

The background of the top section features a large, semi-transparent watermark of the word "AITHER" in a bold, sans-serif font, overlaid on a geometric pattern of overlapping triangles in various shades of blue and teal.

Water market drivers in the southern MDB: Implications for the dairy industry

Report prepared for Dairy Australia

Friday 29 July 2016

A I T H E R

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Abbreviations

GL	Gigalitre (one billion litres)
LTAAY	Long Term Average Annual Yield
ML	Megalitre (one million litres)
NRM	Natural Resource Management
sMDB	Southern Murray-Darling Basin

Glossary

Allocation	A water allocation (temporary water) is a right to a physical volume of water
Entitlement	A water entitlement (permanent water) is an ongoing right to receive a share of available water, as water allocations, in any given season

Executive summary

Dairy Australia engaged Aither to assess the implications of contemporary water market drivers on water allocation prices and aggregate water use in the dairy industry.

This report builds on previous work undertaken by Aither that analysed the allocation market in the southern Murray-Darling Basin (sMDB) and focused on:

- the historical and future effects of reductions in water available for consumptive use as a result of the volume of water entitlements purchased for environmental uses by the Commonwealth
- the future effects of changes in water demand by agricultural industries.

These reports paint an increasingly complete picture of the drivers of allocation prices in the sMDB and future trends under different scenarios, but they analyse these drivers in isolation. This gap is addressed in the current report, which examines the overall effects of Commonwealth environmental water purchases and changes in demand by irrigation industries and urban water authorities, allowing for the possibility that the combined effects are larger than the sum of individual effects. This report also compares the market impacts of two alternative water recovery mechanisms: Commonwealth environmental water purchases and on-farm infrastructure upgrades.

The study aims to inform the dairy industry, including dairy farmers, suppliers and processors, who are undertaking operational and investment decisions that depend on water markets, either directly or indirectly. The study could also inform government policy, and is particularly relevant to the implementation of the Basin Plan and the modernisation of the Goulburn Murray Irrigation District.

Methodology

Aither's water allocation price models were used to simulate the effects of different water demand scenarios under different water allocation scenarios.

The demand scenarios capture different sources of changes in demand for allocations – Commonwealth environmental water purchases and other sources (irrigation industries and urban water authorities) – both in isolation and combined. The demand scenarios look back at changes over the last ten years and look towards changes that could occur over the next five years.

The water allocation scenarios were developed based on recent seasons:

- low allocation season – similar to 2015-16 (around 4200 GL allocated to entitlements in the sMDB)
- moderate allocation season – similar to 2014-15 (around 5200 GL allocated)
- high allocation season – similar to 2011-12 (around 6900 GL allocated).

The analysis was also extended to include an extremely low allocation season - similar to 2008-09 (around 1900 GL allocated).

Market price impacts

The overall supply of water is highly variable from season to season and explains most of the short-run variation in water allocation prices. This is evident over the last five years, with drying conditions

the primary driver of increasing water allocation prices (Aither 2016a). However, a range of other drivers also have a significant longer-term impact on water markets. These include Commonwealth environmental water purchases, and the expansion of irrigation industries such as cotton and nuts.

The key findings are as follows:

- The Commonwealth has purchased around 845 GL of entitlements in the sMDB so far through tenders, expressed in Long Term Average Annual Yield (LTAAY).¹ For the 2014-15 water year, these purchases led to the Commonwealth Government receiving 15 per cent of total water allocated to all entitlements in the major trading zones of the sMDB.
- Water allocation prices could now be 13 to 36 per cent higher in a moderate allocation season than they would otherwise have been without Commonwealth environmental water purchases (when the price would be \$101 per ML). The range reflects the estimates generated using different models, and is consistent with the results of previous analysis (Aither 2016a).
 - Further environmental water purchases of 200 GL LTAAY are estimated to increase allocation prices by around 3 per cent in moderate allocation seasons, with the effect increasing with the volume purchased.
- Other environmental water recovery mechanisms can also affect allocation prices. While the available evidence base is limited, it is plausible that the price impacts of additional on-farm efficiency programs could be as large as, or larger than, equivalent Commonwealth environmental water purchases. This is influenced by the requirement for farmers to transfer some of their entitlements to the Commonwealth in return for funding and is an area for further research.
- Outside extremely low water allocation seasons, irrigation industries and urban water authorities have not been large aggregate drivers of sMDB water allocation prices over the last decade. This is because the growth in demand for allocations in some industries (such as nuts and cotton) has tended to be offset by the contraction of other industries (such as rice and dairy).
 - This could change in the future, depending on the extent to which projected expansions in nuts and cotton are realised. This is especially relevant in extremely low allocation seasons, when increased demand by urban water authorities and the nut industry could interact with future environmental water purchases to further increase already high allocation prices.
 - On the other hand, further contraction in the wine grape sector and potential adjustment in the dairy industry associated with the recent milk price collapse could result in decreased demand in these industries, which could offset increases in demand by cotton and nuts industries.
- The combined effects of Commonwealth environmental water purchases and net increases in demand by irrigation industries and urban water authorities mean that water markets in the sMDB could appear quite different in 2020-21, compared with 2005-06. Water allocation prices are estimated to increase from \$101 per ML in 2005-06 to \$131 per ML in 2020-21 (30 per cent) in moderate allocation seasons.
 - The equivalent estimate for extremely low allocation seasons is an increase from \$453 to \$702 per ML (55 per cent), although there is greater uncertainty around this estimate. This is consistent with anecdotal evidence that demand for water allocations is firming (becoming less responsive to price) (Aither 2016b).

¹ This figure, and the modelling undertaken in this report, does not include an additional 110 GL of purchases through other mechanisms, including water purchased through irrigator-led group proposals and water purchased through the Victorian Government associated with the Goulburn-Murray Water Connections Program.

Implications of environmental water recovery

With an additional 200 GL LTAAY of water purchases for the environment on top of the volume already purchased, the allocations to entitlements acquired by the Commonwealth would exceed water use by all major irrigation industries in the sMDB other than livestock (including dairy). The reallocation of water to environmental uses has benefits and costs, and it is important for good public policy to be clear about both so that informed decisions can be made.

In total, allocations to entitlements acquired through the buyback so far would have generated approximately \$440 million in net returns if used in agriculture between 2008-09 and 2015-16. The annual opportunity cost in 2015-16 was estimated at \$130 million. The opportunity cost should be considered explicitly in determining the extent of further water recovery through environmental water purchases. The principle of weighing the benefits and costs also applies to other water recovery mechanisms, such as on farm efficiency programs.

Implications for the dairy industry

At the farm level, higher water allocation prices would accentuate the pressures already confronting dairy farmers. Individual dairy farms will be affected differently based on the numerous factors including their holdings of water entitlements. For example, a dairy farmer with a substantial portfolio of entitlements could benefit from higher water allocation prices in some seasons (as they could receive more from selling allocations), whereas a similar farmer without entitlements could be exposed to substantial financial losses, particularly in extremely low water allocation seasons.

As allocation prices increase, dairy farmers will seek further opportunities to reduce water use by adjusting their production systems. Water use is estimated to be substantially lower in the dairy industry in 2020-21 compared to 2005-06, partly as a result of higher water allocation prices, and partly as a result of falling dairy demand for water. Water use by livestock industries (including dairy) is estimated to fall from around 2280 GL in 2005-06 to 1270 GL in 2020-21 (44 per cent) in moderate allocation seasons, although most of this change has already occurred. There is greater uncertainty regarding the impacts in extremely low allocation seasons. Water use by livestock industries (including dairy) is estimated to fall from around 790 GL in 2005-06 to 330 GL in 2020-21 (58 per cent) in extremely low allocation seasons. These estimates do not account for the recent fall in milk prices received by dairy farmers.

Even small changes in the prices of important inputs, such as water, can result in significant changes in profitability and production. The farm-level changes in profitability and production in response to the changes in water allocation prices outlined in this report are an area for further research. There would also be value in considering the effects of changes in water allocation prices alongside other key factors that influence dairy farmers, such as changes in milk prices and feed prices.

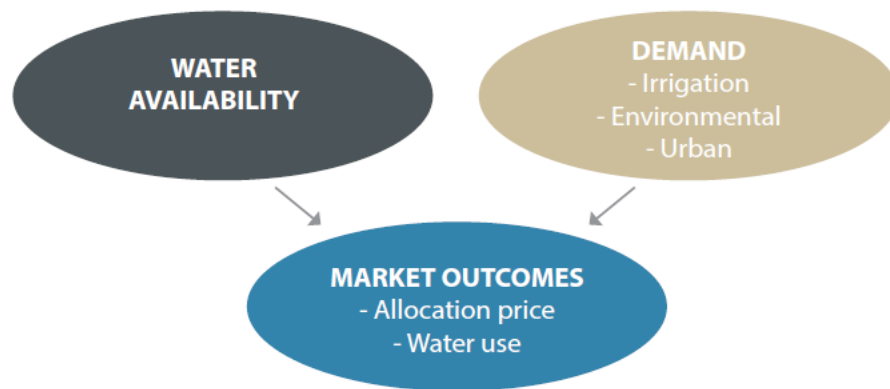
The estimated water market impacts have broader implications for the dairy industry. In particular, milk production in the sMDB is unlikely to recover to pre-millennium drought levels given predicted water allocation prices unless there are offsetting improvements in milk prices, other input prices or production technologies.

The recent fall in milk prices announced by Murray Goulburn and Fonterra highlights the potential for these other factors to exacerbate rather than moderate the effects of higher water allocation prices. There are also consequences for processors if milk production does not recover. In particular, processors require a sufficient and consistent supply of milk to remain profitable. Assessing the magnitude of this risk requires a detailed knowledge of the cost structure of processing operations and is an area for further research.

More generally, there is also the potential for changes in the dairy industry to have impacts on broader socio-economic effects on regional communities, especially in the Goulburn Broken and North Central regions in northern Victoria where dairy is a major industry in the regional economy.

WATER MARKET DRIVERS IN THE SOUTHERN MDB: IMPLICATIONS FOR THE DAIRY INDUSTRY

Water prices and availability are becoming more volatile. Drivers include a drying climate, environmental allocations, and changing demand among different sectors. Dairy Australia engaged Aither to explore the effects of these drivers on water allocation (temporary) prices, and water use by the dairy industry.



Changes in water availability and demand (including the Commonwealth environmental share of annual allocations) have large impacts on allocation prices.

Estimated southern MDB water allocation prices under different underlying water availability and demand scenarios (\$/ML)			
	2005-06 demand	2015-16 demand	2020-21 demand
Extremely low allocation season (2008-09 water availability)	453	603	702
Low allocation season (2015-16 water availability)	172	207	231
Moderate allocation season (2014-15 water availability)	101	118	131
High allocation season (2011-12 water availability)	32	37	41

Note: As an example, the first cell of the table can be interpreted as follows. If water availability conditions were similar to 2008-09 and demand conditions were similar to 2005-06, the estimated allocation price would be \$453 per ML. Reading across rows shows the impacts of demand changes over time (including environmental demand) at different levels of water availability.

Changes in allocation prices and irrigation demand have significant implications for water use in the dairy industry.

Estimated surface water use by the southern MDB dairy (and other livestock) industry under different underlying water availability and demand scenarios (GL)			
	2005-06 demand	2015-16 demand	2020-21 demand
Extremely low allocation season (2008-09 water availability)	793	406	331
Low allocation season (2015-16 water availability)	1938	1190	1023
Moderate allocation season (2014-15 water availability)	2277	1450	1267
High allocation season (2011-12 water availability)	2950	1939	1715

Volume of Commonwealth purchases: The Commonwealth has purchased around 845 GL of entitlements through tenders in the sMDB so far, expressed in Long Term Average Annual Yield (LTAAY). For the 2014-15 water year, these purchases led to the Commonwealth Government receiving 15 per cent of total water allocated to all entitlements in the major trading zones of the sMDB.

Allocation price effects of Commonwealth purchases: Isolating the effects of these purchases, allocation prices could be 13 to 36 per cent higher in a moderate allocation season such as 2014-15, than they would otherwise have been. Further environmental water purchases of 200 GL LTAAY are estimated to increase allocation prices by around 3 per cent in moderate allocation seasons, with the effect increasing with the volume purchased.

Opportunity cost of Commonwealth purchases: Allocations to entitlements acquired through Commonwealth environmental water purchases would have generated approximately \$440 million in net returns if used in agriculture between 2008-09 and 2015-16.

Policy implications: The reallocation of water to environmental uses has benefits and costs. It is important for good public policy to be clear about both so that informed decisions can be made. This also applies to other water recovery mechanisms.

Allocation price effects of on-farm water use efficiency programs: The price impacts of additional on-farm water use efficiency programs could be as large as, or larger than, equivalent Commonwealth environmental water purchases.

1. Introduction

1.1. Overview

Dairy Australia engaged Aither to assess the implications of contemporary water market drivers on water allocation prices and aggregate water use in the dairy industry. This report considers changes in water allocation prices and water use that have occurred over the last ten years, and projections for the next five years.

Aither has previously reported on:

- the historical and future effects of reductions in water available for consumptive use as a result of purchases of water entitlements for the environment by the Commonwealth (Aither 2016a)
- the future effects of changes in water demand by agricultural industries (Aither 2016b).

For the first time, this report examines the combined effects on the dairy industry of supply and demand drivers in the water market, recognising that they do not operate in isolation. It further extends Aither's previous analysis by considering the effects of changes in water demand by urban water authorities.

The study aims to inform the dairy industry, including dairy farmers, suppliers and processors, who are undertaking operational and investment decisions that depend on water markets, either directly or indirectly. The study could also inform government policy, particularly around the implementation of the Basin Plan and the modernisation of the Goulburn Murray Irrigation District.

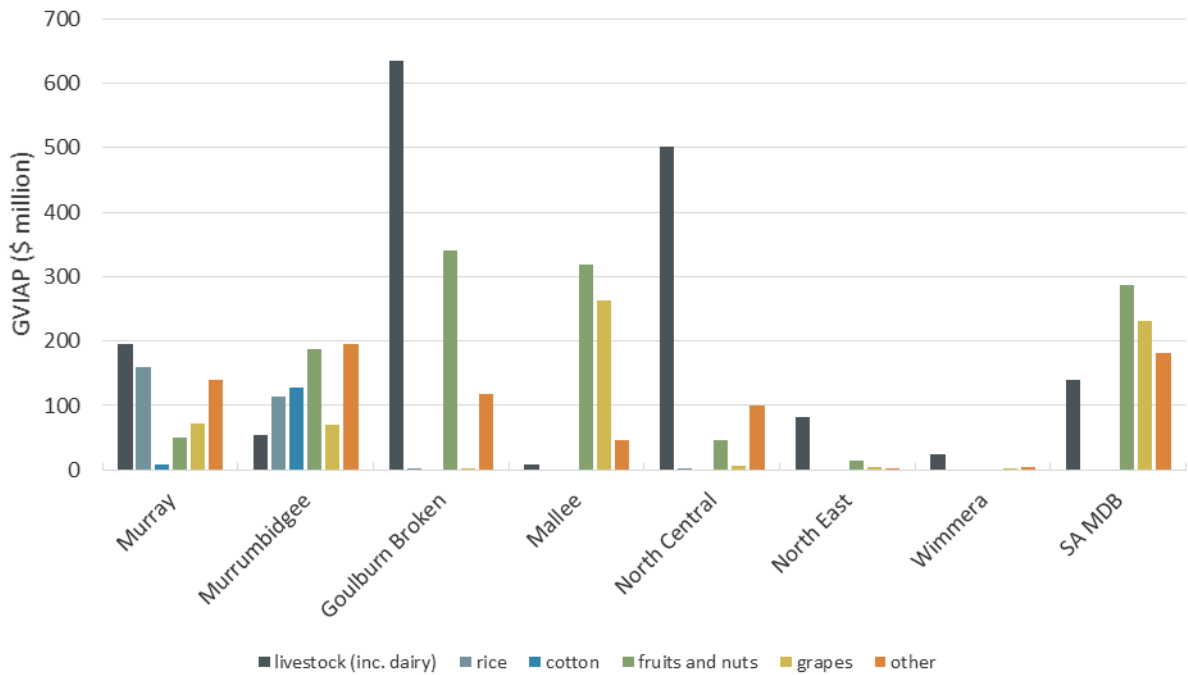
1.2. Background and motivation for the study

1.2.1. Dairy production in the sMDB

The dairy industry is one of the largest irrigation industries in the southern Murray-Darling Basin (sMDB), with a farmgate value of production of around \$1.2 billion from 1700 farms (UDV 2016). The main dairy areas in the sMDB are the North Central and Goulburn Broken regions of northern Victoria (Figure 1 and Figure 2). In these regions, dairy is the dominant irrigated agricultural industry. There is also a significant dairy production in the Murray region of southern New South Wales.

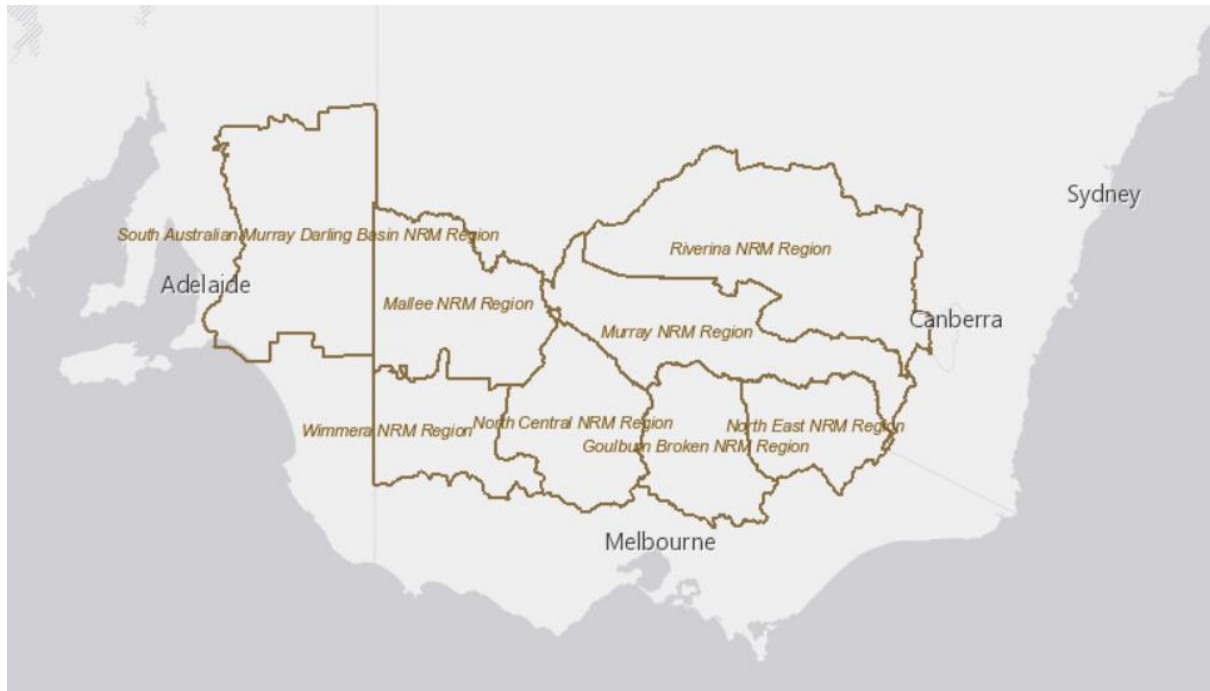
Box 1: An important note on the data used in this report

Much of the analysis in this report is drawn on ABS data. This has two important implications. First, the geographical analysis is based on the Natural Resource Management regions instead of Dairy Australia regions. For context, the Murray Dairy Australia region spans the Goulburn Broken, North Central, North East and Murray NRM regions. Second, dairy is aggregated with other irrigated livestock activities. This is reflected in this report by the term 'livestock (including dairy)'. Dairy accounts for the vast majority of irrigated livestock activities in the sMDB, but precise estimates of the share of dairy are unavailable.



Source: Aither irrigated agriculture database, based on ABS and ABARES data.

Figure 1 Gross value of irrigated agricultural production by activity and NRM region in the sMDB, 2013-14



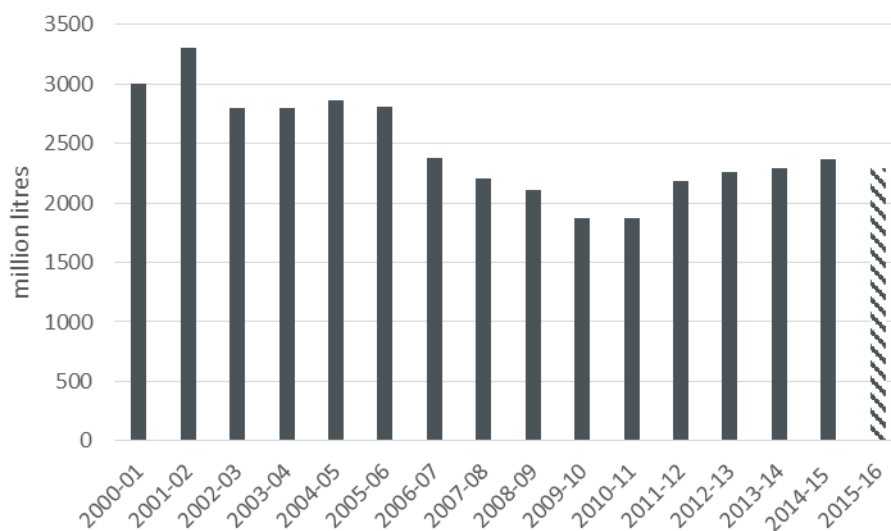
Source: ArcGIS and ABS data.

Figure 2 Map of NRM regions in the sMDB

There has been a downward trend in milk production over the last 16 years in the sMDB (Figure 3). Prior to the worst years of the millennium drought, the Goulburn Broken, North Central, North East and Murray regions produced around 2800 million litres per year. Annual milk production fell to around 1800 million litres at the end of the drought before recovering gradually to around 2300 million litres in the last few years. This raises a number of questions:

- Will milk production recover to pre-drought levels?
- Are current levels of milk production the new norm?
- Will the long term decline in milk production continue?

The answers to these questions depend on what happens to input prices, output prices and production technology (which converts inputs into outputs). Although this report focuses on changes in water prices, it is recognised that water markets are just one determinant of production and profitability in the dairy industry (Box 2).



Notes: Estimates for 2015-16 are preliminary.
 Source: Dairy Australia.

Figure 3 Total milk production in the Goulburn Broken, North Central, North East and Murray regions, 2013-14

Box 2: Other determinants of production and profitability in the dairy industry

Production and profitability in the dairy industry has a number of determinants beyond water prices. Milk prices are the major determinant, with a strong positive association between milk prices and profitability that persists even after statistically controlling for other factors (Aither 2016b). In April 2016, Murray Goulburn announced that it would reduce milk prices paid to farmers from \$5.60 to between \$4.75 and \$5.00 per kilogram milk solids for 2015-16 (Murray Goulburn 2016). Fonterra also cut its milk prices the following month (ABC 2016b). In June, Murray Goulburn announced an opening milk price for 2016-17 of \$4.31 per kilogram milk solids; Fonterra's opening price was \$4.75. As well as reducing profitability, this will lessen incentives for production.

Feed prices are another important determinant. Purchased feed is a substitute for home grown feed produced with irrigation water. This substitution was evident in 2007-08 and 2008-09 when an increase in purchased feed allowed milk production to be largely maintained despite a decrease in the volume of irrigation water applied. Milk prices and feed prices are also important in understanding the demand for irrigation water by the dairy industry, with higher milk prices and feed prices increasing demand. These issues are discussed in more detail in Aither (2016b).

1.2.2. Water markets and the dairy industry

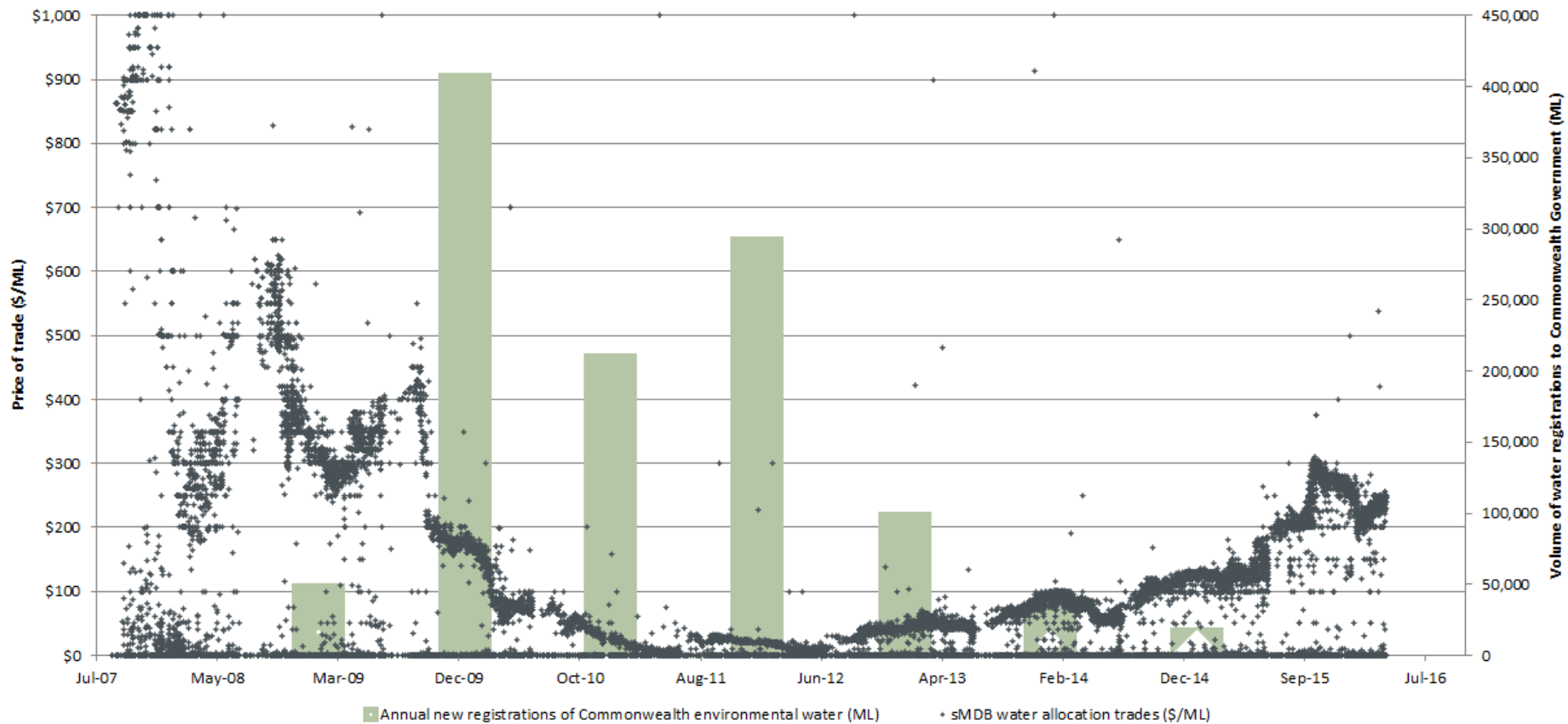
Irrigation water is a major input to dairy production in the sMDB, where most dairy farmers irrigate pastures or cereal crops. Some have access to both surface and groundwater. Pumping groundwater can be expensive, meaning many farmers will only substitute towards groundwater when surface water allocation prices are relatively high (Aither 2016b). This report only considers surface water.

There are two main types of water rights – water allocations (temporary water) and water entitlements (permanent water). Water allocations are rights to a physical volume of water. Water entitlements are ongoing rights to receive a share of available water, as water allocations, in any given season. In 2003-04, dairy farmers in the Goulburn Murray Irrigation District held an estimated 710 gigalitres (GL) of high reliability entitlements. This had fallen to around 470 GL by 2012-13 (Dairy Australia 2016). This coincided with around 415 GL of Victorian high reliability entitlements being acquired by the Commonwealth through environmental water purchases (Aither 2016a). It is likely that many of the entitlements sold by dairy farmers over this period were eventually acquired by the Commonwealth.

Some dairy farmers who sold entitlements left the industry, while others remained in the industry and became more reliant on the allocation market as a source of irrigation water. The sale of entitlements during the first few years of the buyback was an effective short run strategy (when evaluated after the fact) for many dairy farmers who remained in the industry. These dairy farmers were able to use the proceeds from the sale of entitlements to reduce debt or make investments. While they then became more reliant on the allocation market, purchasing water on the allocation market was initially inexpensive. After the millennium drought broke, allocation prices remained below \$100 per megalitre (ML) between 2010-11 and 2013-14 (Figure 4).

However, the sale of entitlements tended to expose these dairy farmers to greater risk to rising water allocation prices, given the greater reliance on purchasing allocations to meet irrigation demand. This has been evident with the return of higher allocation prices in 2014-15 and 2015-16. In years when allocation prices are high, dairy farmers who sold their entitlements will generally be less profitable than if they had retained their entitlements, and may experience greater cash flow problems.²

² This is because when allocation prices are high, the value of allocations to higher reliability entitlements, either in agricultural production or sold on the market, tends to exceed the annualised cost of owning higher reliability entitlements.



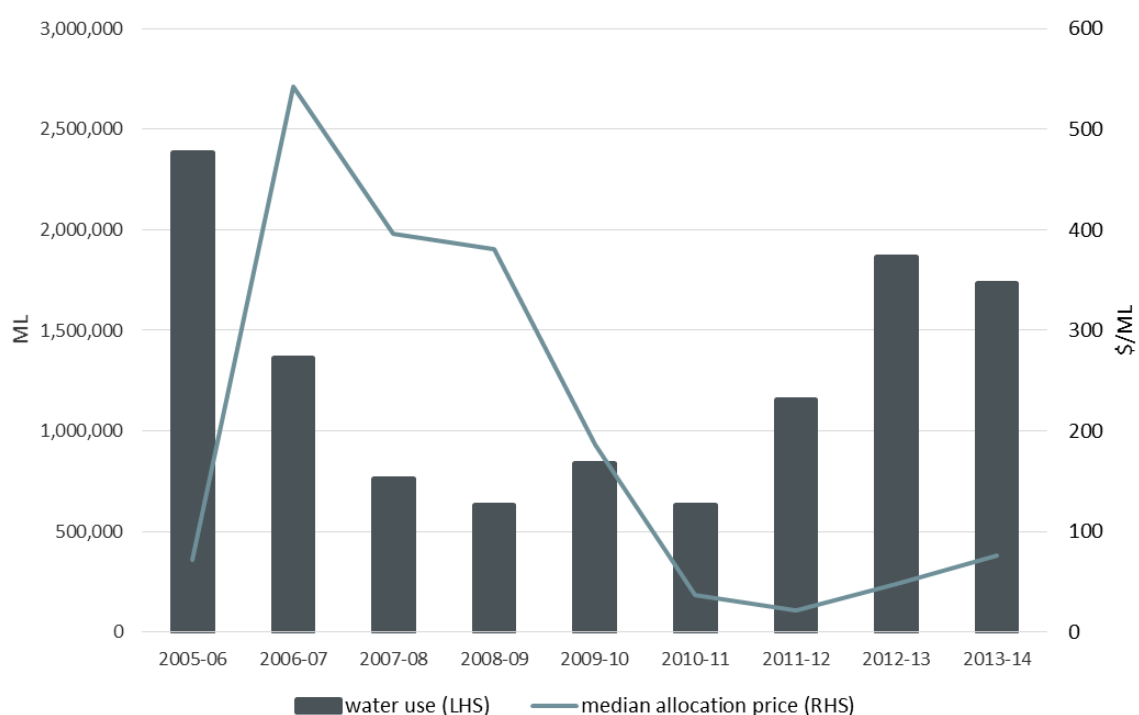
Source: Aither water markets database.

Figure 4 Commonwealth environmental water purchases and prices of allocation trades in the Greater Goulburn, August 2007 to March 2016

The allocation market also has a substantial effect on water use decisions by dairy farmers. Every dairy farmer has different objectives and circumstances, as well as different ways of making water use decisions. However, there are some commonalities. In particular, higher allocation prices tend to reduce water use, whereas lower allocation prices tend to increase water use. This is not limited to dairy farmers who are reliant on the allocation market as a source of irrigation water. Dairy farmers with significant entitlement portfolios typically still adjust their water use in response to water allocation prices, often buying additional water when it is inexpensive and selling water when it is expensive.

This helps to explain the dramatic changes in water use by livestock (including dairy) industries in the sMDB over time, of which dairy is the dominant water user (Figure 5). Median annual allocation prices increased from around \$70 per ML in 2005-06 to over \$380 per ML between 2006-07 and 2008-09, with traded prices peaking at around \$1000 per ML (not shown). Along with falling allocations, this contributed towards a reduction in water use in livestock (including dairy) from about 2400 GL in 2005-06 to 630 GL in 2008-09. Allocation prices subsequently fell, as discussed above. However, it took a number of seasons for water use to recover due to factors such as reduced herd size as a result of previous destocking and high rainfall in dairy regions. These factors moderated the demand for irrigation water in 2010-11 and 2011-12.

Given the importance of the allocation market to the dairy industry in the sMDB, there is value in better understanding the drivers of allocation prices and future trends under different scenarios.



Note: Includes groundwater.

Source: Aither irrigated agriculture database, based on ABS and ABARES data.

Figure 5 Water use by livestock activities (including dairy) in the sMDB, 2005-06 to 2013-14

1.3. Previous reports

This report builds on two previous reports by Aither into the allocation market in the sMDB (Aither 2016a, b). The allocation market is relatively simple at a conceptual level. The supply of allocations interacts with the demand for allocations from various uses – such as irrigation industries, environmental water holders, and urban water authorities – to determine the price. Changes that reduce supply or increase demand lead to a higher price, whereas changes that increase supply or decrease demand lead to a lower price.³ While conceptual analysis of the allocation market has value, most relevant strategic and policy questions for individual farmers, industries and governments relate to magnitudes (that is, whether the impact is small or large).

In this regard, the genesis of Aither (2016a) was the observation that although it was recognised by governments and stakeholders that Commonwealth environmental water purchases had increased allocation prices, there were different views over the magnitude of the impact. These disputes persisted, in part, because there is no simple way to measure the impact. Water allocation prices have changed since Commonwealth environmental water purchases commenced in 2007-08, but some of these impacts are attributable to other factors. Attributing the entire change in allocation prices to any single factor would result in bias.

Aither (2016a) addresses this by using statistical methods to isolate the effects of Commonwealth environmental water purchases from changes in supply caused by drought and changes in demand by irrigation industries. Aither found that while drying climatic conditions were the prime driver in increasing water allocation prices between 2010-11 and 2014-15, about a quarter of the increase was attributable to Commonwealth environmental water entitlement purchases further reducing the water available for irrigation. The model was also used to estimate the impacts of an additional 200 GL of future environmental water purchases on allocation prices, within the legislated 1500GL cap on buybacks.

Similarly, Aither (2016b) was motivated by anecdotal evidence of plans by the cotton and nuts industries to expand production, and conjecture around the implications for allocation prices in the future. Consultations were undertaken with stakeholders throughout the sMDB to:

- (i) develop projections of future water demand by different irrigation industries and
- (ii) provide data to build a more detailed model of the allocation market.

The resulting model was used to estimate the impacts of the projected future changes in water demand by irrigation industries on allocation prices from 2015-16 to 2020-21.

These previous reports paint an increasing complete picture of the supply and demand drivers of allocation prices in the sMDB and future trends under different scenarios, but they analyse these drivers in isolation. In Aither (2016a), changes in Commonwealth environmental water purchases are modelled holding water demand by irrigation industries constant. The opposite scenario is modelled in Aither (2016b), holding allocations constant at a level post-environmental purchases. These reports do not consider the potential for interactions. This gap is addressed in the current report.

1.4. Scope

The scope of this report for Dairy Australia includes a recalculation of the main results from the previous reports (discussed above) to provide context. However, the scope is considerably broader. In particular, the report analyses the overall effects on the sMDB allocation market of Commonwealth

³ The analysis is only slightly more complex within an irrigation season.

environmental water purchases and changes in demand by irrigation industries and urban water authorities, allowing for interactions. The report also considers the impacts of Commonwealth environmental water purchases against an alternative water recovery mechanism, on-farm infrastructure upgrades.

The scope of this report does not include:

- **Modelling impacts on entitlement markets.** However, entitlement markets are closely linked to the allocation market, since the value of an entitlement is derived from the current and future value of allocations associated with it. Hence, changes in the allocation market will tend to flow through to entitlement markets. This could be a focus of further Aither modelling.
- **Modelling long-term impacts on the allocation market.** There is always uncertainty around projections of changes in demand for allocations. This uncertainty increases with longer projections. The projections used in this report look five years into the future. This is long enough to highlight possible trends that could be relevant to long term planning by industries and governments, but short enough to be confident in the general robustness of the projections. This time frame is also suited to the models used in this report, which do not allow for long term adjustments by irrigators in response to changes in allocation prices (i.e. in technical terms, Aither models short run effects).
- **A complete technical description of the models used.** These are publically available (see Aither 2016a, b), however the report does cover further updates of the models undertaken to complete this project.

1.5. Structure

The remainder of the report is structured as follows:

- Section 2 discusses the methodology applied, including the scenarios modelled.
- Section 3 presents the main modelling results.
- Section 4 provides additional analysis to extend the main results.
- Section 5 outlines the main implications for the dairy industry and governments.

2. Methodology

Appendix A provides an overview of the models used in this report and the caveats. The models were applied to simulate a number of demand scenarios. To illustrate the effects of the demand scenarios across different types of seasons, each demand scenario was modelled under three water allocation scenarios. This section describes the scenarios and the modelling approach.

2.1. Demand scenarios

The demand scenarios capture two different sources of changes in demand for allocations – Commonwealth environmental water purchases and other sources (irrigation industries and urban water authorities) – both in isolation and combined.⁴ The demand scenarios look back at changes that have occurred over the last ten years and look forward towards changes that could occur over the next five years (Table 1).

Table 1 Demand scenarios

Source of demand change	Looking back (2005-06 to 2015-16)	Looking forward (2015-16 to 2020-21)
Commonwealth environmental water purchases	Scenario 1	Scenarios 4a and 4b
Irrigation industries and urban water authorities	Scenario 2	Scenario 5
All of the above	Scenario 3	Scenario 6

The demand scenarios were developed based on a number of sources of evidence (Table 2). The backward-looking scenarios draw on historical data. There is greater uncertainty around the forward-looking scenarios. In particular, the volume of future Commonwealth environmental water purchases is unknown, and depends on the extent to which:

- the Murray-Darling Basin Plan’s sustainable diversion limits (SDL) are adjusted based on supply measures⁵
- water is recovered through other means, such as infrastructure programs
- legislation constrains the volume of water that can be recovered through Commonwealth environmental water purchases.

In Scenario 4a, it is assumed that another 200 GL in Long Term Average Annual Yield (LTAAY) is purchased in the sMDB (which is consistent with Aither 2016a). As sensitivity analysis, in Scenario 4b, it is assumed that 306 GL LTAAY is recovered. Dairy Australia requested the higher scenario to include a potential additional 106GL under the $\pm 5\%$ SDL adjustment mechanism.

⁴ Commonwealth environmental water purchases can be seen as increasing demand for allocations or reducing the supply of allocations to consumptive uses. These interpretations are equivalent. This report uses the demand-side interpretation.

⁵ Supply measures are projects that allow equivalent environmental outcomes to be achieved with less environmental water. This enables the sustainable diversion limits to be adjusted downwards, subject to a 5 per cent limit on the total adjustment. A number of environmental works and rule changes have already been agreed to as supply measures by the Murray-Darling Basin Authority Ministerial council.

There is also uncertainty around the change in demand for allocations by irrigation industries. The scenarios are largely based on projections by stakeholders from December 2015. However, since then, commodity prices have fallen for almonds and dairy, meaning that the overall growth in demand for allocations by irrigation industries could be overstated. Sensitivity analysis was undertaken in Aither (2016b) to explore the implications of different growth assumptions.

Table 2 Basis for demand scenarios

Scenario		Basis	Source
Historical (last 10 years)	1: Buyback	Historical data on Commonwealth environmental water purchases ⁶	Aither (2016a)
	2: Irrigation and urban	Historical data on changes in demand by irrigation industries and urban water authorities	Aither irrigated agriculture database
	3: All	Combination of 1 and 2 above	As above
Future (next 5 years)	4a: Buyback (+200GL)	Hypothetical additional 200 GL of Commonwealth environmental water purchases (LTAAY)	Hypothetical
	4b: Buyback (+306GL)	Hypothetical additional 306 GL of Commonwealth environmental water purchases (LTAAY)	Hypothetical
	5: Irrigation and urban	Stakeholder consultation regarding potential changes in demand by irrigation industries and a hypothetical additional 25 GL of demand by urban water authorities during low allocation seasons only	Aither (2016b) and hypothetical
	6: All	Combination of 4a and 5 above	As above

2.2. Water allocation scenarios

The following core water allocation scenarios were developed based on recent seasons:

- low allocation season – similar to 2015-16 (around 4200 GL allocated to entitlements in the sMDB)
- moderate allocation season – similar to 2014-15 (around 5200 GL allocated)
- high allocation season – similar to 2011-12 (around 6900 GL allocated).

In Section 4.1, the analysis is extended to include an extremely low allocation season - similar to 2008-09 (around 1900 GL allocated).

⁶ Excludes purchases under The Living Murray and state-based programs.

2.3. Modelling approach

This report draws on two Aither models of the allocation market in the sMDB. The models share many similarities, but also have some fundamental differences. One model (statistical model) builds on price and volume data from Aither's water markets database. The other (stakeholder model) is based on evidence of water use behaviour collected from stakeholders throughout the sMDB. The models also differ in their functional forms (Box 2). While both models have been updated and refined over time, recent versions have been publically documented (Aither 2016a, b).

These models were developed to answer different policy questions. The statistical model is better at predicting annual median allocation prices given the influence of demand factors such as rainfall within irrigation areas, whereas the stakeholder model can be applied to a broader range of scenarios, including estimating the implications of demand changes by individual irrigation industries. (See Appendix A for more information).

The main results in this report are generated using the stakeholder model. While there are a large number of scenarios, the modelling approach is relatively straightforward. Each demand scenario was run for each water allocation scenario using the stakeholder model, given the need to examine industry-level changes.⁷

⁷ The stakeholder model was linked to the statistical model, with the statistical model being used to estimate base allocation prices. The stakeholder model was used to estimate the percentage changes in allocation prices, which were then applied to the base allocation prices. This allows the estimated allocation prices to better reflect differences in the demand for allocations across different seasonal conditions, for example, by accounting for low rainfall within irrigation regions in low allocation seasons and the resulting increases in demand for allocations.

3. Results

As discussed in the previous section, the models were applied to estimate the implications of different demand and water allocation scenarios. In this section, the results are analysed in detail.

3.1. Scenario 1: Historical buyback

The stakeholder model was used to simulate what median water allocation prices would have been in 2015-16 under different water allocation conditions, with and without the Commonwealth environmental water purchases over the last decade. (In this scenario, it is also assumed that there was no growth in irrigation and urban demand over this period, in order to isolate the effects of the Commonwealth environmental water purchases.) The difference between prices with and without, is the estimated effect of the Commonwealth environmental water purchases.

Commonwealth environmental water purchases alone are estimated to have increased allocation prices from \$172 to \$196 per ML (\$24 per ML or 14 per cent) in low allocation seasons, \$101 to \$114 per ML (\$13 per ML or 13 per cent) in moderate allocation seasons, and \$32 to \$36 per ML (\$4 per ML or 12 per cent) (Figure 6).

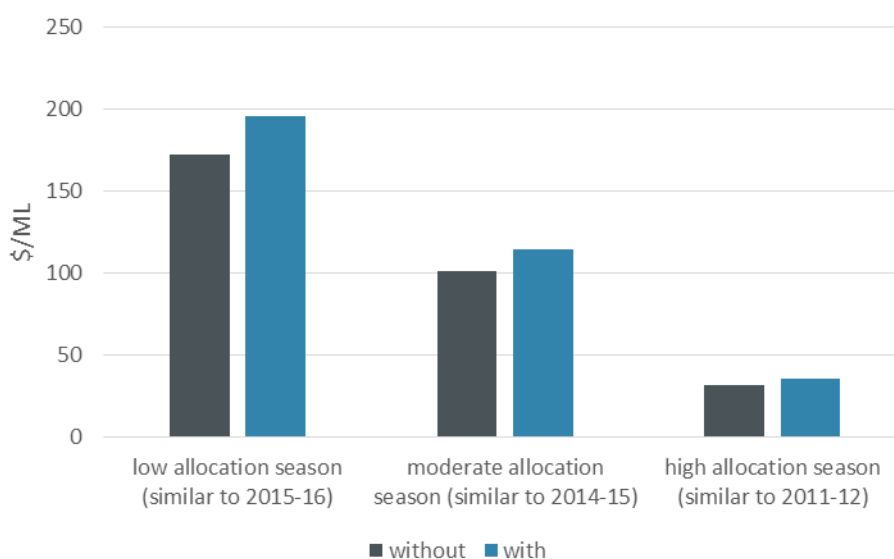


Figure 6 Modelled sMDB water allocation prices with and without historical Commonwealth environmental water purchases (Scenario 1)

These estimated impacts are smaller than the equivalent estimates presented in Aither (2016a), although they are of a broadly similar order of magnitude. Section 4.2 presents a full comparison between the results across models and discusses the reasons for differences.

Allocation prices in low allocation seasons are below the peaks observed in 2015-16 (which is used to define 'low allocation'), even when Commonwealth environmental water purchases are factored in. This partly reflects the assumption made for this scenario that there was no growth in irrigation and urban demand over the last decade. It is also a consequence of using median prices to calibrate the

models, which smooths out the peaks and troughs. When interpreting the results, note that allocation prices will often be significantly higher or lower than the median at different times in the season.

The stakeholder model was also used to estimate changes in water use as a result of the increases in allocation prices estimated. Livestock (including dairy) is estimated to have experienced a reduction in water use from around 2280 to 1940 GL (14 per cent) in moderate allocation seasons due to the increase in water allocation prices that can be attributed to Commonwealth environmental water purchases (Figure 7). This means that around 40 per cent of the water allocated to the Commonwealth⁸ in moderate allocation seasons has, in a sense, come from livestock (including dairy). This is because livestock (including dairy) has the largest base water use and the equal second largest percentage change in water use of the irrigation industries considered. The latter reflects that livestock (including dairy) tends to be more responsive, or elastic, to changes in allocation prices than fruits and nuts, and grapes.

The equivalent figures for low and high allocation seasons are presented in Appendix B.

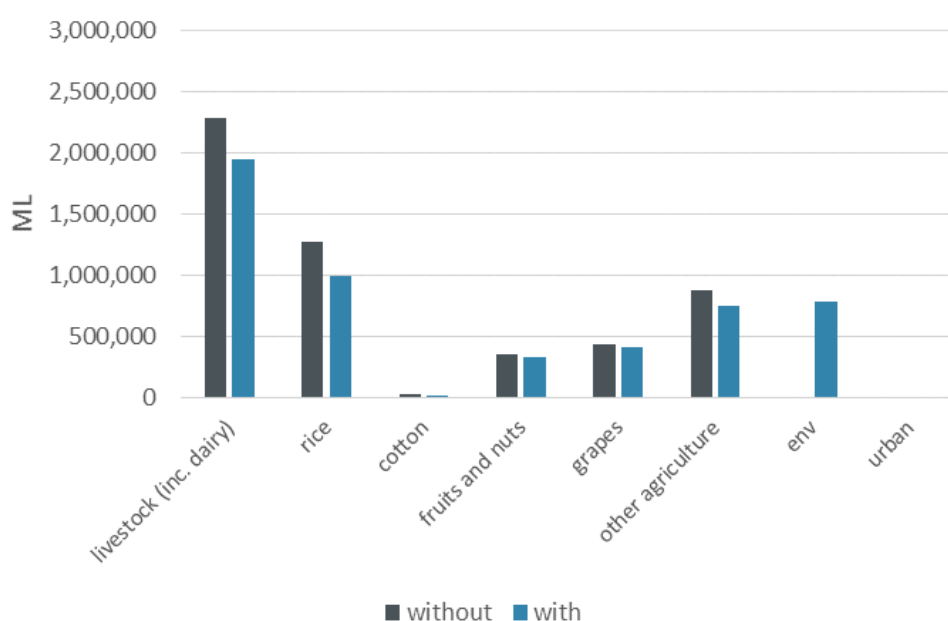


Figure 7 Modelled sMDB surface water use with and without historical Commonwealth environmental water purchases, moderate allocation season (Scenario 1)

3.2. Scenario 2: Historical irrigation and urban

Changes in demand for allocations by irrigation industries and urban water authorities over the last decade are not estimated to have had a large effect of allocation prices (Figure 8). Across the sMDB between 2005-06 and 2015-16, there was a substantial decrease in demand for allocations by livestock (including dairy) and rice, offset by a substantial increase in demand by nuts and cotton. Outside extremely low allocation seasons, these shifts have largely offset each other. These changes are estimated to have increased allocation prices from \$172 to \$181 per ML (\$9 per ML or 5 per cent)

⁸ Specifically, Commonwealth entitlements acquired through purchases.

in low allocation seasons, \$101 to \$104 per ML (\$3 per ML or 4 per cent) in moderate allocation seasons, and \$32 to \$33 per ML (\$1 per ML or 3 per cent) in high allocation seasons.

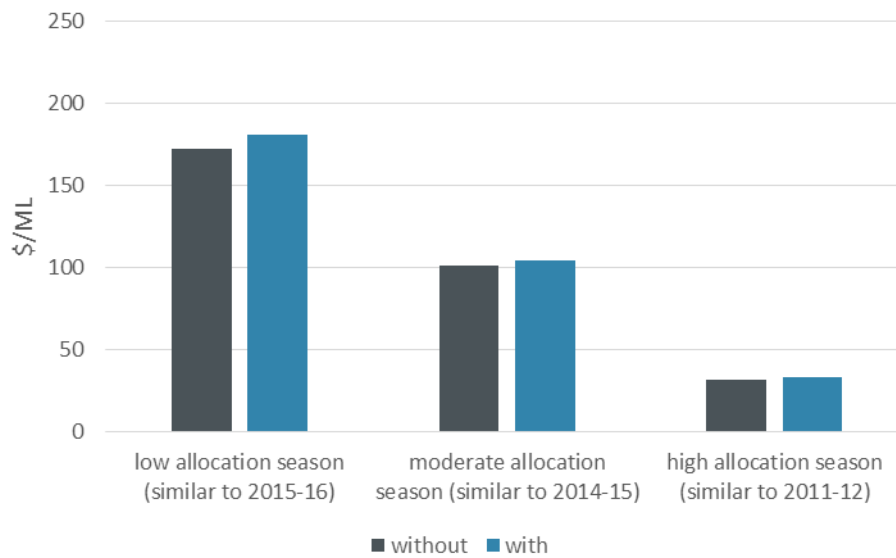


Figure 8 Modelled sMDB water allocation prices with and without historical changes in demand by irrigation industries and urban water authorities (Scenario 2)

The shifts in sector demand for allocations, and resulting changes in allocation prices, are estimated to have caused significant changes in water use in the sMDB between 2005-06 and 2015-16. Livestock (including dairy) is estimated to have experienced a reduction in water use from around 2280 to 1720 GL (24 per cent) in moderate allocation seasons (Figure 9). This decline is mainly due to an inward shift in demand for allocations by livestock (including dairy) over that period, as the livestock (including dairy) industry has contracted. This is evident in the downward trend in milk prices, discussed above. There have also been changes towards production systems that use less water, but this has been less important in driving demand for allocations. The inward shift in demand for allocations by livestock (including dairy) has been exacerbated by higher allocation prices.

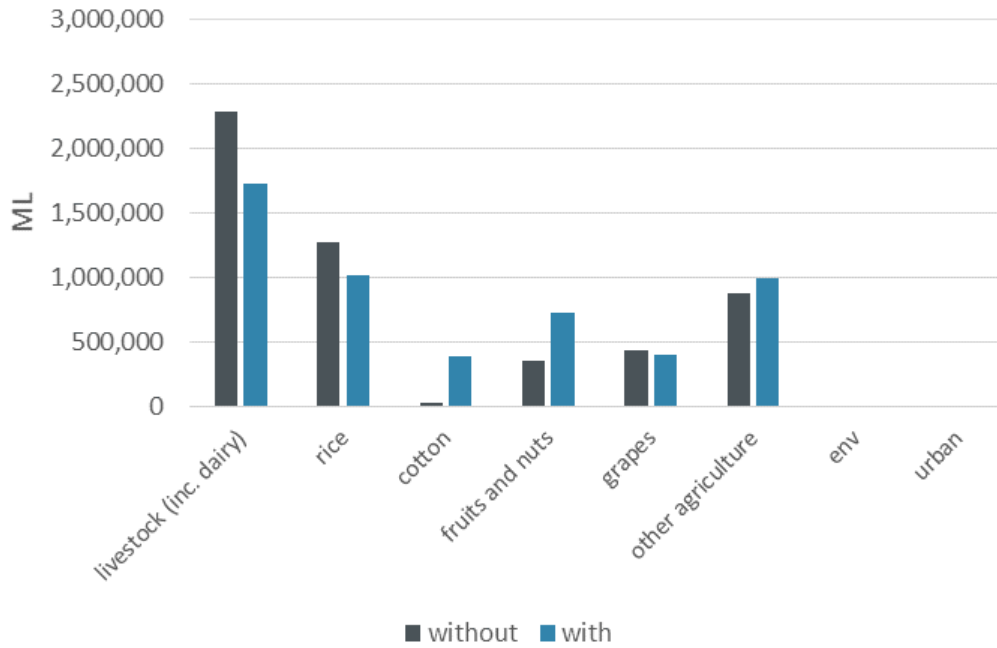


Figure 9 Modelled sMDB surface water use with and without historical changes in demand by irrigation industries and urban water authorities, moderate allocation season (Scenario 2)

3.3. Scenario 3: All historical

The previous scenarios examine in isolation the effects of Commonwealth environmental water purchases and changes in demand for allocations by other market participants, namely irrigation industries and urban water authorities. Modelling these changes together illustrates that the overall effect will tend to be slightly larger than the sum of individual effects. In this case, the interaction only has a small effect because the change in allocation prices associated with changes in demand for allocations by irrigation industries and urban water authorities are small.

The changes in the allocation market between 2005-06 and 2015-16 are estimated to have increased allocation prices from \$172 to \$207 per ML (\$35 per ML or 20 per cent) in low allocation seasons, \$101 to \$118 per ML (\$17 per ML or 17 per cent) in moderate allocation seasons, and \$32 to \$37 per ML (\$5 per ML or 16 per cent) in high allocation seasons (Figure 10).

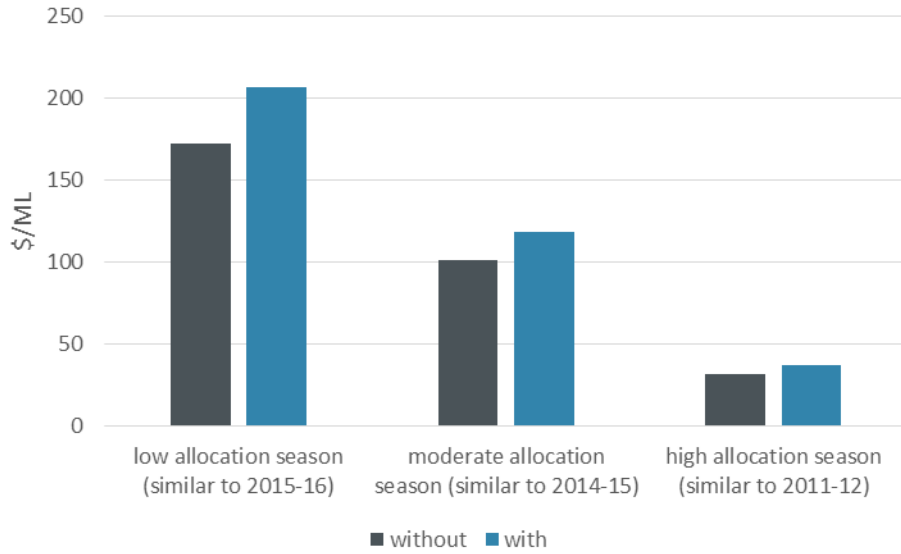


Figure 10 Modelled sMDB water allocation prices with and without historical changes (Scenario 3)

The modelled changes in water use (Figure 11) show that there have been significant underlying structural changes in water use by irrigation industries in the sMDB between 2005-06 and 2015-16, independent of changes in water allocations. In particular, there has been a large underlying decrease in water use by livestock (including dairy) from about 2280 to 1450 GL (36 per cent) in moderate allocation seasons and from about 1940 to 1190 GL (39 per cent) in low allocation seasons. Around one third of this decrease is estimated to be due to Commonwealth environmental water purchases.

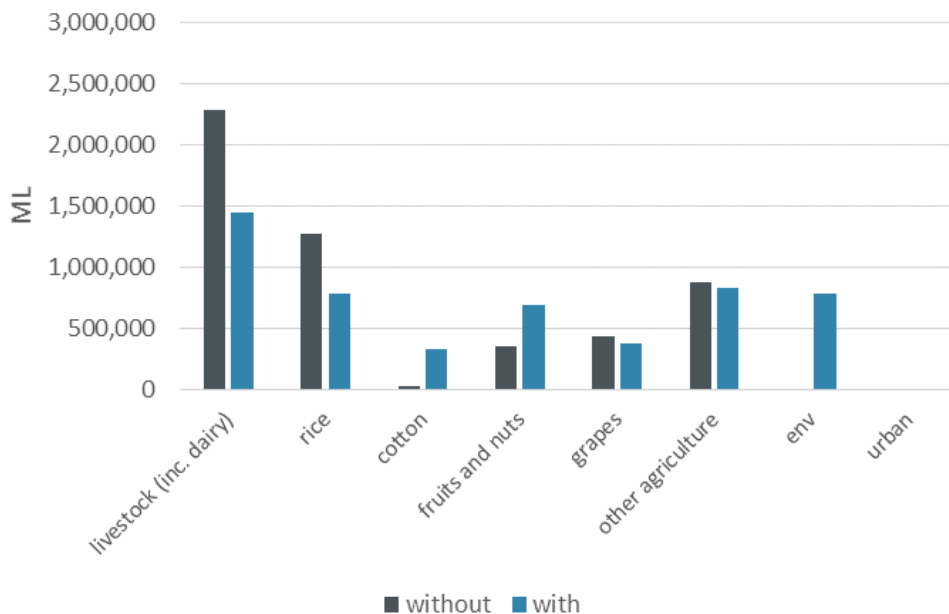


Figure 11 Modelled sMDB surface water use with and without historical changes, moderate allocation season (Scenario 3)

The following scenarios are similar to the scenarios presented above, except that they look forward, from 2015-16 to 2020-21.

3.4. Scenarios 4a and 4b: Future buyback

Further Commonwealth environmental water purchases would also increase allocation prices. A hypothetical additional 200 GL LTAAY of Commonwealth environmental water purchases is estimated to increase allocation prices from around \$207 to \$214 per ML (\$7 per ML or 4 per cent) in low allocation seasons, \$118 to \$122 per ML (\$4 per ML or 3 per cent) in moderate allocation seasons, and \$37 to \$38 per ML (\$1 per ML or 3 per cent) in high allocation seasons (Figure 12). The magnitude of the estimated price impacts is around 30 per cent of the estimated price impacts of historical Commonwealth environmental water purchases.

Increasing the additional volume of water being purchased to 306 GL LTAAY would result in larger price impacts, with the relationship between the volume purchased and price impact being approximately linear over this range.

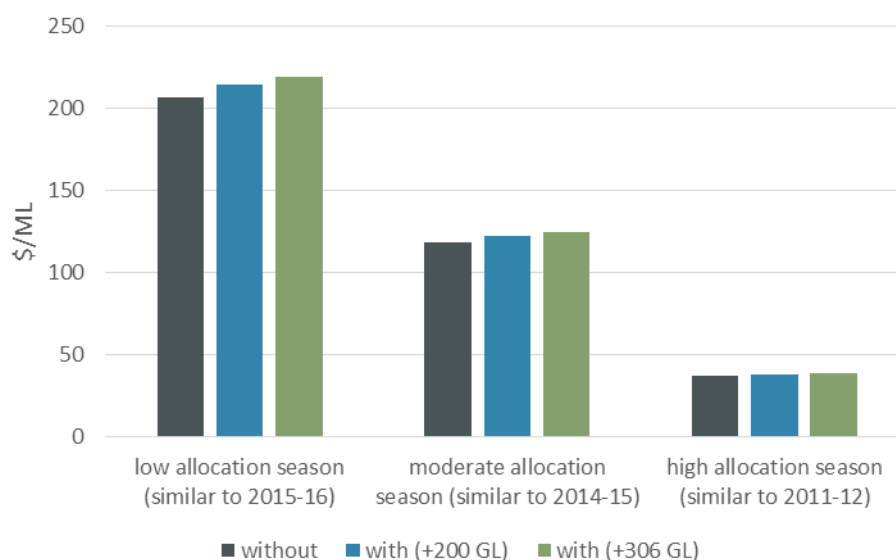


Figure 12 Modelled sMDB water allocation prices with and without future Commonwealth environmental water purchases (Scenarios 4a and 4b)

Depending on the volume of additional water purchased, the increases in allocation prices could cause water use by livestock (including dairy) to fall from 1450 GL to between 1380 GL (5 per cent) and 1350 GL (7 per cent) in moderate allocation seasons (Figure 13). If an additional 200 GL were purchased, the volume of water available to the Commonwealth Environmental Water Holder from all purchases in a moderate allocation season would exceed the volume used by major irrigation industries such as rice, and fruits and nuts.

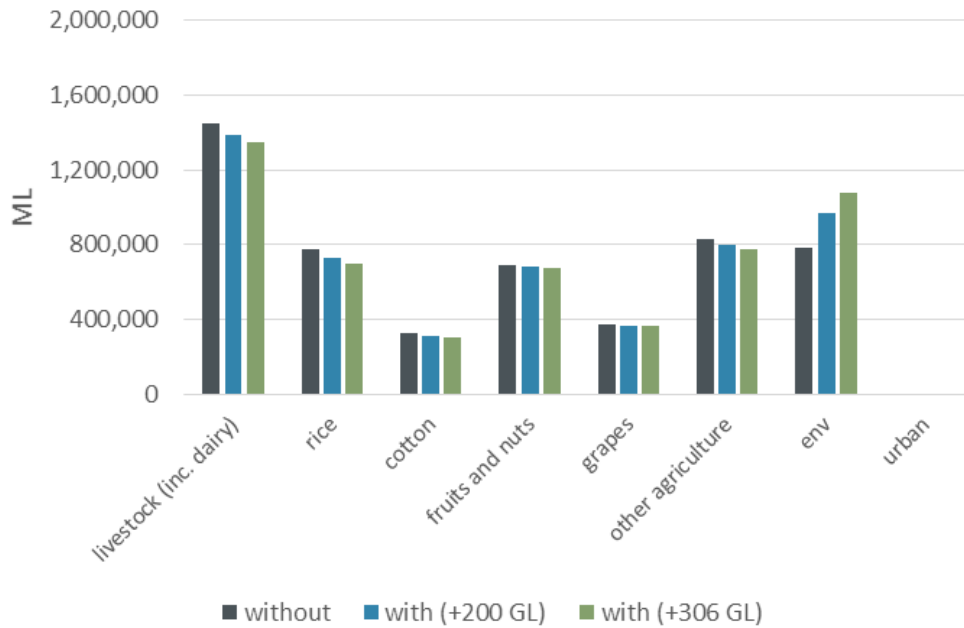


Figure 13 Modelled sMDB surface water use with and without future Commonwealth environmental water purchases, moderate allocation season (Scenarios 4a and 4b)

3.5. Scenario 5: Future irrigation and urban

In applying the stakeholder model in Aither (2016b), Aither consulted with stakeholders across the sMDB in late 2015 regarding their expectations for irrigation industries between 2015-16 and 2020-21. The consultations were used to develop projections which suggest significant growth for cotton and nuts, and a contraction for grapes.

As discussed in Aither (2016b), the recent fall in almond prices brings into question whether the full extent of projected changes in demand for allocations will be realised. The fall in milk prices received by dairy farmers will also tend to reduce demand for allocations relative to what was modelled, to the extent that lower prices continue. The projected changes for irrigated agriculture were modelled together with an additional hypothetical 25 GL in LTAAY increase in demand from urban water authorities (in low water allocation seasons only).

These future changes are estimated to increase allocation prices from \$207 to \$223 per ML (\$16 per ML or 8 per cent) in low allocation seasons, \$118 to \$126 per ML (\$8 per ML or 7 per cent) in moderate allocation seasons, and \$37 to \$39 per ML (\$2 per ML or 6 per cent) in high allocation seasons (Figure 14).

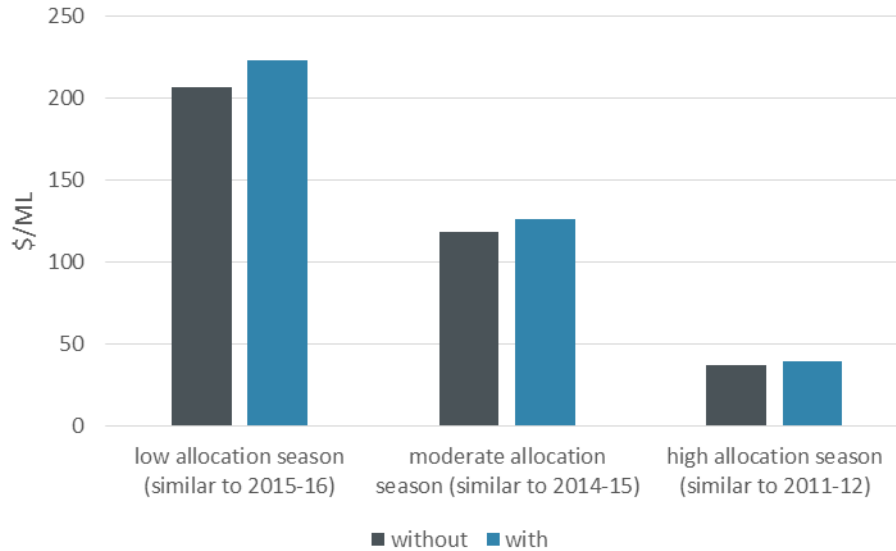


Figure 14 Modelled sMDB water allocation prices with and without future changes in demand by irrigation industries and urban water authorities (Scenario 5)

The changes in allocation prices are estimated to reduce water use in livestock (including dairy) from about 1450 to 1330 GL (9 per cent) in moderate allocation seasons (Figure 15). This water will essentially be used by the cotton and nuts industries, which are estimated to increase their water use.

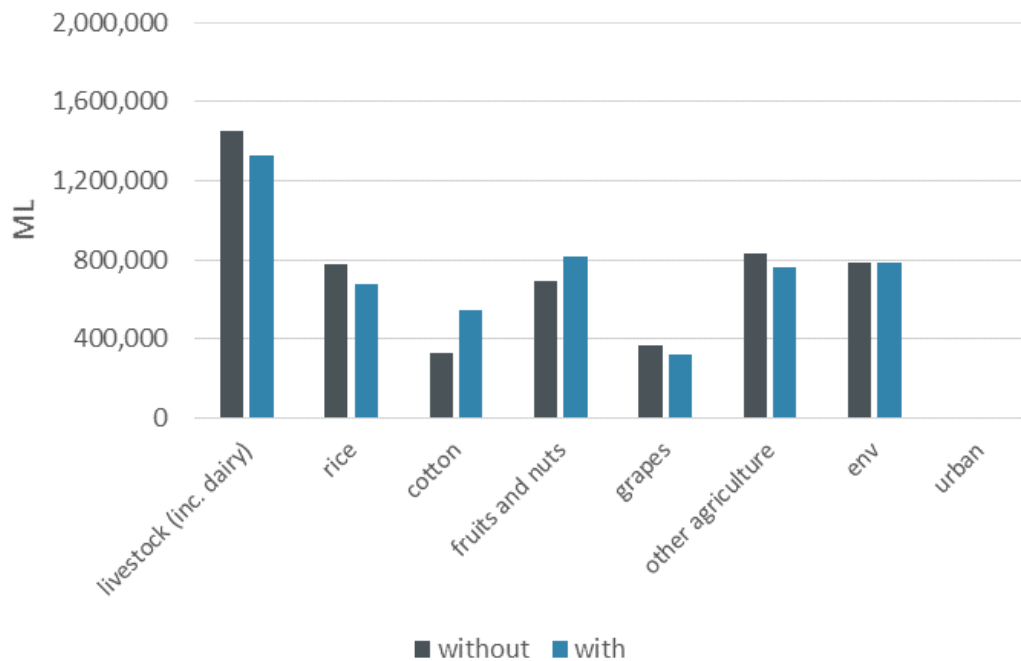


Figure 15 Modelled sMDB surface water use with and without future changes in demand by irrigation industries and urban water authorities, moderate allocation season (Scenario 5)

3.6. Scenario 6: All future

Taking into account the combined effects of hypothetical additional Commonwealth environmental water purchases (Scenario 4a), the projected expansion and contraction in different irrigation industries and hypothetical increases in demand by urban water authorities (Scenario 5), there are likely to be further significant changes in the sMDB allocation market between 2015-16 and 2020-21.

Over the next five years, allocation prices are estimated to increase from \$207 to \$231 per ML (\$24 per ML or 12 per cent) in low allocation seasons, \$118 to \$131 per ML (\$13 per ML or 10 per cent) in moderate allocation seasons, and \$37 to \$41 per ML (\$4 per ML or 9 per cent) in high allocation seasons (Figure 16). These impacts could be larger if future Commonwealth environmental water purchases exceed 200 GL in LTAAY.

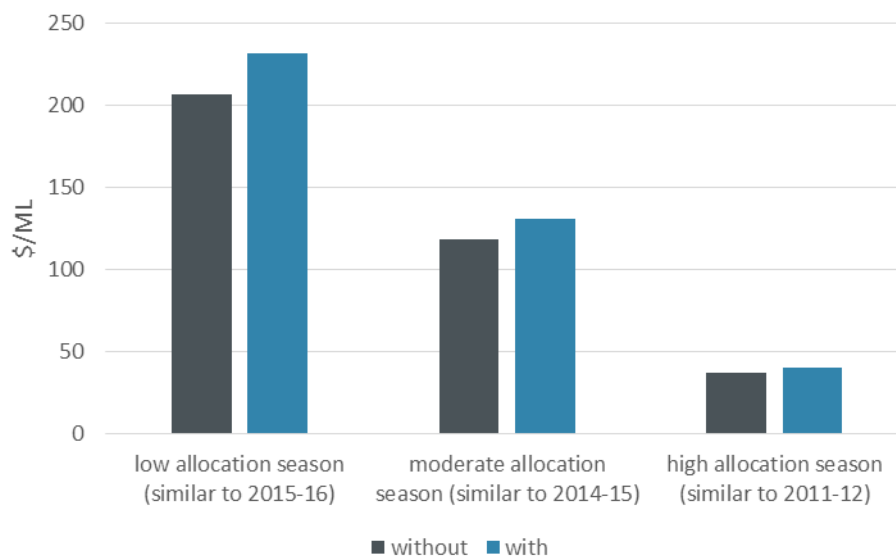


Figure 16 Modelled sMDB water allocation prices with and without future changes (Scenario 6)

While there is uncertainty over future trends, the modelled changes in water use (Figure 17) highlight the potential for the broad structural trends evident for irrigation industries in the sMDB over the last decade to continue in the medium term. Water use for livestock (including dairy) is estimated to fall from 1450 to 1270 GL (13 per cent) in moderate allocation seasons and from 1190 to 1020 GL (14 per cent) in low allocation seasons. Although this is significant, the modelled rate of decrease is slower than over the previous decade. This does not capture the effects of recent declines in milk prices received by dairy farmers.

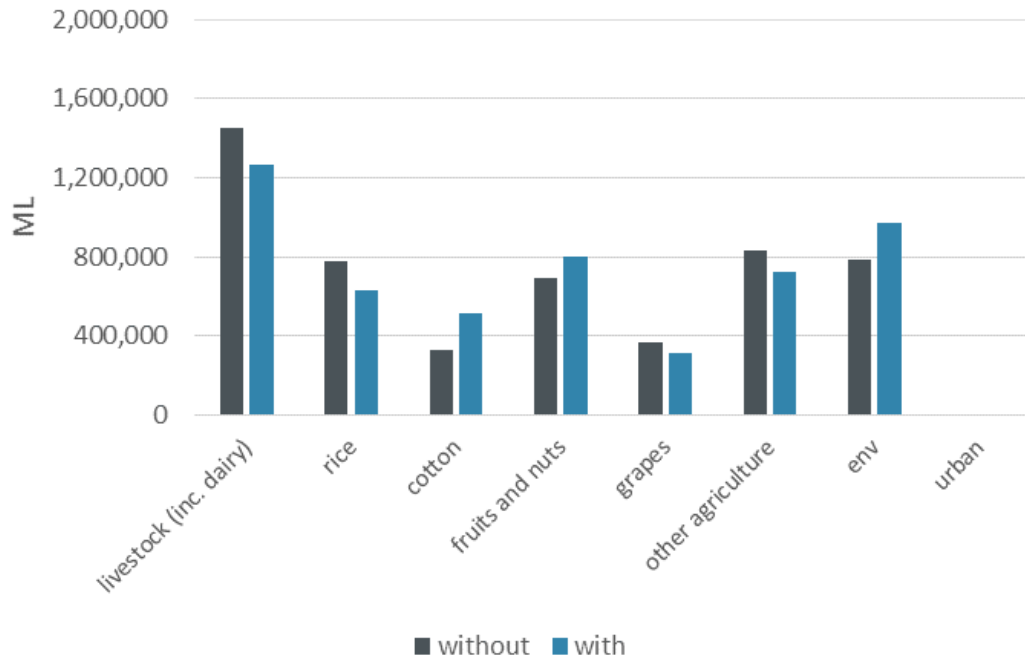


Figure 17 Modelled sMDB surface water use with and without future changes, moderate allocation season (Scenario 6)

4. Additional analysis

The previous section covers the main results. This section provides additional analysis of issues around extremely low allocation seasons, Commonwealth environmental water purchases (including the opportunity cost of Commonwealth environmental water purchases), and on-farm infrastructure upgrades as an alternative to Commonwealth environmental water purchases.

4.1. Future price impacts in extremely low allocation seasons

The water allocation scenarios modelled above cover a range of different common scenarios. Although extreme scenarios occur less frequently, they can have a substantial effect on the dairy industry when they do occur. To account for this, the stakeholder model was also run for an extremely low allocation season, corresponding to the worst year of the millennium drought, 2008-09.

The model was used to estimate the median water allocation price in 2020-21 under a repeat of water allocation conditions experienced in 2008-09, when allocations to entitlements in the sMDB were around 1900 GL. The model was run with and without the combined effects of future changes in demand (as represented by Scenario 6).

Based on current settings, including around 240 GL allocated to entitlements acquired through previous Commonwealth environmental water purchases, allocation prices are estimated to be in the order of \$603 per ML. The projected changes in demand over the next five years are estimated to increase allocation prices from \$603 to \$702 per ML (\$99 per ML or 16 per cent) in a repeat of an extremely low allocation season like 2008-09. The modelled impact is larger in both percentage change and absolute terms than the equivalent estimates for low, moderate and high allocation seasons (Section 3.6).

The large impact is due partly to the nature of demand for water by irrigation industries. The curvature of the demand curve (Figure 18) means that removing a given volume of water from irrigated agriculture has a larger absolute price impact when the volume allocated is lower. It also reflects the fact that much of the projected expansion in demand is in the nuts industry and urban water, which tend not to reduce water use significantly in response to higher prices.

If these projections eventuate, there is likely to be a considerable increase in already high allocation prices in the event that severely constrained allocation conditions return.

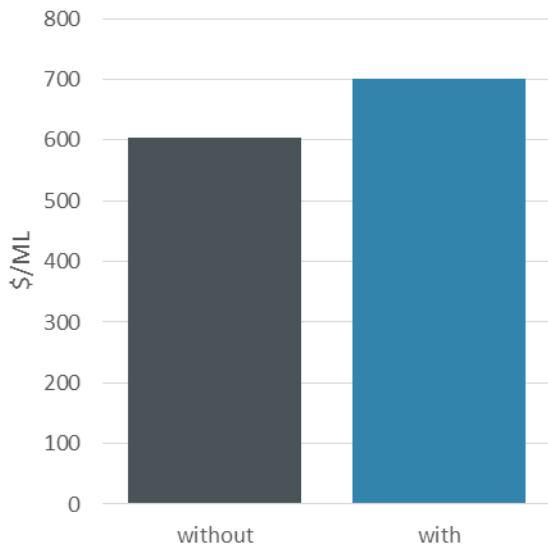


Figure 18 Modelled sMDB water allocation prices with and without future changes, extremely low allocation season (similar to 2008-09)

4.2. Comparison with statistical model

As discussed, all of the modelling reported above uses the stakeholder model. This was necessary because some of the scenarios could only be simulated in the stakeholder model, since the statistical model does not allow for disaggregation by industry. However, Scenario 1 can also be modelled using the statistical model. Scenario 1 was the subject of an earlier report by Aither for the Department of Agriculture and Water Resources which used the statistical model to examine the price effects of Commonwealth environmental water purchases (Aither 2016a). The results from the earlier report are directly comparable to the results presented in Section 3.1.

This section compares the results of the stakeholder model for Scenario 1 with the results of the statistical model published in Aither (2016a) and a more recent version of the statistical model, which has been updated to allow for an additional year of data and some refinements. Figure 16 can be interpreted as follows:

- The first set of results ('stakeholder') are identical to those presented in Section 3.1.
- The second set of results ('initial statistical') are a replication of the analysis in Aither (2016a).⁹
- The third set of results ('revised statistical') are based on an updated version of the statistical model.

This comparison shows that the estimated price impacts are lower for the stakeholder model than the statistical model, for the water allocation scenarios simulated. Moreover, the revised version of the statistical model generates larger results than the initial version used for Aither (2016a). Under the

⁹ There is no low water allocation scenario, because the estimate of final allocations used in that report for the low water allocation season, 2015-16, was based on preliminary estimates. As the 2015-16 season has progressed, allocations have been lower than expected at the start of the season. Hence, the allocations applied to the initial version of the statistical model for 2015-16 are not comparable to the allocations applied in the revised version or the stakeholder model.

revised model, Commonwealth environmental water purchases are estimated to have increase allocation prices from \$172 to \$221 per ML (\$49 per ML or 28 per cent) in low allocation seasons, from \$101 to \$137 per ML (\$36 per ML or 36 per cent) in moderate allocation seasons, and from \$32 to \$47 per ML (\$15 per ML or 47 per cent) in high allocation seasons. The estimated price impacts in the revised statistical model are around twice that of the stakeholder model, suggesting that the estimates presented above may be slightly conservative, but the results are of a broadly similar order of magnitude in both dollar and percentage change terms.

As discussed above, a different modelling approach was adopted in this report because of the need to model scenarios that are disaggregated by industry. As discussed in Appendix A, the differences between the results are heavily influenced by technical assumptions around the functional form which effect the estimated responsiveness of price to changes in the volume of water available.

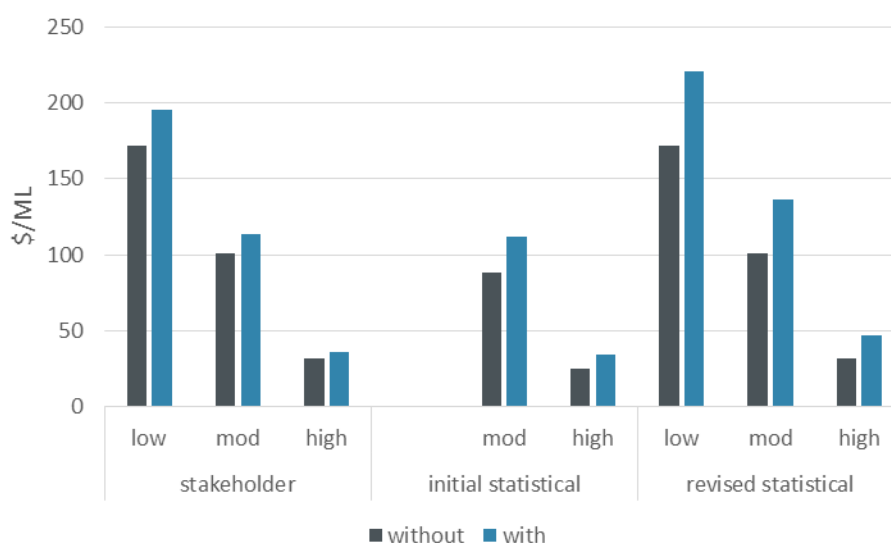


Figure 19 Modelled sMDB water allocation prices with and without historical Commonwealth environmental water purchases (Scenario 1), comparison across models

4.3. Opportunity cost of purchased water

Commonwealth environmental water purchases have both benefits and costs. There are benefits associated with improved environmental outcomes in both the short and long term, but also costs associated with reduced agricultural production. The opportunity cost of reduced agricultural production is the forgone agricultural profits as a result of reallocating water from agriculture. It is based on agricultural profits rather than agricultural revenue, since irrigators often adjust their use of other inputs when they reduce their water use. For example, a farmer who shifts from irrigated to dryland production could spend less on fertiliser. In this case, forgone agricultural revenue would overstate the opportunity cost because it would ignore the potential for savings on other inputs.

It is possible to use the statistical allocation price model to estimate the opportunity cost based on the area under the demand curve between the modelled volumes of water use with and without Commonwealth environmental water purchases.

In 2008-09 and 2009-10, the Commonwealth was purchasing substantial volumes of water entitlements, but the overall portfolio was still relatively small in comparison to the size of the portfolio

currently held. This resulted in a relatively small volume of Commonwealth allocations and limited the annual opportunity cost to below \$40 million per year for these years. The estimated annual opportunity cost remained below \$40 million per year in 2010-11 and 2011-12 despite increasing Commonwealth allocations because allocation prices were very low (Figure 20).

Since then, allocation prices have increased resulting in an annual opportunity cost of around \$90 million in 2014-15 and \$130 million in 2015-16. The annual opportunity cost is likely to be around \$130 million again next water season. In total, Commonwealth allocations between 2008-09 and 2015-16 would have generated approximately \$440 million in profits if used in agriculture (Figure 21).

These estimates do not include the opportunity cost of water acquired through other mechanisms, such as infrastructure programs, or water held by other environmental water holders. They also do not capture planned environmental water. The estimates were generated under the assumption that the Commonwealth Environmental Water Holder does not trade allocations. The sale of allocations in the Goulburn in November 2015 would have reduced the opportunity cost in 2015-16 by around \$7 million. Otherwise, the Commonwealth Environmental Water Holder has not traded allocations in the sMDB.

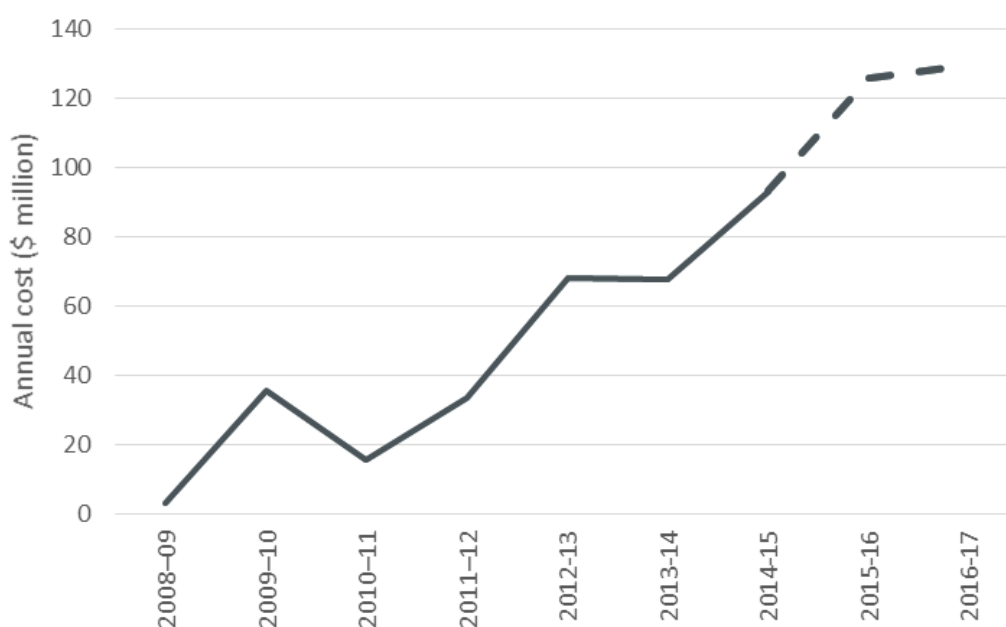


Figure 20 Annual opportunity cost of allocations to entitlements acquired through Commonwealth environmental water purchases in the sMDB, 2008-09 to 2016-17

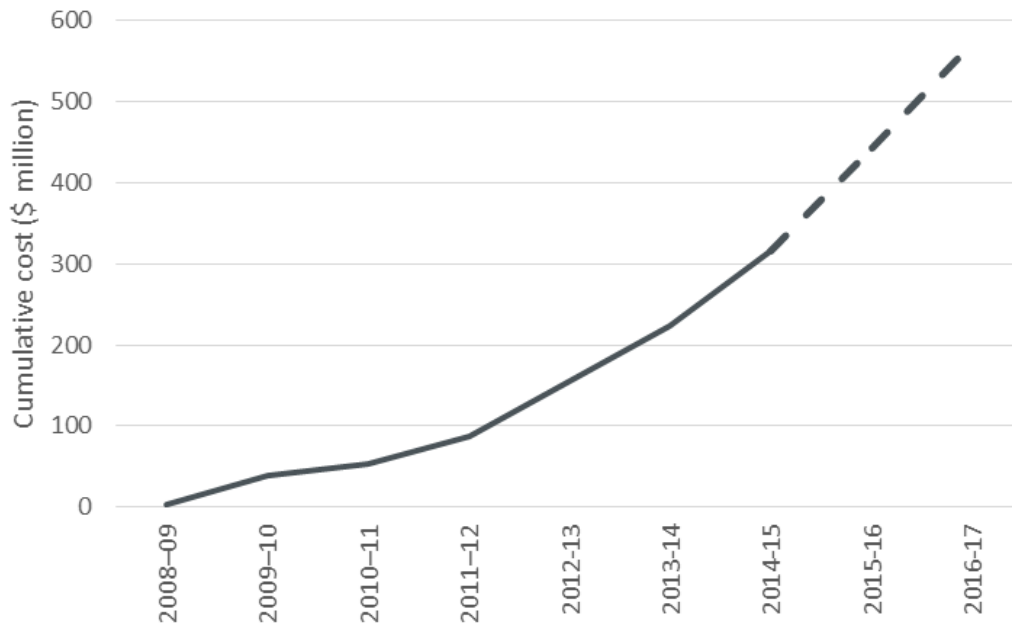


Figure 21 Cumulative opportunity cost of allocations to entitlements acquired through Commonwealth environmental water purchases in the sMDB, 2008-09 to 2016-17

4.4. Price impacts of on-farm efficiency programs

Suppose that instead of recovering an additional 200 GL in LTAAY from Commonwealth environmental water purchases, the same volume was recovered through on-farm efficiency programs. Setting aside whether it would be feasible to recover this volume of water through additional on-farm efficiency programs and the wider benefits and costs, what are the potential implications for allocation prices?

The impact of these programs on allocation prices could be negative or positive. This depends on the volume of water transferred to the Commonwealth (on the supply side) how the demand for allocations by irrigators responds to on-farm efficiency programs (on the demand side). This balance of supply and demand ultimately determines whether irrigators subsequently enter the allocation market to buy or sell allocations due to their participation in the program, and the impacts on allocation prices.

If demand for allocations by irrigators is unchanged by the programs, the impact will be to increase allocation prices by the same amount as Commonwealth environmental water purchases. This is because supply falls without a change in demand (as occurs under Commonwealth environmental water purchases). The impact will be larger if demand for allocations increases, and smaller if demand for allocations falls.

There are anecdotal accounts that some irrigators have reduced their demand for allocations as a result of on-farm efficiency programs, whereas others have increased their demand. This is consistent with economic theory, which suggests that the ability to delivery water more efficiently to the crop has two opposing incentive effects, one to reduce water use and the other to increase water use, and that the relative strength of these effects will depend on the circumstances of individual irrigators. At this stage, there is insufficient empirical evidence to determine the overall impact on demand for allocations across the market. However, it is plausible that the price impacts of future on-farm

efficiency programs could be as large as, or larger than, equivalent Commonwealth environmental water purchases. This is an area for further research.

5. Conclusions

The overall supply of water is highly variable from season to season and explains most of the short run variation in water allocation prices. This is evident over the last five years, with drying conditions having been the primary driver of increasing water allocation prices (Aither 2016a). However, there are also a range of other drivers that have a significant longer term impact on water markets. This report uses a quantitative modelling approach to estimate the magnitude of these impacts and inform decision making in the sMDB dairy industry.

Environmental water recovery

One driver is the reallocation of water to the environment through various programs including Commonwealth environmental water purchases. In this report, two models with different characteristics were used to estimate the impacts of Commonwealth environmental water purchases since the program started in 2007-08. The results suggest that water allocation prices could be 13 to 36 per cent higher in a typical season than they would otherwise have been without Commonwealth environmental water purchases. The range reflects the estimates generated using different models, and is consistent with the results of previous analysis (Aither 2016a). Further environmental water purchases would increase allocation prices, with the effect increasing with the volume purchased.

The potential for Commonwealth environmental water purchases to increase allocation prices is well understood. However, other environmental water recovery mechanisms can also affect allocation prices. While the available evidence base is limited, it is plausible that the price impacts of additional on-farm efficiency programs could be as large as, or larger than, equivalent Commonwealth environmental water purchases. This is an area for further research. It is separate from whether it is feasible to recover a significant volume of water through additional on-farm efficiency programs and the wider benefits and costs.

Irrigation industries and urban water authorities

Outside extremely low water allocation seasons, irrigation industries and urban water authorities have not been large drivers of the sMDB water market in aggregate over the last decade. This is because the growth in some industries (such as nuts and cotton) has tended to be offset by the contraction of other industries (such as rice and dairy). However, this could change in the future, depending on the extent to which projected expansions in nuts and cotton are realised. This is especially relevant in extremely low allocation seasons, when increased demand by urban water authorities and the nuts industry could interact with future environmental water purchases to further increase already high allocation prices.

Combined effects of changing industry and environmental demand to 2020-21

The combined effects of these drivers means that water markets in the sMDB could appear quite different in 2020-21 to 2005-06. Over this period, water allocation prices are estimated to increase from \$172 to \$231 per ML (34 per cent) in low allocations seasons, \$101 to \$131 per ML (30 per cent) in moderate allocation seasons, and \$32 to \$41 (28 per cent) per ML in high allocation seasons. These figures are expressed in real 2015-16 dollars.

Opportunity cost of environmental water

With an additional 200 GL of water purchases for the environment, the allocations to entitlements acquired by the Commonwealth would exceed water use by all major irrigation industries in the sMDB other than livestock (including dairy). The reallocation of water to environmental uses has benefits

and costs, and it is important for good public policy to be clear about both so that informed decisions can be made. In total, allocations to entitlements acquired through the buyback would have generated approximately \$440 million in net returns if used in agriculture between 2008-09 and 2015-16. The annual opportunity cost in 2015-16 was estimated at \$130 million. The opportunity cost should be considered explicitly in determining the extent of further water recovery through environmental water purchases. This principle of weighing the benefits and costs also applies to other water recovery mechanisms, such as on farm efficiency programs.

Implications for dairy

At the farm level, higher water allocation prices would accentuate the pressures already confronting dairy farmers. Individual dairy farms will be affected differently based on the numerous factors including their holdings of water entitlements. For example, a dairy farmer with a substantial portfolio of entitlements could benefit from higher water allocation prices in some seasons (as they could receive more from selling allocations), whereas a similar farmer without entitlements could be exposed to substantial financial losses, particularly in extremely low water allocation seasons. Allocation prices are estimated to increase from about \$603 to \$702 per ML (16 per cent) over the next five years in extremely low allocation seasons (similar to the worst years of the millennium drought). This could motivate some dairy farmers to rebalance their entitlement portfolios to include more high reliability entitlements, although this would increase the prices of those entitlements.

As allocation prices increase, dairy farmers will seek further opportunities to reduce water use by adjusting their production systems. Water use is estimated to be substantially lower in the dairy industry in 2020-21 compared to 2005-06, partly as a result of higher water allocation prices, and partly as a result of falling demand for water. Water use by livestock (including dairy) is estimated to fall from around 2280 to 1270 GL (44 per cent) in moderate allocation seasons, although most of this change has already occurred. These estimates do not account for the recent fall in milk prices received by dairy farmers. The dairy industry is not alone in experiencing a substantial reduction in water use, with rice being similarly affected.

Even small changes in the prices of important inputs, such as water, can result in significant changes in profitability and production. The farm level changes in profitability and production in response to the changes in water allocation prices outlined in this report are an area for further research. There would also be value in considering the effects of changes in water allocation prices alongside other key factors that influence dairy farmers, such as changes in milk prices and feed prices.

The estimated water market impacts have broader implications for the dairy industry. In particular, milk production in the sMDB is unlikely to recover to pre millennium drought levels unless there are offsetting improvements in milk prices, other input prices or production technologies. The recent fall in milk prices announced by Murray Goulburn highlights the potential for these other factors to exacerbate rather than moderate the effects of higher water allocation prices. If milk production does not recover, this would have consequences for processors. In particular, processors require a sufficient supply of milk to remain profitable. Assessing the magnitude of this risk requires a detailed knowledge of the cost structure of processing operations and is an area for further research. More generally, there is also the potential for changes in the dairy industry to have broader socio economic effects on regional communities, especially in the Goulburn Broken and North Central regions in northern Victoria where dairy is a major industry in the regional economy.

6. References

Aither 2016a, *Supply-Side Drivers of Water Allocation Prices: Identifying and Modelling Supply-Side Drivers of Water Allocation Prices in the Southern Murray-Darling Basin*, accessed May 2016, available at < <http://www.environment.gov.au/water/rural-water/restoring-balance-murray-darling-basin/water-allocation-price-supply-side-drivers-southern-mdb>>.

--- 2016b, *Contemporary Trends and Drivers of Irrigation in the Southern Murray-Darling Basin*, accessed May 2016, available at < <https://rirdc.infoservices.com.au/items/16007>>.

Dairy Australia 2016, data provided.

Fonterra Australia 2016, *Fonterra Australia Revises Milk Price for May and June 2016 and Introduces Support Loan*, accessed June 2016, available at < <http://www.fonterra.com>>.

Murray Goulburn 2016, *Supplier Briefing: Murray Goulburn Announces Revised Forecast, Appoints Interim CEO*, accessed June 2016, available at < <http://www.mgc.com.au/media/33308/chairmans-supplier-briefing-murray-goulburn-announces-revised-forecast-appoints-interim-ceo.pdf>>.

United Dairyfarmers Victoria (UDV) 2016, *Dairy in the Basin*, accessed May 2016, available at < *Dairy in the Murray Darling Basin*, http://www.australiandairyfarmers.com.au/_literature_196490/Final_Fact_Sheet_-_Dairy_in_the_Basin>.

Wittwer G. and Dixon P. 2011, *Water Trading, Buybacks and Drought in the Murray-Darling Basin: Lessons from Economic Modelling*, accessed May 2016, available at < <http://www.copsmodels.com/ftp/workpapr/g-222.pdf>>.

Appendix A - Aither water allocation price models

Overview

This report draws on two Aither models of the allocation market in the sMDB. The models share many similarities, but also have some fundamental differences. One model builds on price and volume data from Aither's water markets database. The other is based on evidence of water use behaviour collected from stakeholders throughout the sMDB. The models also differ in their functional forms (Box 2). While both models have been updated and refined over time, recent versions have been publically documented (Aither 2016a, b).

These models were developed to answer different policy questions. The statistical model is better at predicting annual median allocation prices given the influence of demand factors such as rainfall within irrigation areas, whereas the stakeholder model can be applied to a broader range of scenarios, including estimating the implications of demand changes by individual irrigation industries. The main results in this report are generated using the stakeholder model, given the need to examine industry level changes.

Box 2: Functional forms used in Aither water allocation price models

Figure 22 shows two hypothetical demand curves. The demand curves were estimated with the same data. The difference is the assumed functional form, which determines the broad shape of the demand function. Both functional forms allow for allocation prices to increase at an increasing rate as the volume of allocations falls (from right to left), but the log log functional form has more curvature than the log linear. Both functional forms have been widely used in estimating demand functions, and have similar performance when applied to the data. In the absence of clear evidence either way, Aither uses the log linear functional form as the default for the statistical model and the log log functional form as the default for the stakeholder model. The motivation behind using different functional forms is to generate a wide range of results as sensitivity analysis. The models differ most when water availability is lower than has been previously observed, highlighting substantial uncertainty in extreme conditions.

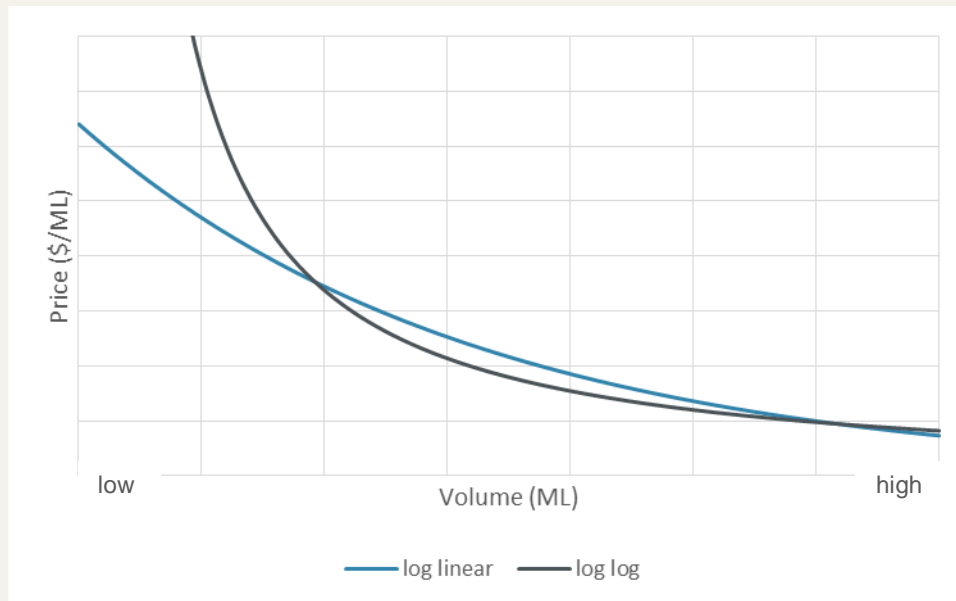


Figure 22 Stylised demand for allocations, effect of different functional forms

An advantage of having two models is that it is possible to compare the results across models. No model is perfect, but if models that use different approaches generate broadly similar results, the results can be interpreted and applied with more confidence.

Statistical model

Overview

Aither's statistical model of the allocation market in the sMDB expands on the approach introduced by Wittwer and Dixon (2011). The premise is that it is difficult to model the water market behaviour of individual irrigators because there is so much individual variation. For example, an irrigator could use a substantial volume of water while their neighbour uses no water because of differences in varieties, soils, risk preferences, or a multitude of other factors. These individual differences tend to even out over a sufficiently large number of irrigators, meaning that water market behaviour tends to be more predictable in aggregate.

The statistical model estimates the aggregate demand for allocations by irrigators. The volume demanded is assumed to depend on a number of factors, including the price of allocations. The relationship between price and the volume demanded gives the demand curve. The volume of allocations demanded is also assumed to depend on other factors. For example, rainfall within irrigation regions (Figure 23) tends to reduce the demand for irrigation water. This was evident in 2010-11 when high rainfall within irrigation regions caused water use per hectare to fall substantially across all major irrigation industries, despite a reduction in allocation prices. An increase in rainfall within irrigation districts causes the demand curve to shift inwards, whereas a decrease in rainfall has the opposite effect. Accounting for these other factors is important in developing a realistic model of the allocation market, such as the statistical model.

The impact of different factors on the volume of allocations demanded was estimated statistically using regression analysis. The version used in Aither (2016a) was calibrated based on data from

1998-99 to 2014-15. In the most recent version presented in this report, the model was calibrated based on data from 1998-99 to 2015-16. There have also been refinements to the treatment of rainfall within irrigation regions. This resulted in some differences between the versions. The results for both versions are presented in Section 4. Aither will continue to update this model over time as new evidence becomes available.

Figure 24 shows actual and estimated allocation prices for the most recent version of the model. The most recent year, 2015-16, is a projection. This demonstrates that the model is effective at explaining historical water allocation prices. Tests undertaken when the statistical model was peer reviewed by leading academics also showed good out-of-sample predictive ability (Aither 2016a).

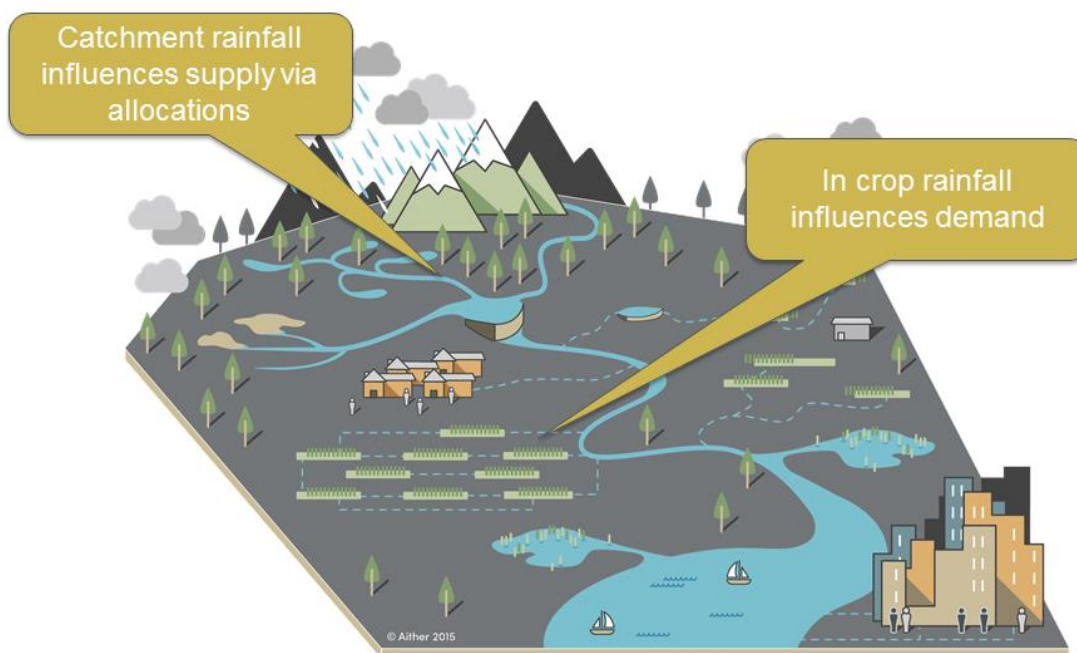


Figure 23 The impact of water allocations and rainfall within irrigation districts

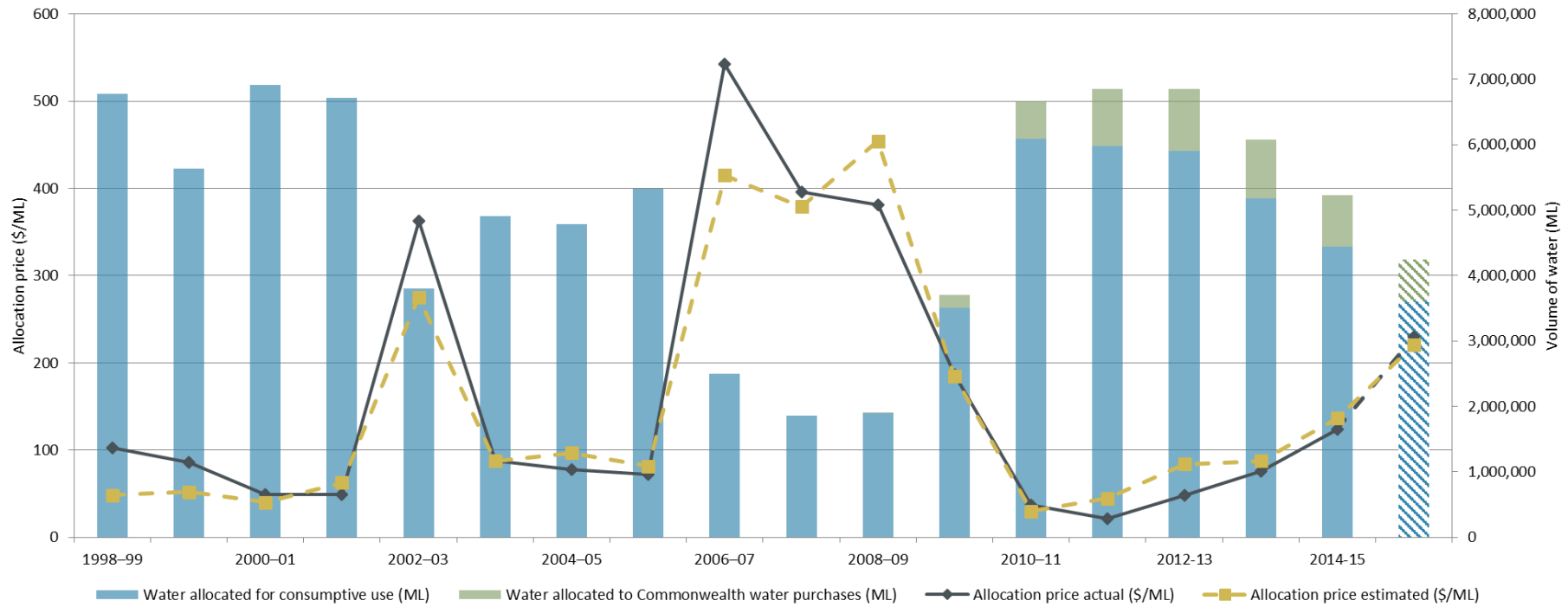


Figure 24 Actual and estimated water allocation prices, 1998-99 to 2015-16

Caveats

Both models assume that the allocation market in the sMDB is a single connected system, without any binding constraints. This is generally a reasonable approximation, although there are times when trade restrictions lead to differences in prices across markets. The models simulate market outcomes over an annual time step, and omit some of the nuances that occur within a season. The models are based on observed water market behaviour, and do not assume that irrigators necessarily make perfect water trading decisions.

The following caveats apply to the statistical model:

- The statistical model does not account for water trade restrictions (for example, limits on net trade out of the Murrumbidgee).
- The statistical model does not simulate within season water market behaviour.
- The sample of time series data available to estimate the statistical model is limited given that liquid allocation markets have only emerged in the last two decades.
- There are likely to be some inaccuracies in recorded allocation prices that cannot be addressed through data cleaning, especially prior to 2006-07.
- The version of the statistical model used in this report does not account for carryover. Carryover was included in a subsequent version of the model, but only had a small impact on the results.

Aither (2016a) provides further technical detail on the modelling approach. It also presents an extensive list of caveats and discusses the potential implications.

Stakeholder model

Overview

The stakeholder model takes a different approach to the statistical model to essentially the same problem – estimating the demand for allocations. But instead of estimating aggregate demand, demand is estimated separately for the following industries:

- livestock (including dairy)
- rice
- cotton
- fruits and nuts
- grapes
- other agriculture.

Demand is then summed over these industries to estimate aggregate demand across all irrigators. This allows changes in demand to be simulated at the industry level. For example, demand for cotton could be increased and demand for rice decreased. The resulting impacts on allocation prices can then be simulated, as well as the implications for water use by industry.

Another difference is that the stakeholder model does not use a statistical approach to estimate demand. The stakeholder model draws on multiple sources of evidence to estimate demand including

the knowledge of stakeholders, such as water brokers, industry groups and rural water authorities. The premise behind the estimation procedure is that a demand curve is comprised of many points, each representing a combination of price and volume. If two points are known, the rest of the demand curve can be filled in (under the assumption that the demand curve follows a log log functional form) (Figure 25).

The observed price and volume combination gives one point on the demand curve. In the stakeholder model, this was determined for each industry based on Aither's water market database and ABS water use data. The calibration was based on the 2013-14 irrigation season, the most recent year for which the ABS water use data are available. (To be clear, the fact that the model was calibrated to 2013-14 does not prevent it from being applied to seasons with markedly different allocation prices.)

The other point on the demand curve was determined by the 'cut off price'. This is defined as the hypothetical price at which demand for allocations by a specific industry would have become negligible, based on 2013-14 conditions. Negligible is assumed to mean 20 per cent of actual water use in that year. The cut off prices are the most important parameter in the stakeholder model. The estimated cut off price is \$165 per ML for rice, and \$250 per ML for cotton and dairy.

The cut off prices for industries with permanent plantings are substantially higher at \$1800 per ML for grapes and \$3000 per ML for fruits and nuts. This reflects the potential for yield reductions in future seasons if permanent plantings do not receive a sufficient water in the current season. These considerations were evident in the millennium drought when many irrigators with permanent plantings purchased (or used) water allocations at prices of around \$1000 per ML to keep their permanent plantings alive, despite losses in that season. These longer term considerations increase the cut off prices above what would appear reasonable considering the only the gross margins in the current season. Another reason why these cut off prices are high is that they relate to the water allocation price at which the most profitable farmers drop out of the market, whereas gross margins usually relate to the average farm.

There is greater uncertainty around the cut off prices for industries with permanent plantings, largely because these values have not been tested by the market. In Aither (2016b), sensitivity analysis was undertaken with different cut off prices. The impacts on the results were not substantial.

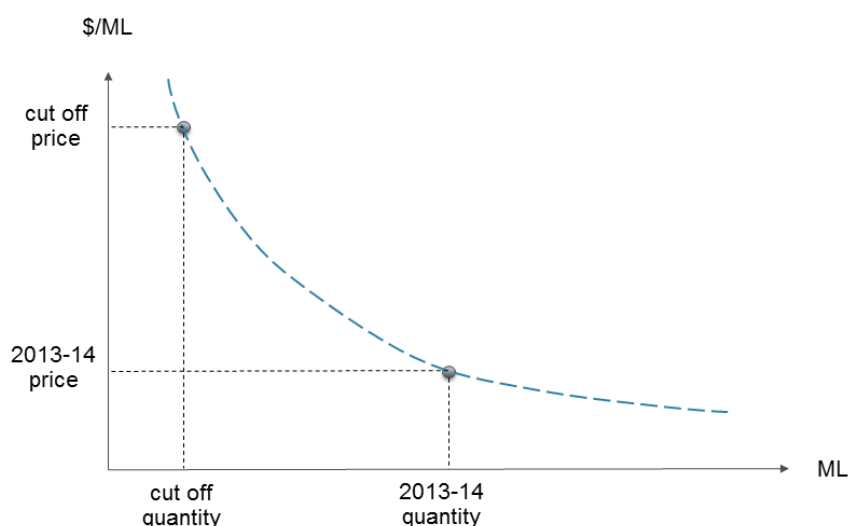
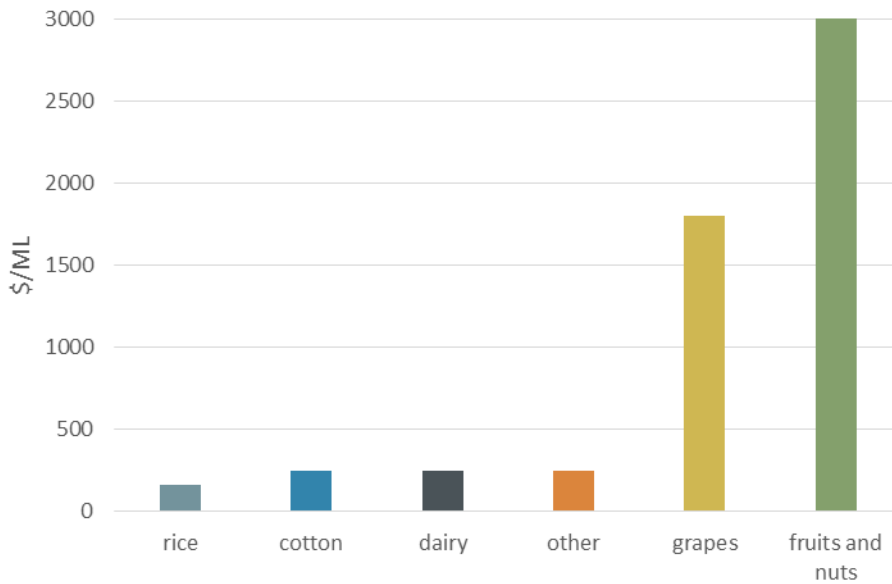


Figure 25 Procedure for estimating industry water demand



Source: Aither estimates.

Figure 26 Estimated cut off price by industry

Caveats

Some of the caveats that apply to the statistical model are also relevant to the stakeholder model, such as the assumption of no water trade restrictions. However, there are caveats that are specific to the stakeholder model:

- While generally reliable, Aither did identify some potential inconsistencies between the ABS water use data used to calibrate the model and equivalent data from other sources.
- Aither has low or moderate confidence in some estimated cut off prices, especially for permanent plantings where the cut off prices are outside market experience.
- The stakeholder model has not yet been validated against historical allocation prices. It is unlikely to explain historical allocation prices as well as the statistical model because the stakeholder model does not account for shifts in demand due to factors such as rainfall within irrigation regions. A hybrid approach is used in this paper to overcome this limitation.

Aither (2016b) provides further information on the evidence underlying the stakeholder model and the caveats.

Appendix B – Additional figures

Scenario 1: Historical buyback

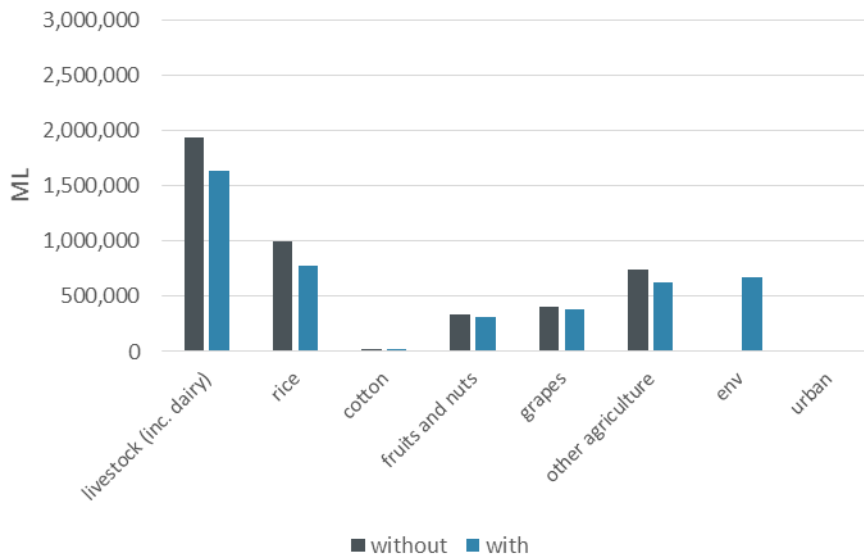


Figure 27 Modelled sMDB surface water use with and without historical Commonwealth environmental water purchases, low allocation season (Scenario 1)

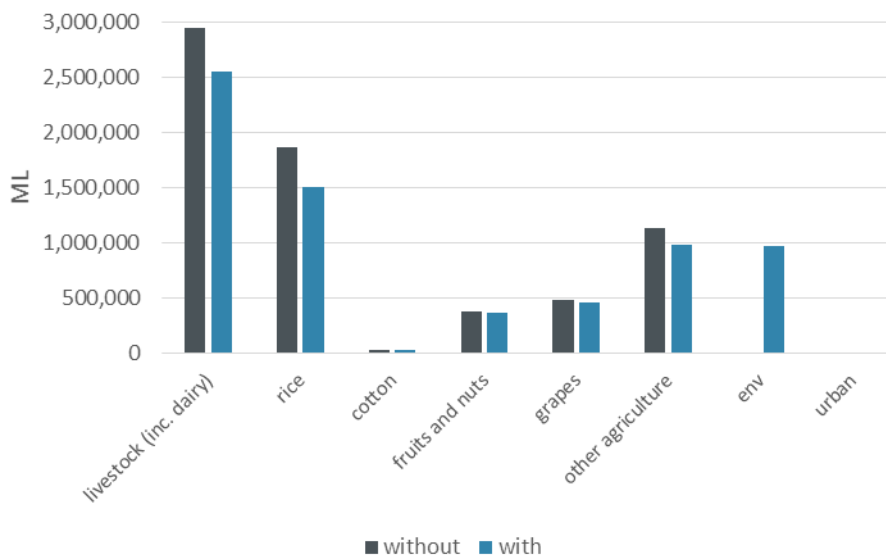


Figure 28 Modelled sMDB surface water use with and without historical Commonwealth environmental water purchases, high allocation season (Scenario 1)

Scenario 2: Historical irrigation and urban

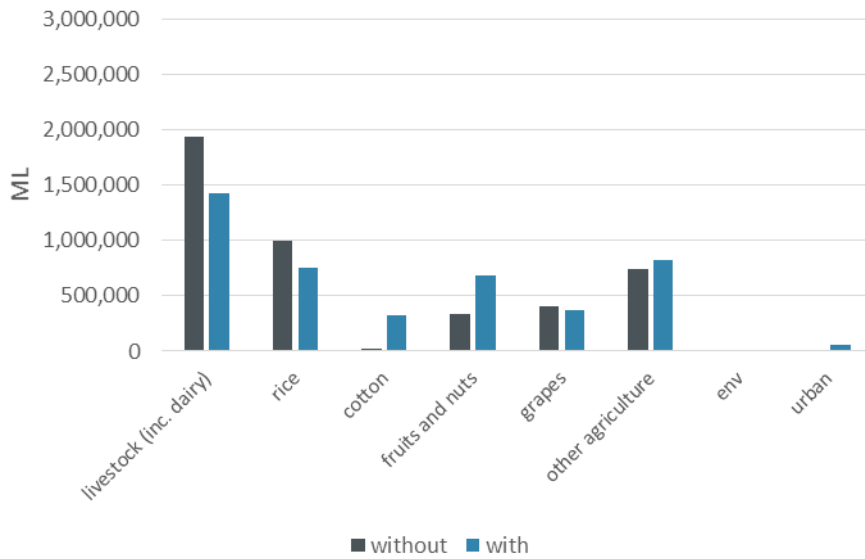


Figure 29 Modelled sMDB surface water use with and without historical changes in demand by irrigation industries and urban water authorities, low allocation season (Scenario 2)

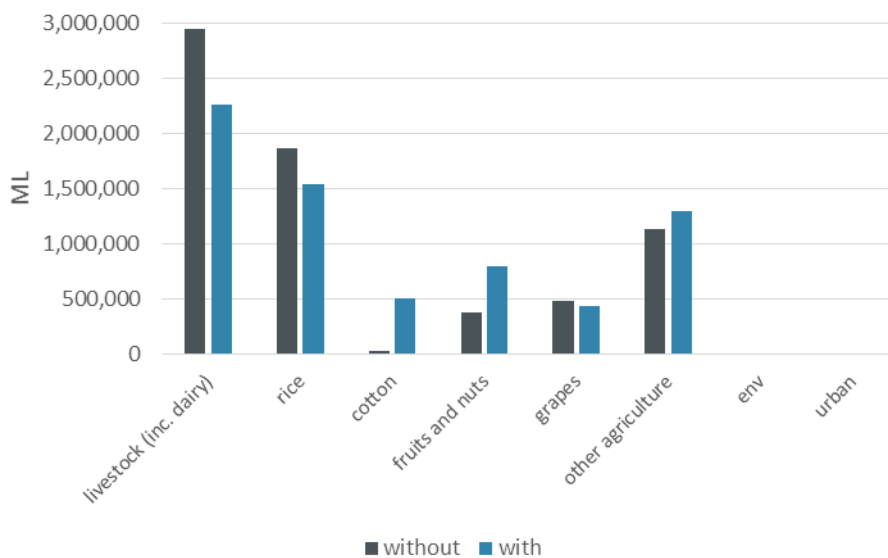


Figure 30 Modelled sMDB surface water use with and without historical changes in demand by irrigation industries and urban water authorities, high allocation season (Scenario 2)

Scenario 3: All historical

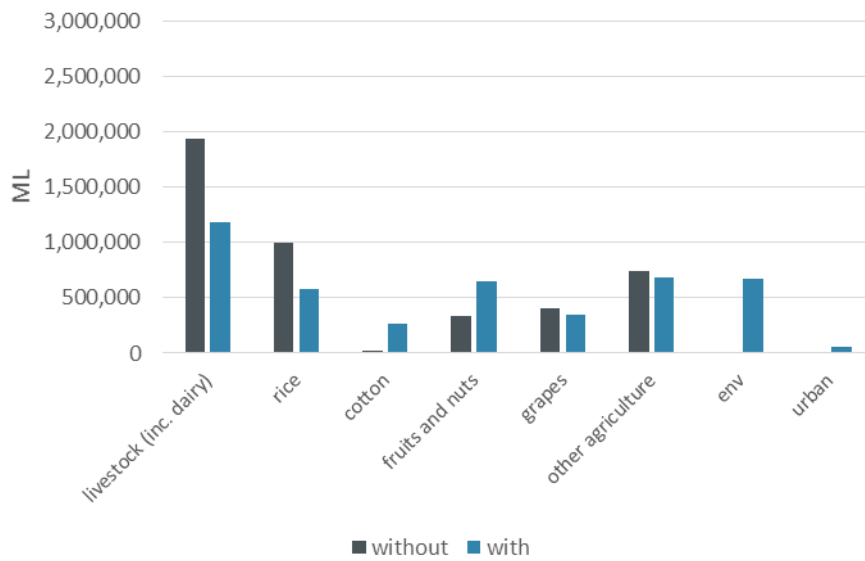


Figure 31 Modelled sMDB surface water use with and without historical changes, low allocation season (Scenario 3)

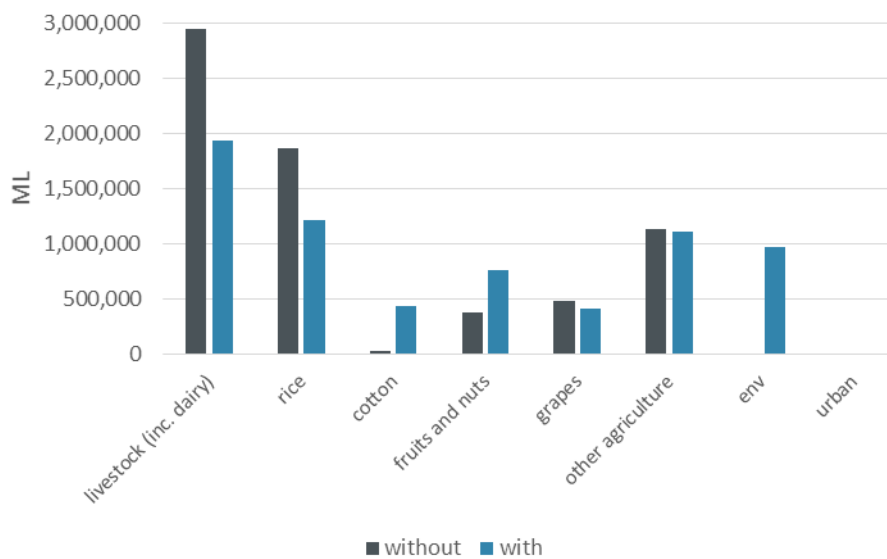


Figure 32 Modelled sMDB surface water use with and without historical changes, high allocation season (Scenario 3)

Scenarios 4a and 4b: Future buyback

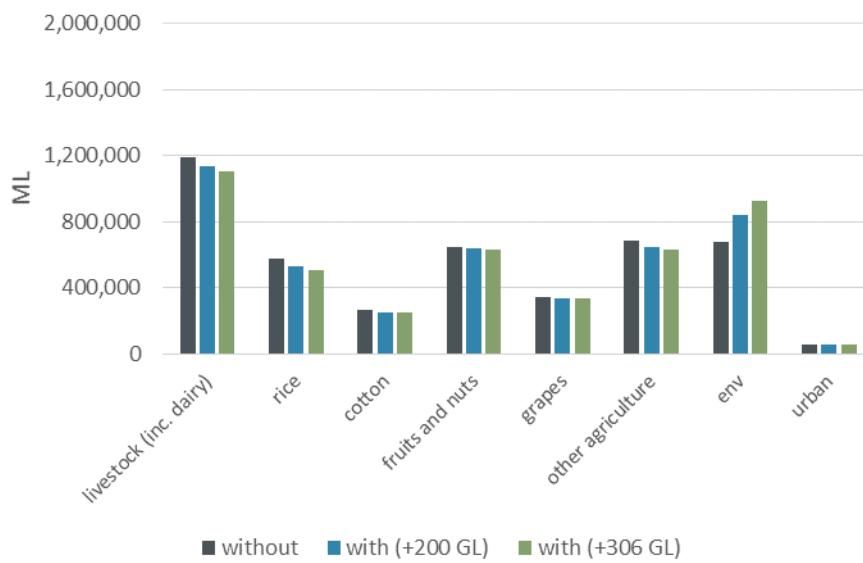


Figure 33 Modelled sMDB surface water use with and without future Commonwealth environmental water purchases, low allocation season (Scenario 4a and 4b)

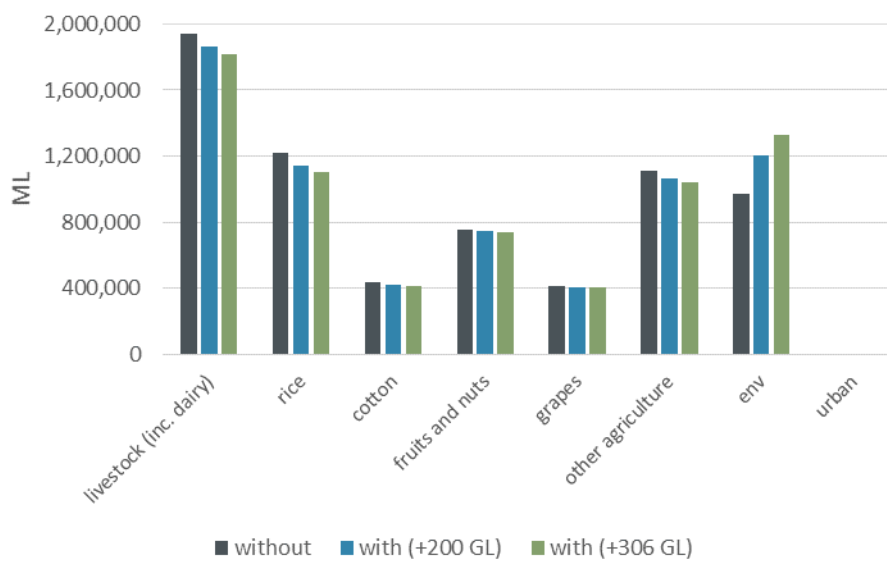


Figure 34 Modelled sMDB surface water use with and without future Commonwealth environmental water purchases, high allocation season (Scenario 4a and 4b)

Scenario 5: Future irrigation and urban

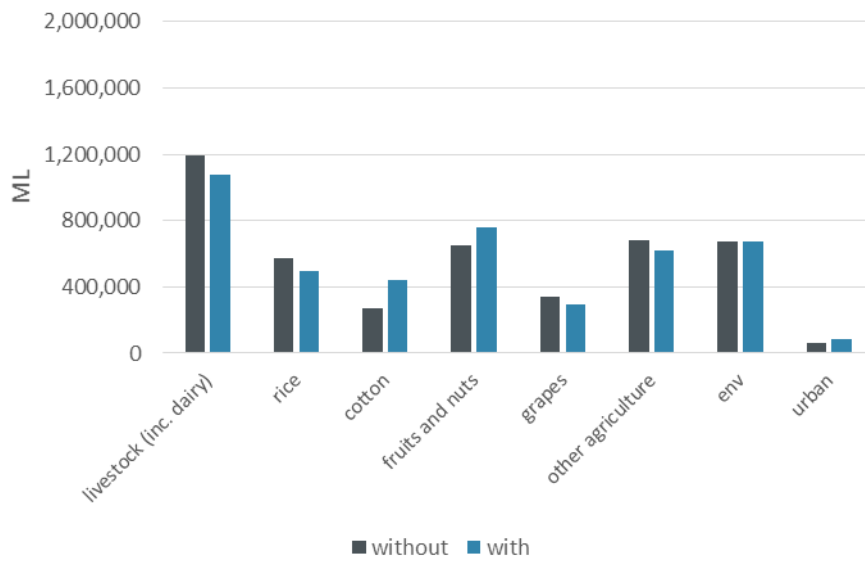


Figure 35 Modelled sMDB surface water use with and without future changes in demand by irrigation industries and urban water authorities, low allocation season (Scenario 5)

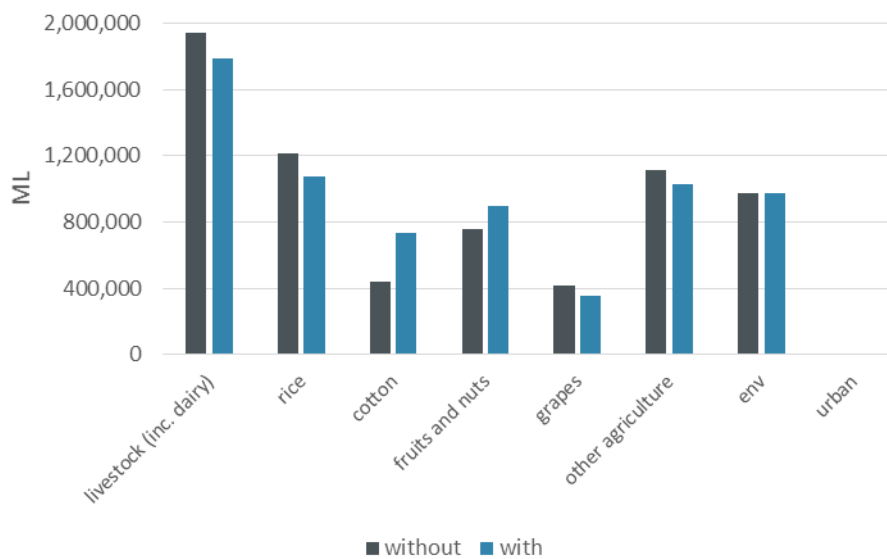


Figure 36 Modelled sMDB surface water use with and without future changes in demand by irrigation industries and urban water authorities, high allocation season (Scenario 5)

Scenario 6: All future

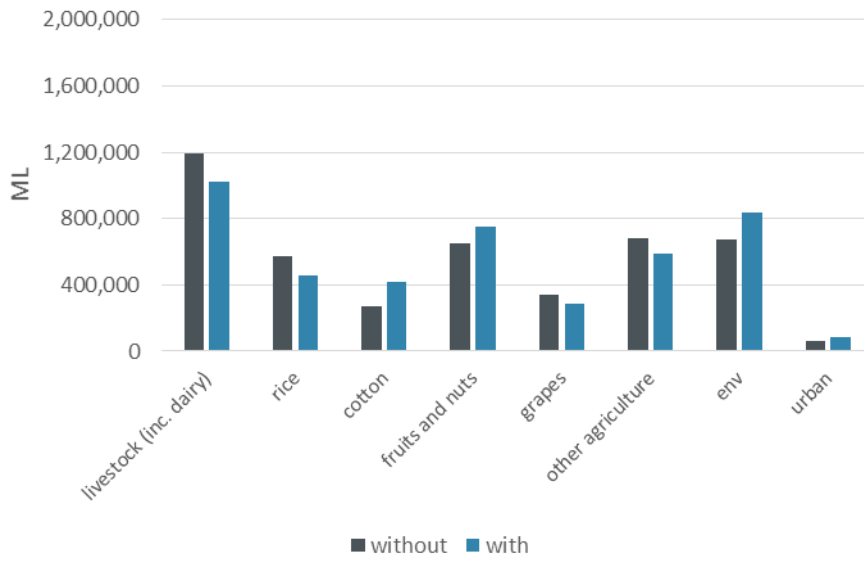


Figure 37 Modelled sMDB surface water use with and without future changes, low allocation season (Scenario 6)

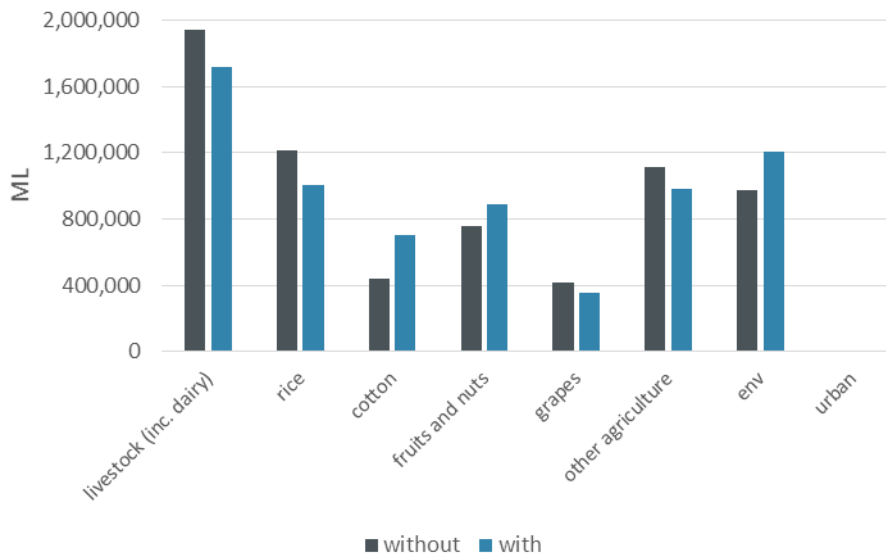


Figure 38 Modelled sMDB surface water use with and without future changes, high allocation season (Scenario 6)

Appendix C – Tables of results

Table 3 Water allocation price impacts associated with different scenarios (real 2016 dollars)

	Scenario	Low allocation season (similar to 2015-16)		Moderate allocation season (similar to 2014-15)		High allocation season (similar to 2011-12)	
		With	Without	With	Without	With	Without
		\$/ML	\$/ML	\$/ML	\$/ML	\$/ML	\$/ML
Historical (last 10 years)	1: Buyback	196	172	114	101	36	32
	2: Irrigation and urban	181		104		33	
	3: All	207		118		37	
Future (next 5 years)	4a: Buyback (+200GL)	214	207	122	118	38	37
	4b: Buyback (+306GL)	219		125		39	
	5: Irrigation and urban	223		126		39	
	6: All	231		131		41	

Table 4 Water allocation price impacts associated with historical Commonwealth environmental water purchases, additional simulations using the statistical model (real 2016 dollars)

	Scenario	Version	Low allocation season (similar to 2015-16)		Moderate allocation season (similar to 2014-15)		High allocation season (similar to 2011-12)	
			With	Without	With	Without	With	Without
			\$/ML	\$/ML	\$/ML	\$/ML	\$/ML	\$/ML
Historical (last 10 years)	1: Buyback	Initial statistical	NA	NA	112	88	34	25
		Revised statistical	221	172	137	101	47	32

Table 5 Surface water use by the sMDB dairy and other livestock industries associated with different scenarios

	Scenario	Low allocation season (similar to 2015-16)		Moderate allocation season (similar to 2014-15)		High allocation season (similar to 2011-12)	
		With	Without	With	Without	With	Without
		GL	GL	GL	GL	GL	GL
Historical (last 10 years)	1: Buyback	1642	1938	1941	2277	2549	2950
	2: Irrigation and urban	1427		1720		2263	
	3: All	1190		1450		1939	
Future (next 5 years)	4a: Buyback (+200GL)	1133	1190	1384	1450	1860	1939
	4b: Buyback (+306GL)	1101		1348		1818	
	5: Irrigation and urban	1077		1328		1790	
	6: All	1023		1267		1715	

Document history

Revision:

Revision no.	2
Author/s	Simon Hone, Chris Olszak, Will Fargher
Checked	Will Fargher
Approved	Chris Olszak

Distribution:

Issue date	Friday 29 July 2016
Issued to	Dairy Australia
Description	Final Report

Citation:

Aither (2016) Water market drivers in the southern MDB: Implications for the dairy industry. A report prepared for the Dairy Australia, July.

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