureau of Statistics (ABS 2016, 2017a,b).

2011, Wittwer 2011). These studies assume that irrigators can adapt and substitute other inputs for water (plus use the water market), helping to maintain production. These modeling results are supported by applied studies (e.g., Wheeler & Cheesman 2013; Wheeler et al. 2014c,d). In particular, Kirby et al. (2014, table 1, p. 157) compared actual farming outcomes in the MDB from 2000–2001 to 2007–2008 and found that the real adjusted gross value of irrigated production fell by just 10%, despite a 70% decline in irrigated surface-water use. All of these empirical studies illustrate that there is no linear relationship between selling irrigation water and decreased agricultural production and/or value. **Figure 4** also illustrates this relationship between water-use and nominal gross values of agricultural production.

A commonly raised concern is that water entitlement trade will result in unused or stranded irrigation assets. In fact, Wheeler & Cheesman (2013) found that 94% of partial entitlement sellers (in an irrigation district) to the RTB program retained their delivery rights, while 83% of those who sold all their water kept their delivery rights. The key point is that irrigators who choose not to terminate delivery rights do so because of they expect to buy either water allocations or water entitlements in the future, or they wish to ensure that their farm can be resold as an irrigation property.

3.3. Water Theft and Compliance

A key consideration of any program intended to increase stream flows through subsidies or via buy-backs is that water allocations assigned to water entitlements are respected such that only those with rights can access the water and divert permitted amounts. In the MDB from 2011–2012 to 2015–2016, the MDBA (2017a) estimated that 64–73% of annual actual consumptive take from surface water was metered. In the sMDB, 77–84% of the surface-water take is metered, whereas in the nMDB, 25–51% of surface-water take is metered.

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Concerns have also been raised about monitoring and compliance with metered take. Recent evidence in NSW shows that, at least in this state, there are serious deficiencies. A September 2017 report commissioned by the state of NSW and authored by Ken Matthews, a former head of the National Water Commission, observed that "The overall standard of NSW compliance and enforcement work has been poor" and that "...water-related compliance and enforcement arrangements in NSW have been ineffectual and require significant and urgent improvement" (Matthews 2017, p. 4). Reform recommendations include greater transparency, more independence, and improved effectiveness of water monitoring and compliance.

These problems were also highlighted by a November 2017 special report to the NSW Parliament by the state's ombudsman (NSW Ombudsm. 2017). This report revealed that there had been three previous ombudsman investigations in 2009, 2012, and 2013. These were not publicly released because of assurances by the relevant department for water regulation that appropriate action would be taken to rectify problems with water diversion monitoring and compliance. The 2017 report highlighted that these assurances were not delivered and that previously identified issues, such as chronic under-resourcing of compliance and enforcement rules, remain.

In addition, a water compliance review by the MDBA was commissioned by the Prime Minister, with a report delivered in November 2017. This review found robust water compliance, regulation, and monitoring in South Australia, the Australian Capital Territory, and Victoria, but that NSW did not have a strong governance culture (especially in regard to unregulated water sources and floodplain history). Queensland also has major weaknesses in its metering, compliance, floodplain take, and monitoring (MDBA 2017b). As a stark example, the review found that in regard to water notices, "in 2016–17, NSW issued 44 warning letters and notices, Queensland 14, SA 355, Victoria 562 and the ACT one" (MDBA 2017b, p. 13). Importantly, in terms of this comparison across states, the number and volume of water rights held in NSW greatly exceed those in SA (Wheeler 2014). In response, on November 26, the South Australian government announced a royal state commission into MDB water theft and other water reform issues.

Without full implementation of all the changes recommended by the MDBA review, Matthews (2017), and the NSW Ombudsman, there is a credible risk that the integrity of water markets and the effectiveness of water recovery will be undermined.

3.4. Costs of Water Recovery

Table 2 shows that, as of September 30, 2017, 1,931 GL of LTAAY water had been recovered by the Australian government for an expenditure of AUD6 billion. This represents two-thirds of the original AUD8.9 billion budget allocated for both the SRWUIP and RTB. The table shows that the cost of water recovery from infrastructure is at least 2.5 times more expensive than purchasing water entitlements from willing sellers under the assumption that there is no change in return flows as irrigation infrastructure is upgraded and irrigation efficiency increases.

Overall, the average cost of water recovery by RTB since 2007–2008 was AUD2,026/ML, while infrastructure cost was AUD4,970/ML. But the costs of water recovery from subsidies from infrastructure could, in fact, be many times more costly per megaliter of water recovered than these figures suggest because of the decline in return flows associated with upgrades in infrastructure. Indeed, depending on the reduction of returns flows with infrastructure subsidies, it is even possible that there has been a net decline in stream flows.

To provide further details about the subsidies to upgrade irrigation, **Table 3** illustrates some key examples of irrigation infrastructure costs and water recoveries by individual projects across the MDB. It is important to note that these costs per megaliter do not account for changes in return flows, groundwater substituted for surface flows, increases in irrigated land, or use of any

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Table 2 Australian government yearly actual administrated expenditure and water recovery listed by program, to September 30, 2017, expressed in long-term average annual yield

Periodw	RTB (AUD million)	Infrastructure (AUD million)	RTB (GL)	Infrastructure (GL)	RTB AUD/ ML	Infrastructure AUD/ML
2007–08	33.1	86.0	14	0	2,299	NA
2008–09	371.7	55.8	243	0	1,533	NA
2009–10	780.2	189.1	311	1	2,511	233,457
2010–11	357.7	221.2	201	66	1,776	3,327
2011–12	540.9	528.6	311	208	1,740	2,547
2012–13	112.9	520.5	56	78	2,012	6,707
2013–14	55.9	492.4	21	233	2,607	2,116
2014–15	60.8	557.1	5	29	12,383	19,344
2015–16	40.0	262.6	9	28	4,689	9,416
2016–17	23.7	522.5	34	58	700	9,012
2017–18 (up to 09/30/17)	116.9	42.8	26	0	4,453	NA
Total	**2,494**	**3,479**	**1,231**	**699.9**	**2,026**	**4,970**

Created from data provided by the Australian Department of Agriculture and Water Resources. Abbreviations: GL, gigaliter; ML, megaliter; RTB, Restoring the Balance (program).

surplus water that had not been previously used that may have been previously available as stream or environmental flows. Importantly, the figures in **Table 3** highlight the very large variation by project of estimated costs of water recovery.

4. EFFECTS OF WATER RECOVERY

The key issue of water recovery is whether it achieves the stated intents of the Water Act 2007, namely, to ensure the return to environmentally sustainable levels of water extraction [object 3d(i)] and to protect, restore, and provide for MDB ecological values and ecosystem services [object 3d(ii)]. Although the full effects of water recovery should not be expected until the water recovery is complete, with approximately two-thirds of the allocated expenditure already spent and the nominal water recovery target 70% (77% with previous state purchases) currently achieved, some beneficial impacts on a basin-level scale should, nevertheless, already be observable by 2018.

The challenge with observing environmental effects is that there may be lags between increases in stream flows and improved environmental outcomes. Further, the high variability of basin inflows means that the state of the environment can improve or decline independent of water recovery programs. Obtaining consistent and historical data sets to analyze trends is also very difficult. Notwithstanding these caveats, it is instructive to review some of the environmental evidence and the effect of water recovery on actual diversions and end-of-system flows.

4.1. Water Recovery and Water Diversions

Figure 5 plots irrigation surface-water diversions against overall water recovered and storage volumes in the sMDB, alongside South Australian barrage flows at the Murray Mouth for the period 1997–1998 to 2016–2017. The annual water recovered starts from essentially zero in 2007, and for each state, peaked in either 2011–2012 or 2012–2013 (with the cumulative amount increasing annually). Basin-wide water recovery has plateaued since 2013–2014 and has only marginally increased since this date. Irrigation surface-water diversions are highly variable and

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Table 3 Infrastructure projects, budgets, and water recovery in Australia by project

Infrastructure programs	Period	Budget (AUD million)	Water recovered (forecast; GL)	AUD/ML
Healthy Waterways (ACT)	2014–19	85	NA (water quality)	NA
Goulburn-Murray Water Connections Stage 2 (formerly Irrigation Renewal)	2009–20	956	102	9,373
NVIRP 2–On-Farm (VIC)	2012–14	43	10	4,300
Sunraysia Modernisation Project (VIC)	2013–17	103	7	14,714
Irrigation Farm Modernisation (NSW)	2012–19	85	12	7,083
Healthy Floodplains (NSW)	2012–18	50	NA (flow reconfiguration)	NA
Metering Scheme Project (pilot) (NSW)	2010–11	22	7.4	2,977
Metering Scheme Project (excludes pilot) (NSW)	2010–17	199	28	7,107
Basin Pipes Project (NSW)	2015–18	137	30	4,567
Nimmie-Caira System Enhanced Environmental Water Delivery Project (NSW)	2013–19	180.1	133	1,354
Private Irrigation Infrastructure Operators Program (NSW)	2010–19	956	113	8,460
Healthy HeadWaters Water Use Efficiency (QLD)	2009–20	155	7	22,143
Private Irrigation Infrastructure Program (SA)	2010–17	14	3.9	3,590
Coorong, Lower Lakes, and Murray Mouth Recovery (SA)	2009–19	160	NA (works and measures)	NA
Riverine Recovery (SA)	2009–19	89	13	6,846
Flows for the Future (SA)	2017–19	12	NA (flows and measures)	NA
Integrated Pipelines (SA)	2009–10	117	NA (works and measures)	NA
On-Farm Irrigation Efficiency (sMDB)	2009–19	559	83 (2014)	6,735
Victorian Farm Modernisation Project	2013–19	100	30 (2014)	3,333
Irrigator-led group proposals (decommissioning) (VIC)	2011–13	0.03	NA	NA
Menindee Lakes (NSW)	2008–24	181	NA (reducing evaporation)	NA
Irrigated Farm Modernization Border Rivers-Gwydir Pilot Project (NSW)	2010–11	7	0.5	14,000
SA River Murray Sustainability	2013–18	120	16.8	7,143
SA Riverland Floodplain Integrated Infrastructure	2015–20	155	NA (works and measures)	NA
Wimmera-Mallee Pipeline (VIC)	2007–09	98	10.3	9,515

Abbreviations: ACT, Australian Capital Territory; GL, gigaliter; MDB, Murray-Darling Basin; ML, megaliter; NA, not applicable; NSW, New South Wales; QLD, Queensland; SA, South Australia; sMDB, southern MDB; VIC, Victoria.

declined precipitously during the worst years of the Millennium Drought, but they subsequently increased with large inflows over the period 2010–2011 to 2013–2014.

The high variability of the diversions makes it difficult to identify any meaningful relationship between basin-wide water diversions and water recovery. Nevertheless, for the sMDB as a whole, some very simple analysis highlights that the two series are negatively correlated ($r = -0.27$) over the period 1997–1998 to 2016–2017, as would be expected (i.e., in general we should expect

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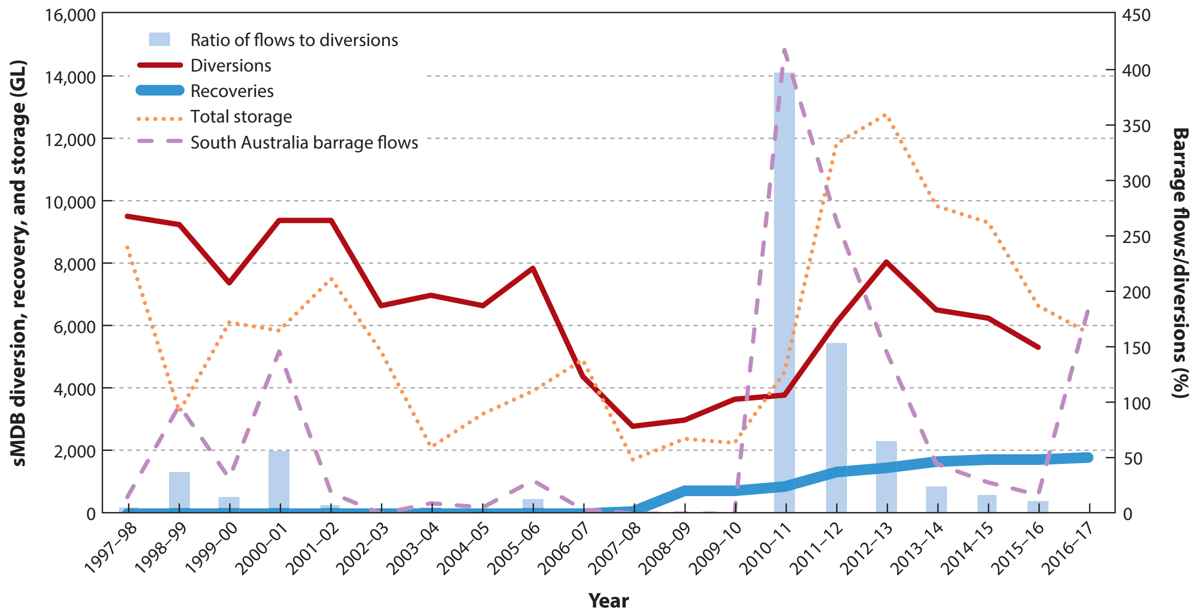

Figure 5

Surface-water diversion, recovery, storage, and South Australia barrage flows [in gigaliters (GL)] from 1997–1998 to 2016–2017 in the southern Murray-Darling Basin (sMDB), Australia. Based on various data provided by the Commonwealth Department of Agriculture and Water Resources (recovery data); Commonwealth Bureau of Meteorology (southern Murray-Darling Basin storage volumes for nine main key storages); South Australian Department of Environment, Water and Natural Resources (South Australia barrage flows; South Australia environmental flow releases); Murray-Darling Basin Authority Water Audit Monitoring reports (southern Murray-Darling Basin diversions; only currently available up to 2015–2016).

diversions from the basin to go down while environmental water recovery goes up). However, they are positively correlated ($r = 0.75$) over the period 2007–2008 to 2015–2016 that coincides with the implementation of the WFF. Obviously, the situation is complicated, given the impact of drought, carryover, and water allocations on diversions over time.

4.2. Environmental Outcomes

Although many factors influence the quality of MDB environmental outcomes, stream flows are a key driver (Williams 2017), and altered flow regimes do produce ecological responses (Bunn et al. 2014). The basin is subject to periodic flooding and drought, but the Millennium Drought saw widespread environmental degradation in the form of high levels of acidity, reduced waterbird breeding events, declines in native fish populations, and widespread tree die-off.

The latest State of the Environment Report published in 2017 provides a series of assessment trends of inland water flows and levels (Argent 2017). The report provides a "poor" assessment grade of inland water flows and levels for the MDB and "longer-term downwards trends in flows seen in nearly 50% of stations, with no change in trends evident since 2011" (Argent 2017, p. 36). Inland water ecological processes and key species populations received a "very poor" assessment grade with a deteriorating trend and "widespread loss of ecosystem function" (Argent 2017, p. 56). By contrast, while the assessment of water quality concerns is very poor, there is an improving trend.

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The Wentworth Group of Concerned Scientists (Wentworth Group 2017) suggested that additional environmental flows delivered under the Basin Plan have contributed to measured improvements in water quality, salinity, and fish in areas that have received environmental watering (e.g., some Ramsar wetlands). Nevertheless, they also found no evidence to date demonstrating basin-wide improvements or that the long-term deterioration in key river condition indicators (e.g., waterbirds and ecological processes) has stopped. Further, they noted that even if the Basin Plan's 3,200 GL/year target reductions (or equivalent) in surface-water diversions were to be delivered in full, it would not ensure an open Murray Mouth, without dredging, in 95% of years.

In summary, as of early 2018, there has been no observable basin-wide improvement in either water flows or inland ecological systems and populations. Indeed, an examination of the simple correlation between flows through the South Australian barrages (a key indicator of the overall health of the MDB) and recovered water in the sMDB from 2007–2008 to 2016–2017 indicates no observable relationship ($r = 0.10$ for the correlation coefficient). Further, the simple relationship between South Australian environmental flow releases and barrage flows gives a correlation of only $r = 0.06$. This finding is of considerable concern because it suggests that the current Basin Plan will fail to deliver adequate flows at the Murray Mouth in periods of drought. Our analysis of water recovery and flows at the Murray Mouth is further supported by the high correlation ($r = 0.84$) between barrage flows and previous year sMDB storage levels, where storage levels are driven primarily by rainfall in the MDB. There is an urgent need for future multidisciplinary modeling work in this area to more fully understand the relationships between water recovery and environmental outcomes.

5. DISCUSSION AND CONCLUSIONS

The MDB water recovery experiment is now a decade old, whereas the Basin Plan intended to ensure sustainable water extraction has been in place for more than five years. With total expenditures to date of AUD6 billion, a halt on buy-back, and 70% (or 77% with previous state purchases) of the total nominal water (as defined by water entitlements) already acquired, there is much that can be learned about water governance in the MDB itself, as well as in other locations.

The first key lesson of the MDB water recovery experiment draws insights from a comparison of buy-backs of water entitlements from willing sellers to subsidies intended to save water and increase irrigation efficiency. Based on nominal costs of recovering water for the environment, subsidies are at least 2.5 times more expensive than buy-backs. Thus, a market-based approach to water recovery is a much cheaper option than subsidy and infrastructure alternatives. A possible reason for this paradox of spending twice as much public funds on subsidies than on buy-backs is institutional path dependence, which also exists in other countries than Australia (Huppert 2013). Such dependence includes informal alliances between politicians, bureaucracies, and irrigator-sector organizations that collaborate to prevent reform that is perceived to be contrary to the interests of irrigators and to maximize irrigation-sector benefits (Marshall & Alexandra 2016). Other research (e.g., Wheeler et al. 2015) also shows no relationship between irrigation infrastructure adoption and overall farm water use. It argues that irrigation policy in Australia in general should be reoriented away from infrastructure spending toward more multilayered and inclusive practices that promote better soil conditions, land coverage, and water management.

Notwithstanding the cost-effectiveness of buy-backs, other jurisdictions that do not have well-developed water rights (Wheeler et al. 2017) will not necessarily be able to fully apply the market-based option, as undertaken in the MDB. Aside from regulation, other market options could involve the use of water funds that would compensate water users for extracting less water if there are no formal existing water rights. In the case of the MDB, there are also other

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market-based options that can be tested. For instance, the Environmental Water Trading Framework developed by the CEWH allows the purchase, sale, carryover, or use of water allocations from environmental entitlements subject to trade conditions in the Water Act 2007. This could allow for trade mechanisms other than the direct purchase of water entitlements in buy-backs, such as leasing and forward contracts of water allocations. The use of water donations or water funds from individuals, trusts, communities, and NGOs (Wheeler et al. 2013, 2014b) to acquire water entitlements also provides another means to increase stream flows, especially in support of local environmental objectives.

A second key lesson is the importance of strong governance and institutions. The market option for water recovery, and indeed the very basis for a water market, is that water rights are exclusive and there is effective monitoring and compliance. Evidence from NSW shows that such monitoring and compliance have, to date, been grossly deficient. There are also findings that much better compliance and monitoring in Queensland are required. Indeed, a reduction in the proportion of unmetered water take in the MDB, especially in the northern part of the basin, would be a starting point for state water reform. Importantly, increasing the reliability and monitoring of current metering must be a priority. In other words, there can be no "set and forget" approach or complacency in monitoring and compliance of water diversions if water markets are to deliver improved outcomes for water users and water recovery.

A related point to the compliance challenge is the need for institutions to develop robust environmental water accounting. Much information on water use, diversions, return flows, storage, carryover, and other important factors is not available publicly, or available at all, and key data sources (such as on water recovery) sometimes provide contradictory information.

A third key lesson is that any large-scale public government program (such as the irrigation subsidy scheme) needs evaluation and assessment, with robust data collection procedures in place. This includes the scientific and economic measurement of all potential negative externalities, such as the measurement of return flows at both catchment and basin scales. The importance of measuring both diversions and return flows was identified as early as 1964 by the US Supreme Court in its decree regarding the consumptive use of water from the Lower Colorado River. This decree stipulated that the United States shall keep complete, detailed, and accurate records of diversions of water from the mainstream return flow of such water and consumptive use of such water (Leake 1984, p. 1).

Yet in 2017, and despite spending some AUD4 billion on irrigation upgrades and subsidies, the Australian government still does not measure return flows that include both point and nonpoint flows to surface and groundwater. Current (and historical) data availability (and consistency) on information such as MDB dam storage levels, barrage flows, salinity loads, and environmental releases, among other data, can also be very difficult, if not impossible, to obtain. As a result, the consequences on stream flows of irrigation upgrades that reduce return flows cannot be accurately determined. Importantly, if return flows represent half or more of the water saved, then subsidies to increase irrigation efficiency will actually reduce stream flows, which is contrary to the key objects of the Water Act 2007. A key lesson, therefore, is the critical importance of environmental data accounting and of measuring both diversions and return flows, especially when the stated intent of such expenditures is to generate public benefits.

A fourth important lesson is the need for water values to ensure that water is sustainably managed (Garrick et al. 2017) and allocated to its highest value in use (including nonuse). Transparent values across competing uses and users provide the basis for sustainable water reallocation to maximize the societal benefits of water. In part, contested values and inadequate measures of nonconsumptive water values have made broad public acceptance of water reform and recovery more difficult. Such values need to be measured. Indeed, the next paradigm shift

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in water management in Australia will be to lawfully recognize the importance of stream flows for First Peoples in the MDB. In contrast to Australia, in the Columbia River Basin in the northwestern United States, such flows are an integral part of environmental water management through formal treaties and legislation (Cosens 2003). Increasing the water allocated to First Peoples could also play an important role in helping to achieve a sustainable basin (Taylor et al. 2017). Such reallocation, however, requires effective mechanisms and bodies to work with First Peoples and to fund changes in water entitlements.

The fifth and final key lesson builds on the governance point from lesson two. There is a critical need for an independent body or agency to provide the evidence and advice to deliver water policy and reform in the public interest. Previously, Australia had the National Water Commission, from 2004 to 2014, that supported water reform, but it no longer exists. A properly funded expert and independent body could have provided the ongoing measurements of return flows, highlighted the inadequate monitoring and compliance of water diversions, coordinated and facilitated monitoring and public data collection, and also evaluated water values across competing uses. Such an expert body may also have made transparent the perversity of spending billions of dollars on irrigation infrastructure that may even run counter to the objects of the Water Act 2007 when an alternative, in the form of voluntary buy-backs of water entitlements, exists and is much more cost-effective.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

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