

The top half of the cover features a large, faint, light-blue watermark of the word "AITHER" in a bold, sans-serif font, set against a background of overlapping geometric shapes in various shades of blue and teal.

Supply-side drivers of water allocation prices

Identifying and modelling supply-side drivers of water allocation prices in the southern Murray-Darling Basin

Final Report

January 2016

A I T H E R

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Aither is an Australian economics and public policy advisory firm with deep expertise in water management, infrastructure and utility industries, the environment and natural resources.

Aither is a leading provider of independent water market advisory services in the Murray Darling Basin and beyond. We provide economic, policy, and strategic commercial advice, analysis and insights to policy makers, regulators and market participants. Through our work, we aim to support and improve better informed policy and decision making.

Our team is made up of water market experts with unparalleled depth and breadth of experience. We have led and advised on the development, implementation and assessment of major entitlement and market reforms across Australia. Recently we have advised on large commercial transactions in water entitlements and supported market participants in the development and implementation of innovative trading strategies. Our team is frequently sought after to present internationally on Australia's water entitlement and market reform journey.

In recognition of our credibility and commitment, Aither received the Australian Water Association Research Innovation Award (Victoria) in December 2015 for the development of our freely available annual [Aither Water Markets Report](#). These reports, along with all our independent periodic market reporting to our clients, are underpinned by our comprehensive database of trading activity and responsive approach.

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Our team provides services across policy advice and analysis, portfolio management, and commercial advice. This includes:

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- Reports on market activity and analysis of trends and drivers
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- Investor, board and executive presentations
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Abbreviations

CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
DotE	Commonwealth Department of the Environment
DSE	Victorian Department of Sustainability and Environment
GL	Gigalitre
ML	Megalitre
NWC	National Water Commission
OEH	New South Wales Office of Environment and Heritage
sMDB	Southern Murray-Darling Basin
TLM	The Living Murray
VEWH	Victorian Environmental Water Holder

Glossary

Annual water requirements (or demands)	Refers to the total volume of water required by irrigators or agricultural producers to meet a certain level of production in a given water year.
Commonwealth water purchases	Commonwealth water purchases refer to water entitlements purchased by the Commonwealth Government under the Restoring the Balance in the Murray-Darling Basin Program, sometimes referred to as 'buyback'.
Elasticity	Demand elasticity is the percentage change in quantity of water demanded in response to a 1 per cent increase in price.
In-crop rainfall	Refers to the total volume of precipitation (rainfall) that falls directly on productive land that is used for irrigated purposes.
Rainfall in growing regions	Refers to the total volume of precipitation (rainfall) that falls within regions in the southern Murray-Darling Basin that has irrigated agriculture production.
Water allocation	Water allocations are the volumes of water allocated to water entitlement holders during the water year (1 July to 30 June). They are a physical good analogous to a commodity, and are extracted from water courses and applied as inputs to production or the environment.
Water availability	Refers to the total volume of water available to all water users in a given water year, which includes both water allocated to all entitlements and rainfall in growing regions.
Water allocated to all entitlements	Refers to the total volume of water allocated by state governments to water entitlement holders during the water year (1 July to 30 June) – including water entitlements held by environmental water holders. Measured as an aggregate volume at the end of the water year (30 June).

Water allocated that is available for consumptive use	Refers to the total volume of water allocated by state governments to water entitlement holders during the water year (1 July to 30 June) – excluding water allocated to water entitlements held by the Commonwealth associated with the water purchases in the southern Murray-Darling Basin. Measured as an aggregate volume at the end of the water year (30 June).
Water allocated to Commonwealth water purchases	Refers to the total volume of water allocated by state governments to water entitlements held by the Commonwealth associated with the water purchases in the southern Murray-Darling Basin. Measured as an aggregate volume at the end of the water year (30 June).
Water entitlement	Water entitlements are ongoing rights to receive an annual share of available water resources in a consumptive pool as established in a specific river system, catchment, or aquifer. Entitlements are generally secure, tradeable, divisible and mortgageable in the same way as land.
Water markets	Water markets are regulated markets where formalised transactions of water entitlements and allocations can occur between parties. There is no single national water market, but rather a number of individual (but in some cases connected) markets. Where hydrological connectivity exists, such as in the SMDB, trade between these markets is possible.
Water price	Refers to the cleared and contracted transaction price reported of allocation and entitlement trades between parties. It does not account for fees or charges, and is importantly distinct from urban water prices.
Water year	The water year refers to the period of time between 1 July and 30 June of the following year. It is the same as a standard financial year.

Executive summary

In September 2015, the Commonwealth Department of the Environment (the Department)¹ engaged Aither to undertake independent analysis of the impact of supply-side drivers – including climatic conditions and Commonwealth water purchases – on water allocation prices in the southern Murray-Darling Basin (sMDB). This report identifies and quantifies the supply-side drivers of water allocation prices in the sMDB. It includes an assessment of the historic allocation market price impacts of these drivers, and possible outcomes under future scenarios.

Participation in Australian water markets

Water markets in Australia have developed substantially over the past two decades. They are now an established part of water policy and management. The formalisation of water markets – especially in the sMDB – enables the attainment of important public and private benefits through the trade of both water entitlements and allocations.

Water allocation markets were developed as an effective and efficient means to manage competing demands for scarce water resources, including to provide water users with a means to manage variability in water supply (including responding to rainfall) within production years. The water allocation market in the sMDB is used by a diverse range of irrigated agriculture producers, water utilities, governments and investors to buy or sell water.

Market participants buy or sell in water allocation markets for a variety of reasons, such as purchasing water to supplement irrigation requirements or selling water that is surplus to requirements in a given season. The price of water allocations at any point in time is determined by the interaction between market participants, each with their own circumstances and reasons for participation in the market.

Supply-side drivers of water allocation prices

While reasons for participation in water markets are varied, in aggregate, prevailing climatic conditions have been the primary drivers of water allocation prices and for participation in water markets historically. Water allocation prices vary dramatically due to the fact that climatic conditions impact both supply (water allocated to all entitlements) and demand for irrigation water. Specifically:

- The total volume of water allocated to all entitlements is important because it constrains the total supply of water available for consumption (including irrigation).
- Irrigators use water allocated that is available for consumptive use in a given year as a controllable water supplement to in-crop rainfall. In years with high in-crop rainfall, the price of water allocations should reduce due to an increase in water availability (supply) and a decrease in water allocation demand (more in-crop rainfall and lesser need to supplement with irrigation water). The opposite is the case in years with low rainfall or periods of sustained drought.

When looking back over the last two decades, total water allocated that is available for consumptive use and prevailing climatic conditions in irrigation areas emerge as the primary drivers of allocation prices. In particular, Aither has developed a model to simulate aggregate level impacts of water

¹ The Water Division of the Department of the Environment, which commissioned this report, is now located in the Department of Agriculture and Water Resources.

availability on annual median water allocation prices, the performance of which is shown in Figure ES1.



Note: Prices reported are annual medians and are real – adjusted for inflation based on annual CPI data from the Australian Bureau of Statistics (\$ per ML). The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure ES1 Observed and modelled historical water allocation prices against water allocated to all consumptive and Commonwealth purchased entitlements, 1998-99 to 2014-15

Commonwealth Government water purchases

The Commonwealth Government, under the Restoring the Balance in the Murray-Darling Basin Program, has purchased approximately 996 GL of water entitlements from market participants in the major trading zones in the sMDB since 2007-08.² The ongoing use of this water is for environmental purposes. The Commonwealth Environmental Water Holder (CEWH) has the ability to trade but, at the time that the analysis undertaken by Aither (September 2015), no water held by the CEWH in the sMDB had been traded back to other market participants³. This environmental water reduces the effective volume of water allocated that is available for consumptive use (Figure ES1). In principle, this reduction in supply can be expected to increase water allocation prices relative to prices without Commonwealth water purchases. While Commonwealth entitlement purchases reduce water allocated for consumptive use, these purchases of water do not reduce rainfall in growing regions.

² In addition to Commonwealth water purchases, other water entitlements are owned by governments and contribute to water recovery objectives of the Basin Plan. Some of this water was never included as part of the consumptive pool before it was secured on behalf of the environment so it has not been included in our assessment. It is possible that some water recovered through on-farm water efficiency programs removed water from the consumptive pool. However, Aither was not provided with sufficient data that would enable robust assumptions to be made about how much water has been recovered through these on-farm water efficiency programs. For this reason, Aither has excluded these volumes of water from calculations of water removed from the consumptive pool by the Commonwealth Government.

³ The CEWH subsequently sold 20 GL of water allocations in the Goulburn system later in 2015. This was not included in the analysis in this report.

Measuring the impact of Commonwealth water purchases

Aither's water allocation price model has been used to quantify the historic and potential impact of supply-side drivers (including Commonwealth water purchases). Based on a set of explanatory variables (e.g. assumptions about water availability in a given year), the Aither model is able to generate estimated annual per Megalitre (ML) median allocation prices for the whole of the sMDB.

To identify and quantify the impact that supply-side drivers have on water allocation prices, a number of scenarios were developed and tested. The scenarios were developed to specifically test for the potential short run impact of:

- Commonwealth water purchases on water allocation prices between 2007-08 and 2014-15
- the current volume of Commonwealth water purchases on future water allocation prices
- an assumed additional 200 Gigalitres (GL) of Commonwealth water purchases in the sMDB.

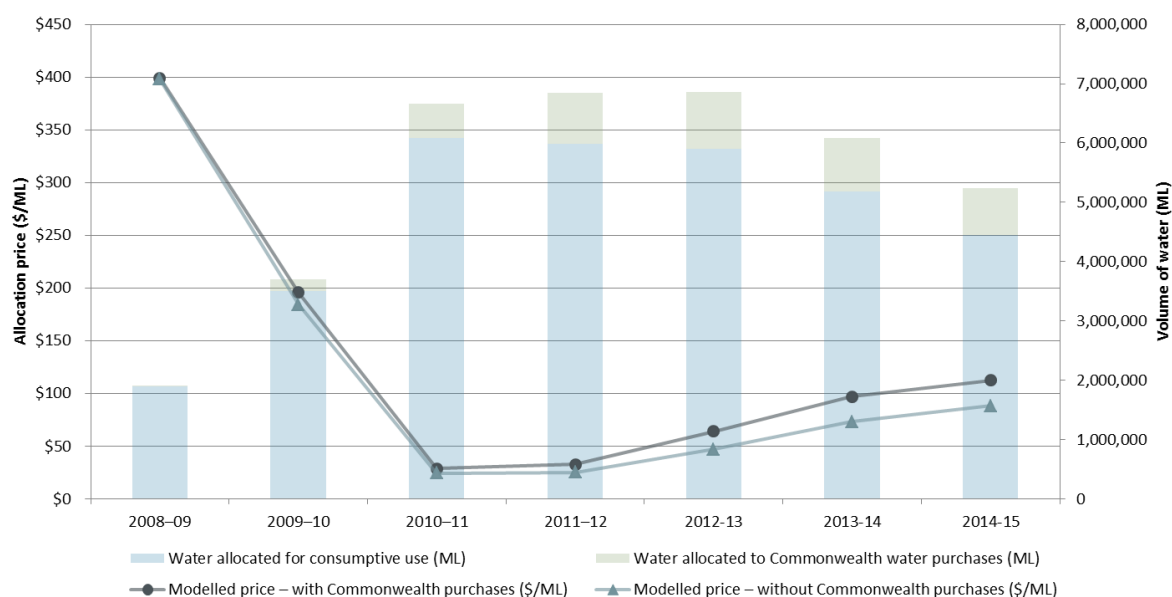
Historical price impact of Commonwealth water purchases

The price model is able to measure the potential impact of Commonwealth water purchases on historical water allocation prices. It does this by comparing modelled historical allocation prices against the modelled historical allocation prices if purchases had not occurred and water allocated to Commonwealth water purchases was available for consumptive use.

The results of this analysis show that as the cumulative volume of Commonwealth water purchases has increased since 2008-09, the potential short-run price impact has also increased – reflected by the price difference between the two data points reported for each year, shown in Figure ES2.⁴ For example, in 2014-15, 18 per cent (786 GL) of water was allocated to Commonwealth purchased entitlements. The difference between modelled annual median prices with and without Commonwealth purchases is \$24 per ML, increasing from \$88 to \$112 per ML.

While modelling indicates that Commonwealth water purchases have increased water allocations prices, inter-annual price shifts appear to be driven more significantly due to overall changes in water availability than Commonwealth water purchases. For example, annual median prices decreased by over 90 per cent from around \$400 / ML during the Millennium drought in 2008-09 to less than \$30 / ML in 2010-11 and 2011-12 in response to extremely wet conditions, even with substantial allocations to the Commonwealth purchases in those years.

⁴ The total volume of cumulative Commonwealth water purchases has not grown significantly since 2012-13.



Note: The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

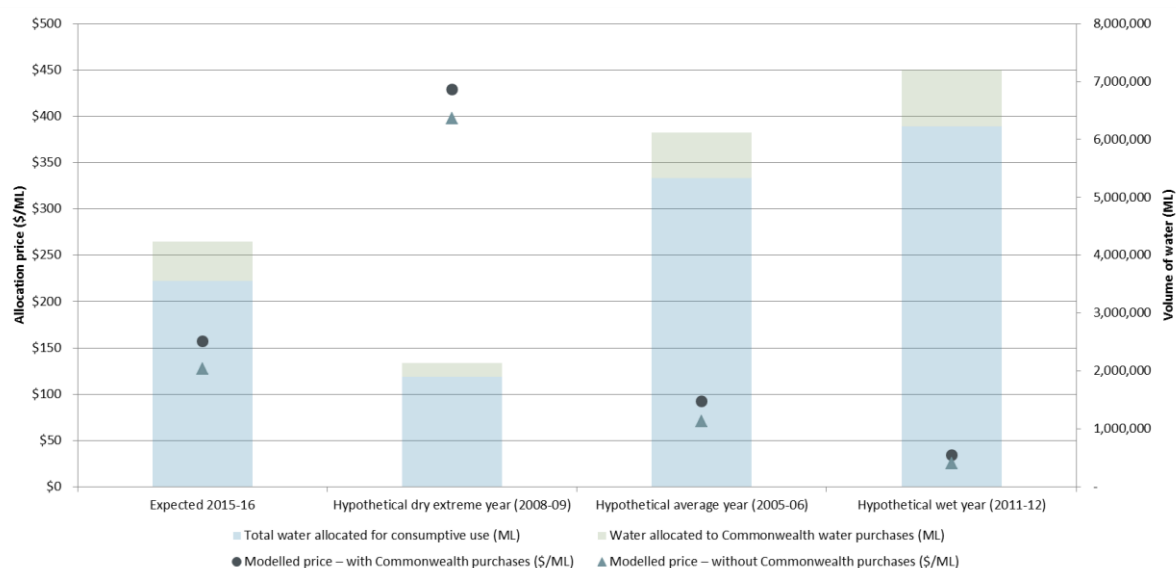
Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure ES2 Historical water allocation price impact of Commonwealth water purchases, 2008-09 to 2014-15

Price impact of current Commonwealth water purchases under future seasonal conditions

Aither's price model is able to estimate the potential impact of water allocated to current Commonwealth water purchases in the sMDB on annual median water allocation prices in hypothetical future years. The results of analysing potential future price impacts suggest that water allocated to current Commonwealth water purchases will tend to have larger short-run price impacts in dry years (\$31 per ML price increase) than wet years (\$9 per ML price increase) – in dollar terms, based on the modelling assumptions (Figure ES3).⁵ Figure ES3 also highlights the much larger impact that changes to water availability can have on prices in comparison to the relatively modest potential price increase impacts of Commonwealth water purchases shown previously in Figure ES2. Specifically, prices in the modelled wet year are less than half those in the average year, and approximately 90 per cent lower than the modelled price in an extreme dry year.

⁵ Please see Section 3.2 for model assumptions.



Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure ES3 Estimated water allocation price impacts of Commonwealth water purchases for hypothetical future water years

Impact of additional Commonwealth water purchases

Based on progress to date with recovering water for the environment in the Murray-Darling Basin, there is the potential that further Commonwealth water purchases will be required. The purchase of additional water for the environment will increase the volume of water held by the Commonwealth (above current volumes), and as a result, further reduce the volume of water allocated that is available for consumptive use in any given future year. Aither assessed the likely price impacts of an assumed 200 GL of additional Commonwealth water purchases in the sMDB.

Analysis of this hypothetical additional Commonwealth water purchase showed that only minor additional price impacts would be felt under all hypothetical future water years – adding a further 2 per cent to median water allocation prices in a repeat of an extreme dry year, 4 per cent in an average year and 6 per cent in a wet year.

Conclusions

The modelling suggests that the current volume of water allocated to Commonwealth water purchases increases annual median water allocation prices in the sMDB above prices that would occur had Commonwealth water purchases not occurred. While material, particularly in dry years, the modelling suggests that Commonwealth water purchases are a less important driver of allocation prices compared with total water availability and prevailing climatic conditions (i.e. water allocated that is available for consumptive use and rainfall in growing regions). Modelling shows that climatic conditions are the prime determinants of variability in water allocation prices, and can explain the majority of inter-annual variability with a high degree of confidence. Specifically, while the impacts of the Commonwealth purchases were typically estimated to be within the range of \$9-\$31 per ML, modelled prices ranged from less than \$40 in wet years to over \$400 in extreme dry years.

It is important to note that the price impact estimates presented in this report are short-run impacts, which assume no structural changes to demand for water in sMDB, and no long term impacts of climate change. Over the longer-term, and with all other factors held constant, increased water prices

associated with the impact of Commonwealth water purchases could force some irrigators to adjust or cease production. As such structural adjustment occurs, the underlying demand for water in the sMDB may decrease, placing downward pressure on allocation prices more generally. However Aither also note that there are a number of important demand-side factors, which along with climate change, will influence the ultimate structure and value of the irrigation sector in the sMDB in the medium to long-term. For example, the current and expected future expansion of the almond and cotton industries has led to an increase in high value demand for water (Aither, forthcoming).

Peer review

This report was provided for peer review to two leading water economists with knowledge of Australian water markets and policy: Professor Lin Crase – La Trobe University; and Professor Quentin Grafton – Australian National University. The peer review process was used to verify the robustness of this report. Both peer reviewers confirmed that the general approach taken to this project was robust, the allocation price model is fit for purpose; results presented are credible; and conclusions are sound. Comments from peer reviewers can be found at Appendix A.

1. Introduction

In September 2015, the Commonwealth Department of the Environment (the Department)⁶ engaged Aither to produce an independent report to identify and quantify the impact that supply-side drivers, including the Commonwealth's water purchases, have on water allocation prices in the southern Murray-Darling Basin (sMDB).

1.1. Report scope

The scope of this report covers an examination of climatic and supply-side drivers of water allocation prices in the sMDB and an assessment of the price impacts that these drivers have had historically and could have under future scenarios. The primary aim of the study is to quantify the relative importance of climatic related factors and Commonwealth water purchases on allocation prices.

Specifically the scope includes an:

- examination of supply-side drivers and their individual impact on water allocation prices to date – including discussion about the source and relative scale of impact on prices
- analysis of the estimated short run impact of supply-related drivers on allocation prices under several future scenarios – including changing water availability scenarios and Commonwealth water purchases in the sMDB.

The scope of the engagement includes using the Aither proprietary water allocation price model to assess the impact of supply-side drivers on water allocation prices. The scope of the engagement did not include any assessment of future changes in irrigation demand or long term impacts of climate change. Aither's scope did not include commentary on the appropriateness or effectiveness of any particular water policy settings or a broader examination of the social, economic and environmental impacts of Commonwealth water recovery initiatives.

1.2. The Aither water allocation price model

Allocation trading decisions by market participants are complex and influenced by a range of factors (see Section 2). This makes it difficult to develop detailed models of individuals or groups of market participants' economic decisions. In particular, it can be difficult to accurately reflect the options available to market participants to respond to reduced water availability. In examining aggregate level drivers of water allocation prices, a suitable alternative is to use statistical models to analyse aggregate water market outcomes more directly.

The Aither allocation price model adopts this aggregate level approach. It generates modelled annual per megalitre (ML) median allocation prices for the whole of the sMDB – i.e. it is not specific to individual trading zones, specific times within an irrigation season, or changes in climatic or supply-demand circumstances within the year. The model is based on a regression analysis that has been calibrated over 17 years of observed data. The model has an R^2 of 90 per cent (Adjusted R^2 value of

⁶ The Water Division of the Department of the Environment, which commissioned this report, is now located in the Department of Agriculture and Water Resources.

0.89), meaning that the model accounts for 90 per cent of the observed variability in historical annual median allocation prices.

The model can be used to generate estimates of annual median allocation prices based on an assumed set of inputs; including the total annual volume of water allocated that is available for consumptive use. The model is able to estimate the potential impact of Commonwealth water purchases on annual median historical and future water allocation prices, given that the cumulative volume of the purchases reduce the volume of water allocated that is available for consumptive use. Please refer to Section 3 for further information about the allocation price model – including the caveats of the model.

1.3. Approach and methodology

Following a qualitative description of the drivers of allocation prices in the sMDB, the approach to developing this report consisted of four tasks:

1. Quality assurance of data inputs.
2. Development of model scenarios.
3. Analysis of model outputs.
4. Reporting and peer review.

1.3.1. Quality assurance of data inputs

As an initial step, Aither undertook a quality assurance process to ensure the accuracy of data inputs used to inform the allocation price model. This process included consulting online state-based water registers and water resource managers (Victoria, New South Wales and South Australia) for water trading and water availability data, and the Bureau of Metrology for climatic data.

Aither focused specifically on assuring data assumptions about the volume of water entitlements purchased by the Commonwealth Government through the Restoring the Balance in the Murray-Darling Basin Program – which is an input to total water allocated that is available for consumptive use. This process included working collaboratively with the Department to ensure that the assumptions are correct to the Department's best knowledge. Aither also used publically available reporting on Commonwealth water purchases to cross check inputs.⁷

All assumptions were made during September 2015, and do not reflect any updates that online state-based water registers and water resource managers or the Bureau of Metrology have made since that time.

1.3.2. Development of model scenarios

After quality assuring data inputs, Aither developed a number of hypothetical future scenarios to be tested through the allocation price model (see Section 4.1 for more details). These scenarios are based primarily on assumptions about future water availability in hypothetical future years. Modelling

⁷ Please see <<https://www.environment.gov.au/water/rural-water/restoring-balance-murray-darling-basin/progress-water-recovery>>.

of these scenarios allowed Aither to estimate the potential impact of Commonwealth water purchases on allocation prices under different future water availability scenarios.

The scenarios tested were developed by Aither and discussed with the Department.

1.3.3. Analysis of model outputs

Following the finalisation of the scenarios, Aither applied its allocation price model to specifically estimate the potential price impact of:

- water availability on historical allocation prices
- Commonwealth water purchases on water allocation prices between 2007-08 and 2014-15
- the current volume of Commonwealth water purchases on future water allocation prices
- a hypothetical additional 200 Gigalitres (GL) of Commonwealth water purchases in the sMDB.

Aither then analysed the outputs of these models. The analysis of outputs is presented in Section 4 of this report.

1.3.4. Reporting and peer review

The analysis and interpretation of model outputs informed the development of a working draft report. Aither provided this working draft report to the Department for initial comment. Upon receiving the working draft report back from the Department with comments, Aither addressed comments before providing a draft report in-confidence to two respected economist peer reviewers with deep knowledge of Australian water markets and policy. Aither provided the draft report (accompanied by a confidential technical description of the price model) to:

- Professor Lin Crase – La Trobe University – Director of Centre for Water Policy and Management.
- Professor Quentin Grafton – Australian National University – Director of the Centre for Water Economics, Environment and Policy.

The peer review was employed to help ensure the robustness of this report. Peer reviewers were specifically asked to comment on whether:

- the general approach taken to this project was robust
- the allocation price model is fit for purpose in the context of this project
- model outputs and other data presented are credible
- The interpretations and conclusions about model outputs and other analysis are sound.

Upon receiving the draft report back from the peer reviewers, Aither addressed relevant comments before finalising the report with the Department (overall comments from peer reviewers can be found at Appendix A). The final report was provided to the Department by Aither in October 2015.

1.4. Structure of the report

This section has outlined the background to this engagement, its scope, and Aither's approach and methodology. The remainder of the report is structured as follows:

- **Section 2** – provides a framework for understanding drivers of water allocation prices in the sMDB.
- **Section 3** – outlines the Aither water allocation price model, how it was used for this engagement, and the associated caveats.
- **Section 4** – describes the application of the model in the context of this project, and presents results and discussion.
- **Section 5** – presents Aither’s conclusions.

2. Background and understanding of water allocation price drivers

This section provides:

- an overview of water markets in the sMDB
- a discussion of the complex nature of allocation trading decisions made by irrigators
- an overview of climate and supply-side drivers of water allocation prices
- an outline of the influence of underlying demand (irrigation industry structure) on allocation prices.

This background provides an important introduction to the modelling approach adopted by Aither for this report, and the key climatic and supply-side drivers of allocation prices that are being tested.

2.1. Water markets in the sMDB

Water markets in Australia have developed substantially over the past two decades. They are now an established part of agricultural, urban and environmental water policy and management in Australia.⁸ The formalisation of water markets – especially in the sMDB – now delivers important public policy outcomes, and provides the private sector with investment flexibility and risk management opportunities.

Water markets in the sMDB are comprised of two distinct but related markets – namely entitlement markets and the allocation markets.

- **Water entitlements** are ongoing rights to receive an annual share of available water resources in a consumptive pool – such as a river system or catchment. Entitlements are generally secure and mortgageable in the same way as land. Each catchment typically has a small number of entitlement ‘classes’ which denote the reliability of receiving water in any given year, and generally all entitlements within a given class are homogenous.
- **Water allocations** are the volumes of water allocated to water entitlement holders during the water year (1 July to 30 June). They are a physical good analogous to a commodity, and are extracted from water courses (or in the case of environmental water, sometimes not extracted) and applied as inputs to production or the environment. Based on the supply and demand for water at a time, the value of allocation per unit varies within, and between years.

There is no single national market for these water products, but rather a number of individual (but in some cases connected) markets. Where hydrological connectivity exists, such as in the sMDB (the focus of this report), trade between these markets or zones is possible. Due to this, prices for water allocations across markets tend to equalise where connectivity and no barriers to trade exist.⁹

⁸ Some urban water authorities have used water markets to purchase water entitlements (and in some cases water allocations) to improve water security in drought periods, but also over the longer-term. Adelaide and Melbourne, as well as regional towns such as Bendigo and Ballarat, provide examples of this (NWC 2010).

⁹ Prices for water entitlements across connected markets do not generally tend to equalise because the products are catchment or system specific and have different conditions related to them – mainly water reliability.

As this report specifically focuses on identifying drivers of water allocation prices and not water entitlement prices, the following sub-sections explore supply and demand-side drivers that potentially impact water allocation prices.

2.2. Reasons for participation in the water allocation market

Water allocation markets were developed in Australia to allow entitlement holders and water users to effectively and efficiently manage variability in water availability within production years. The water allocation market in the sMDB is used by a diverse range of irrigated agriculture producers (including rice, dairy, horticulture, cotton and others, which all have different seasonal water demands) to buy or sell water based on annual water requirements (or demands).

The heterogeneous production landscape across the sMDB, and differing water demand profiles that this generates, is important to underpinning the efficient functioning of water allocation markets. Since water demand differs between producers at any given point in time, individual producers can use the allocation market to sell water excess to requirements or buy additional water to meet water requirements. If production was homogenous (i.e. all rice or all cotton for example) allocation markets would not be as useful because water requirements of producers would be similar, and there would not necessarily be a mix of both buyers and sellers in the market at the same time (i.e. all would be trying to sell or buy simultaneously).

Market participants buy or sell water allocations for a variety of reasons, such as buying water to supplement irrigation requirements or sell water that is not required in a given season. Despite the fact that most participants have unique reasons for participating in water allocation markets, there are a number of fundamental underpinnings that help to understand allocation market participation, such as:

- irrigators have historically drawn on their water entitlements to supply the majority of their irrigation demand, and therefore water allocation trading has historically occurred at the margin of this water demand¹⁰
- water allocation trading plays different roles in different irrigated industries based on how flexible respective water demand profiles are.

These issues highlight that allocation trading decisions are complex. This fact justifies taking an aggregate approach to modelling allocation prices based on observed historical allocation price outcomes, and overarching drivers. Each of these elements is further explained below.

2.2.1. Water allocation trading typically occurs at the margin of water demand

Historically, most irrigators in the sMDB hold water entitlements of some kind. Water allocation trading from these entitlements generally occurs at the margin of water use – once irrigators have considered soil moisture, rainfall expectations and water allocated to their own water entitlements. The market price of water allocations is set at the willingness to pay for water (and willingness to accept payment in exchange for water) at the margin of any individual's requirements. Importantly, this means that the average willingness to pay for all irrigation water (i.e. as indicated by the average gross margin per

¹⁰ Although this is changing to some extent as some irrigation enterprises are now fully or highly reliant on allocation purchases.

ML of water use) is unlikely to represent the price of allocations in the market. For instance, a farmer keen to finish off an irrigation crop is likely to pay more than the average gross margin per ML.¹¹

Changing landscape of water entitlement ownership

In recent years there has been a noticeable change in the landscape of water entitlement ownership in the sMDB – specifically an increase in:

- the number of irrigators that are fully reliant on purchasing water allocations to meet total annual water requirements – they own no, or very little, water entitlements themselves.

Some dairy and rice farmers and horticulturalists sold all or part of their water entitlements to the Commonwealth Government through the Restoring the Balance in the Murray-Darling Basin Program, and this has increased their reliance on purchasing water from allocation markets each year.

- external investors in sMDB water markets who own water entitlements but have no water requirements for primary production – they generally sell 100 per cent of their allocations to the market in a given year.

While it can still be assumed that most water allocated that is available for consumptive use in the sMDB (excluding water for urban use) is owned by irrigators that use the majority of that water for their own production in most years, recently there have been a number of external investors entering the market to secure portfolios of water entitlements. Depending on their business structure, most of these investors do not use any of this water for primary production themselves. Instead they generally place all water allocated to these entitlements onto the water allocation market for sale. The prices they obtain for their allocations reflect the underlying supply and demand conditions.

2.2.2. Flexibility of within-season water demand

There are three primary sources of irrigated agriculture demand for water allocations in the sMDB:

- permanent plantings and horticulture – which have fixed water requirements
- dairy – which has semi-interruptible water requirements
- cotton, rice and mixed cropping – which have interruptible water requirements.

As noted previously, the existence of differing water requirements based on water availability of these types of production are important in underpinning the efficient functioning of water allocation markets in the sMDB. The relative flexibility of water requirements for production determines the volumes of water allocation bought or sold at any point in time.

Horticulturalists (including the large wine grape and almond industries in the Sunraysia region) have relatively fixed water demands that must be met each year to ensure production levels and to keep long lived perennial plantings alive. For this reason most horticulturalists prefer to hold high reliability water entitlements to meet a large proportion of their annual water demand. When high reliability entitlements receive less than 100 per cent allocation, horticulturalists have historically needed to enter the allocation market to buy additional water to sustain their plantings – which is what happened during the Millennium Drought.

¹¹ While a cost to irrigators who are required to buy water at a price more than the average gross, it is also important to consider that this higher price paid for water will benefit the seller of that water.

Dairy farmers (and irrigators supplying fodder) are large users of irrigation water in the sMDB, and demand in the dairy sector plays an important role in influencing the price in the water allocation market. Unlike horticulture, which has inflexible water demands, dairy has semi-interruptible water requirements. Dairy farmers can adjust herd size, mix annual and perennial pastures and mix feed that is grown or purchased to reduce annual water requirements.¹² Dairy farmers weigh up the costs of purchasing allocation water to sustain production versus the cost of purchasing additional fodder.

Cotton production is emerging as an alternative to rice and other annual crops in the Murrumbidgee system in the sMDB – cotton planting has moved further south due to market opportunities, and new cotton varieties that are cold resistant and are able to yield in a shorter growing season. Cotton only uses about 75 per cent of the water required by rice on a per hectare basis. Because cotton is grown as an annual crop, producers can choose on a year to year basis not to plant or reduce planting area which can help to manage seasonal water requirements. Cotton producers benefit from active commodity markets for outputs in future seasons, however, as cotton producers regularly sell future production in advance, the penalties associated with not meeting these levels of production can influence decisions to plant and purchase water allocations despite low water availability and high water allocation prices.

Rice and other interruptible crops have completely flexible water requirements on an annual basis. Rice growers decide each year in October and November how much rice they are going to plant. This largely determines water requirements for the remainder of the irrigation season. Given the relatively low gross margin per ML of water used, rice growers are averse to planting more rice than what can be watered from early season allocations to their entitlements, which are typically NSW General Security in the Murray and Murrumbidgee. When water availability is low across the sMDB, rice growers will not generally enter the allocation market to purchase water to sustain production (they are essentially out-bid by other participants).

All irrigators make a number of within-season decisions about the level of production that they wish to meet – and thus total water requirements for a season. These decisions are based on a number of factors (some external to water markets), however, the aggregate level of production decided upon across all irrigated sectors crucially impacts the total level of water demand in the sMDB in a given water year. If an individual's water requirements for production exceed their own water availability then it is likely that they will need to enter the market to buy water allocations, which could increase the price of allocation water. The opposite is the case when water availability exceeds water requirements for production in a given year.

Given that water trading decisions are being made at the margin (see Section 2.2.1), it is not surprising that trading decisions are made progressively throughout the irrigation season as irrigators adjust their water use and production decisions in response to prevailing conditions. For example, an absence of expected in-crop rainfall can force irrigators to enter the water allocation market late in the irrigation season and this can drive allocation prices higher. Many irrigators plan for a proportion of their irrigation requirements to be met from in-crop rainfall, and if this does not eventuate, some of these irrigators need to access water allocation markets to secure additional water to finish off their crops – effectively increasing demand for water. In such instances, the willingness to pay for water allocations in the market may be much higher than the average gross margin per unit of water. Alternatively, if it rains towards the end of the season, irrigators may have excess water requirements that they can sell on the market, or carryover to next year.

¹² As a result, fodder prices play an important role in influencing water allocation market prices.

2.3. Climatic and supply-side-drivers of allocation price

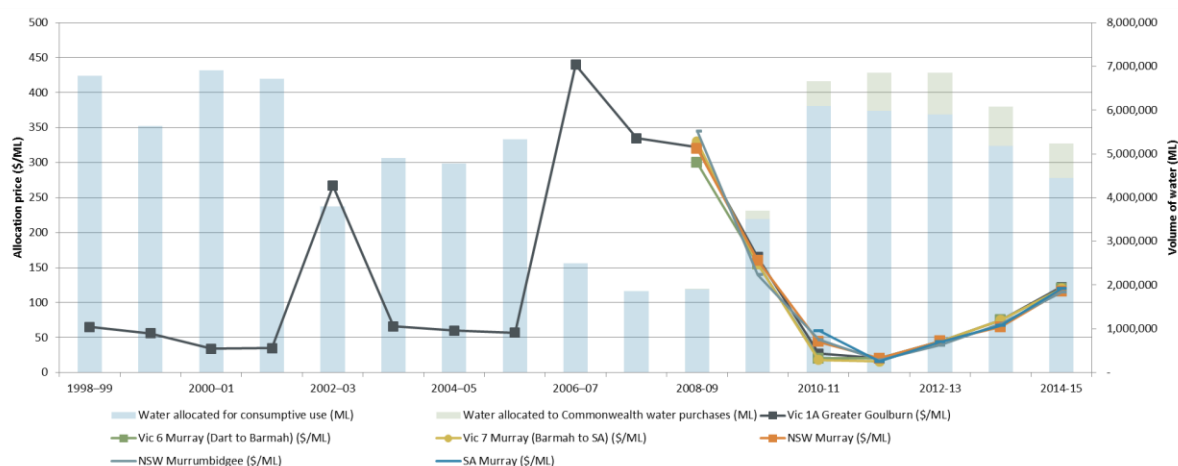
As discussed above, the price of allocations at any point in time is determined by complex interactions between a large number of market participants with their own unique circumstances and objectives. However, in aggregate, prevailing water availability conditions have historically been the primary drivers of annual median water allocation market prices. This section analyses this overall relationship, and then considers the implications of the Commonwealth Government's purchase of water entitlements for the environment.

2.3.1. Total water availability and rainfall

Water allocated to entitlements

Water allocated to all entitlements is primarily driven by catchment rainfall and inflows in relevant catchments, as well as volumes held in major storages. Based on significant variability in rainfall and climatic conditions over the past decade, inter-annual water allocations have fluctuated considerably (Figure 1). Over the period from 1998-99, water allocated that is available for consumptive use in the sMDB (which is a subset of water allocated to all entitlements) has fluctuated from a low of 1,860 Gigalitres (GL) of water (2007-08) to a high of 6,914 GL of water (2000-01) – a difference of over 5,000 GL of water (based on end of season allocations to the main regulated surface water entitlements).

The volume of water allocated that is available for consumptive use is important because it constrains the total supply of irrigation water, and when matched with demand for water, this is a key driver of water allocation market volumes traded and prices. As shown in Figure 1, observed allocation prices have closely correlated with inter-annual shifts in water allocated that is available for consumptive use – in years of low water availability allocation prices are generally high and in year of high water availability allocation prices are generally low. Recent years have reinforced the strong correlation between water allocated that is available for consumptive use and allocation prices. Allocation prices have been gradually trending upwards since 2011-12, but that increase intensified in 2014-15 with a more marked reduction in water allocated that is available for consumptive use (Figure 1).



Note: Prices reported are annual medians and are nominal (\$ per ML). The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

Source: New South Wales Water Register 2015, South Australian Water Register 2015 and Victorian Water Register 2015. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

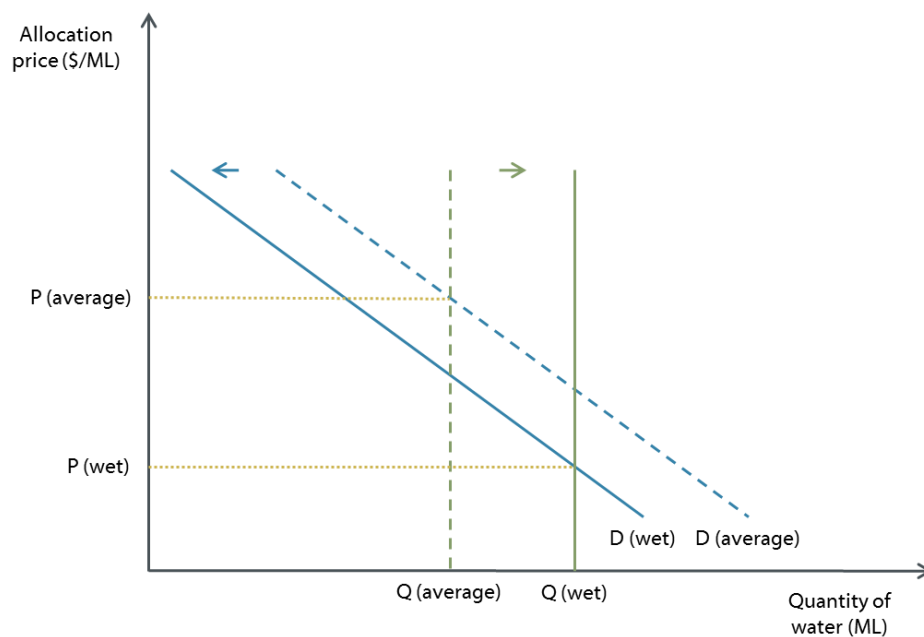
Figure 1 Total water allocated and annual median allocation prices, major southern Murray-Darling Basin trading zones, 1998-99 to 2014-15

The cumulative volume of Commonwealth water purchases between 2008-09 and 2012-13 has also reduced the overall volume of water available for consumptive use in any given year (Figure 1). The total volume of Commonwealth purchased water entitlements has stabilised over recent years.

In crop rainfall

Irrigators use water allocated that is available for consumptive use in a given year as a controllable water supplement to in-crop rainfall. Given the relatively low average rainfall across most of the agricultural areas within the sMDB, in most years, water allocated that is available for consumptive use is important in meeting relatively high-water demand crops (i.e. water demand of production exceeds rainfall). Rainfall also influences dryland agricultural conditions, including the production of hay, which is a substitute for water as an input to dairy farming. It is considered that the dryland drought conditions in 2002-03 were the major driver of increased allocation prices, as dairy farmers needed to purchase additional water in the absence of limited hay and other fodder.

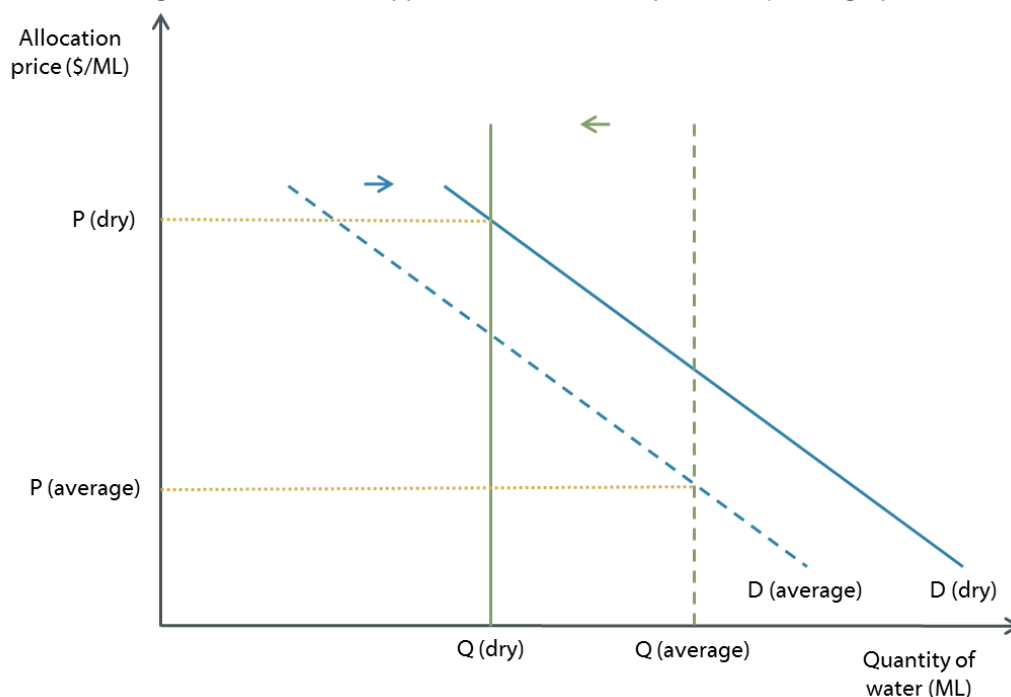
As a result of the relationship between total water allocated and in crop rainfall, in years with high rainfall (wet years), the price of water allocations can be expected to reduce due to both an increase in water availability (supply) and a decrease in water allocation demand (more in-crop rainfall and lesser need to supplement with irrigation water). Figure 2 shows how in wet years a reduction in demand for irrigation water and an increase in water allocations can collectively reduce the price of water allocations. Importantly, storages provide the potential to smooth out the impact of dry conditions and low rainfall over multiple years.



Source: Aither 2015.

Figure 2 Impacts of a wet year on the price of water allocations

The opposite is the case in years with low rainfall (dry years) or periods of sustained drought (see Figure 3). In these years, the price of water allocations increases due to a combination of a decrease in water allocated that is available for consumptive use (supply is constrained) and an increase in demand for irrigation water as a supplement to low in-crop rainfall (and high prices for fodder).



Source: Aither 2015.

Figure 3 Impacts of a dry year on the price of water allocations

The impact on allocation prices of water purchases by the Commonwealth for the environment

As explained above, total water allocated that is available for consumptive use in a given water year plus rainfall in growing regions influences demand for water allocations and thus price.

Commonwealth water purchases of water entitlements for the environment have the effect of reducing the volume of water allocated that is available for consumptive use (see Figure 4). However, it is important to recognise that Commonwealth water purchases do not affect in-crop rainfall and broader dryland conditions that also continue to have an impact on water allocation prices.

Under the Restoring the Balance in the Murray-Darling Basin Program, the Commonwealth has purchased approximately 996 GL of water entitlements from market participants in the major trading zones in the sMDB since 2007-08 (listed in Table 1). This table demonstrates that the Commonwealth has not purchased significant volumes of water entitlements since before the start of the 2012-13 water year (i.e. 1 July 2012).

Table 1 Cumulative water entitlements purchased by Commonwealth Government – registered at start of water year (GL)

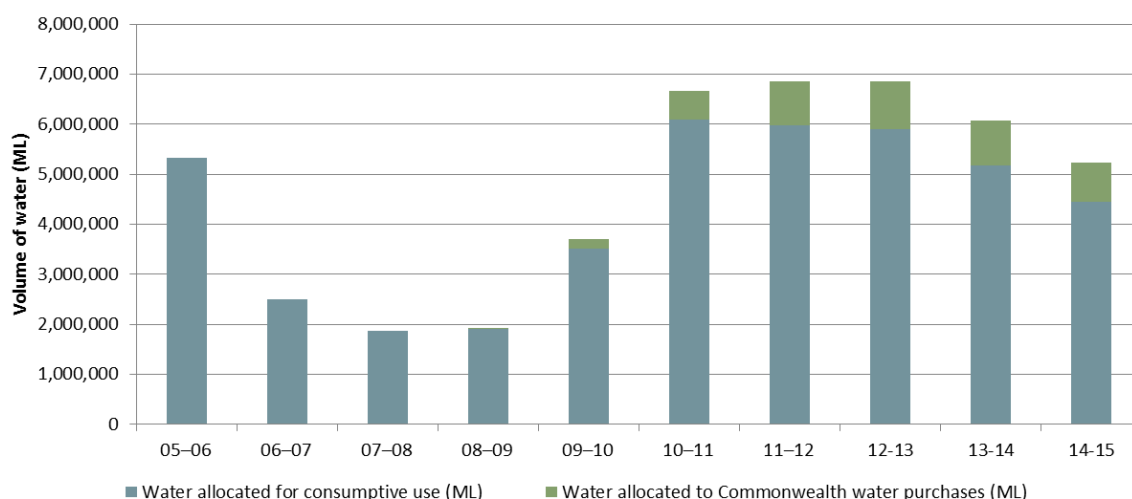
Entitlement type	07-08 ¹	08-09	09-10	10-11	11-12	12-13	13-14	14-15
Vic 1A Greater Goulburn HRWS	-	1	54	96	182	187	187	188
Vic Murray HRWS	-	6	75	138	222	228	229	229
NSW Murray HS	-	-	-	1	3	9	15	15
NSW Murrumbidgee HS	-	-	-	-	3	4	5	5
SA Murray HS	-	1	39	67	93	96	96	96
Vic 1A Greater Goulburn LRWS	-	1	10	11	11	11	11	11
Vic Murray LRWS	-	1	10	11	11	11	11	11
NSW Murray GS	-	8	171	195	218	248	253	253
NSW Murrumbidgee GS	-	14	64	99	152	184	189	189
Total	0	32	424	618	895	978	995	996

Source: Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Note: 1) While water was purchased by the Commonwealth Government in 2007-08, Aither has assumed that these entitlements would not have been registered to the Commonwealth Government until the beginning of the next water year – i.e. the Commonwealth Government would not have received any water allocations from these entitlements in the year in which they were purchased. This assumption was confirmed with the Department of the Environment.

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.¹³ Figure 4 and Table 2 present the impact that Commonwealth water purchases have had on the volume of water allocated that is available for consumptive use since purchases commenced. As the cumulative portfolio of Commonwealth water purchases has grown, so has the overall reduction in the volume of water allocated that is available for consumptive use – which was one of the central aims of the purchases.

¹³ The volume of water allocated to Commonwealth entitlements varies based on allocations to each of the held entitlement types. All entitlements held by the Commonwealth Government for environmental purposes (including purchases) are subject to the same water allocation processes as any other water entitlements.



Note: The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

Source: New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure 4 Impact of Commonwealth water purchases on volume of water allocated that is available for consumptive use, major sMDB trading zones, 2005-06 to 2014-15

Table 2 Impact of Commonwealth water purchases on volume of water allocated that is available for consumptive use, major sMDB trading zones, 2008-09 to 2014-15

Year	Water allocated to all entitlements (GL)	Water allocated to Commonwealth water purchases (GL)	Percentage water allocated to Commonwealth water purchases (%)
2008-09	1,905.7	6.5	0.3%
2009-10	3,705.6	199.6	5%
2010-11	6,662.0	574.2	9%
2011-12	6,850.5	872.8	13%
2012-13	6,855.9	955.7	14%
2013-14	6,079.2	903.5	15%
2014-15	5,233.9	785.8	15%

Source: Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Note: The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

Water allocated to Commonwealth water purchases is used for environmental purposes. At the time that analysis for this report was undertaken, no water held by the Commonwealth in the sMDB had

been traded back to other market participants,¹⁴ which reduces the overall volume of allocated water that is available for consumptive use.¹⁵ To the extent that demand for water allocations has not fallen since the Commonwealth has made its water purchases (i.e. there has not been any structural adjustment), one would expect water allocation prices to increase relative to what the prices might have been without Commonwealth water purchases.¹⁶ This is one of the hypotheses being tested in this report.

While the Commonwealth Government has not previously sold water allocations in the sMDB, in September 2015, the Commonwealth Environmental Water Office (CEWO) announced that it intended to sell a small volume of Victorian Goulburn allocations while this report was being developed.¹⁷ For the purposes of the analysis in this report, Aither assume that the Commonwealth Government does not buy or sell water allocations in the sMDB in future years, which would alter the impact of the purchases on supply of allocations. This assumption was confirmed with the Department as suitable at the time of preparing the report.¹⁸

Other environmental water

In addition to Commonwealth water purchases in the sMDB, additional water entitlements are owned by the Commonwealth and state governments and contribute to environmental water portfolios and the water recovery objectives of the Basin Plan. The major environmental water holders that manage this water include the Commonwealth Environmental Water Holder (CEWH), the Victorian Environmental Water Holder (VEWH), the Murray Darling-Basin Authority managing The Living Murray (TLM) initiative and New South Wales Office of Environment and Heritage (OEH).

Most of this other environmental water (i.e. water that is not purchased directly from the market by the Commonwealth Government) has been recovered through:

- infrastructure investments in irrigation systems and networks to reduce evaporation and seepage losses
- on-farm efficiency programs
- the reclassification of other water.

Some of this water was never included as part of the consumptive pool before it was secured on behalf of the environment. However, a proportion of the water recovered as a result of infrastructure investments (particularly the on-farm and off-farm water use efficiency programs) is also contributing to the consumptive pool, including through return flows.¹⁹ In this report, it is assumed that other environmental water held by the Commonwealth and other environmental water holders is not a measurable driver of water allocation prices. Further detailed analysis of the source of all water

¹⁴ Volumes of environmental water have been traded back to market participants in the northern Murray-Darling Basin. 340 ML of Commonwealth environmental allocation water was sold in the Peel system in 2014 and 10 GL of Commonwealth environmental allocation water was sold in the Gwydir system in 2014 (CEWO 2015).

¹⁵ See Kirby et al. 2006.

¹⁶ This does not rule out the possibility that water allocation prices could fall, due to factors other than Commonwealth Government entitlement purchases.

¹⁷ Subsequently, the CEWH traded just over 20 GL of allocation water in late November 2015 from entitlements in Vic 1A Greater Goulburn, which was after the analysis for this study had been completed.

¹⁸ It is also noted that investigating the potential future sale of water allocations by the Commonwealth Government is beyond the scope of this report.

¹⁹ It is possible that some water recovered through on-farm water efficiency programs removed water from the consumptive pool. However, Aither was not provided with sufficient data that would enable robust assumptions to be made about how much water has been recovered through these on-farm water efficiency programs. For this reason Aither has excluded these volumes of water from calculations of water removed from the consumptive pool of water by the Commonwealth Government.

entitlements held for environmental purposes would need to be carried out to further assess this assumption and this additional work was beyond the scope of Aither's engagement.

2.4. Longer-term shifts in industry structure and underlying water demand

While supply-side drivers (such as water availability and short-term shifts in production), can be shown to influence water allocation market outcomes and prices, there is also a longer-term demand-side story that is important to acknowledge but harder to quantify.

There are two separate elements to consider:

- Underlying changes in demand unrelated to the price impacts of Commonwealth purchases
- Structural adjustment in response to water market price impacts of Commonwealth purchases (i.e. exit of some irrigators).

In relation to the first point, demand for irrigation water in the sMDB is not static – as the structure of irrigated agriculture sectors change, so too does the underlying demand for water. Over the past decade, longer-term shifts in production have been observed in the sMDB as production of higher-value higher water demand crops has increased. For example, since at least 2012–13, high-value commodities such as fruit and nuts with high fixed water demands have increased their share of water use in the sMDB. The production of fruit and nuts has strengthened over the period in response to heightened consumer demand for almonds, walnuts and hazelnuts – the almond industry in particular is one of Australia's fastest-growing horticultural sectors. As almonds and other nuts have relatively high fixed water demands in order to optimise fruit and tree growth, the investment has resulted in an increase in water use for nut trees within the sMDB from 366 GL in 2005–06 to 540 GL in 2012–13 (ABS 2013).

Similarly, growth in water demand from cotton has also occurred, as cotton producers have commenced planting in the sMDB. The New South Wales Murrumbidgee system in particular has experienced a sharp rise in cotton production in recent years, which has traditionally not been grown in the area. The transition to cotton production has been driven by the emergence of cold-tolerant and faster yielding cotton varieties, and investment in three new cotton gins within the region. Cotton production has likely displaced water used in the rice industry in the sMDB.

While the demand for water has increased among cotton, fruit and nut producers, the dairy industry has likely remained relatively static, and bulk wine grape producers have struggled with low commodity prices.

Overall, the impact of changes in demand in recent years is unclear. However, it is likely that increased production of higher-value commodities, such as nuts in the sMDB, has led to increased fixed water demands as a percentage of total water demand in the sMDB and a higher willingness to pay for water allocations. In addition to supply-side decreases, these developments have the potential to place increased pressure on water allocation prices in periods where water availability is low.

However, it is also important to note that Commonwealth water purchases could be expected to result in longer-term reductions in demand, as irrigators that sell entitlements make adjustment decisions and exit the industry. This longer term response is equally difficult to predict, and is not included in our 'short run' modelling of the price impacts of Commonwealth water purchases.

3. The Aither water allocation price model

As outlined in the previous section, several factors are likely to drive water allocation prices including both supply and demand-side drivers. In particular, water allocated that is available for consumptive use and in-crop rainfall both play a role in influencing median annual allocation prices, but so too do longer-term shifts in production through altering the underlying demand for water.

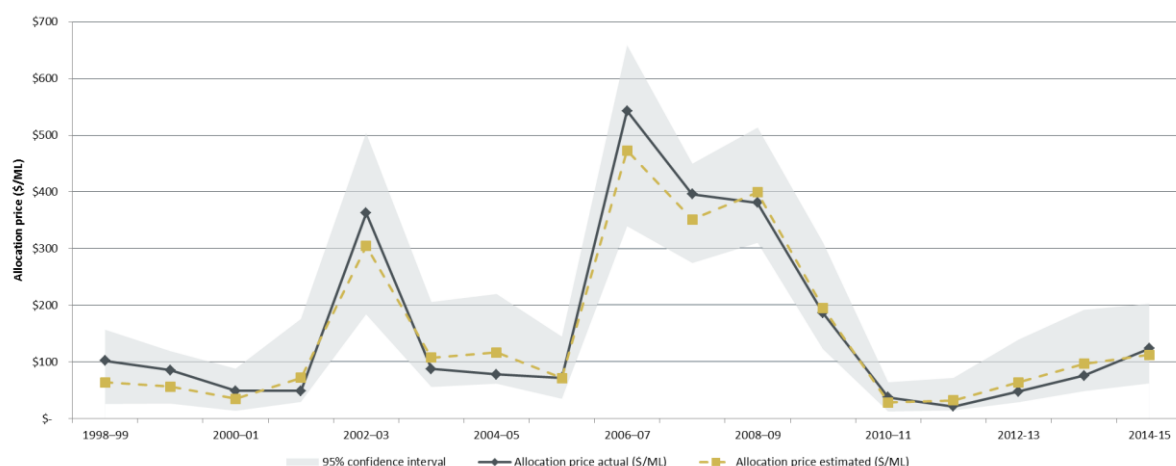
Aither has developed an allocation price model that allows for changes in a number of the supply-side drivers discussed in the previous section to generate changes in estimated future annual median allocation prices for the sMDB based on an aggregate demand curve for water.

3.1. Overview of the model

As allocation market participants' trading decisions are complex and influenced by a range of factors, it is appropriate to examine aggregate level drivers of allocation prices, such as total water allocated that is available for consumptive use, rather than trying to develop detailed models of individual economic decisions. It effectively provides an aggregate demand curve for water allocations.

The water allocation price model adopts this aggregate level approach. It generates estimated annual median per ML water allocation prices for the whole of the sMDB based on key overarching drivers, as opposed to attempting to model individual decisions by market participants. Since water allocation prices tend to equalise across connected trading zones in the sMDB, the model generates a system wide allocation price (i.e. it is not trading zone specific). The model expands on the approach introduced by Wittwer & Dixon (2011).

The model is calibrated based on historical observed annual median water allocation prices and generates estimates of future allocation annual median prices based on assumptions about hypothetical future water years. Figure 5 shows the close correlation between actual median allocation prices since 1998-99 and the prices estimated by the model. Figure 5 also shows a 95 per cent upper and lower confidence interval for the modelled historical prices. In particular, the model has performed particularly well in estimating annual median allocation prices since 2005-06.



Note: Prices reported are annual medians and are real – adjusted for inflation (\$ per ML).

Source: Aither 2015.

Figure 5 Performance of the model relative to actual allocation prices, 1998-99 to 2014-15

The model is built using the Microsoft Excel™ platform and uses regression analysis to develop an estimated future median allocation price based on assumptions about a number of explanatory variables – particularly related to water allocated that is available for consumptive use and prevailing climatic conditions in key growing regions (Wittwer & Dixon 2011).²⁰ As price is a function of total water availability, the model is also able to measure the potential impact of Commonwealth water purchases on historical and future annual median water allocation prices by calculating the difference between estimated annual median prices with and without water allocations to Commonwealth-purchased environmental entitlements (i.e. assuming purchases hypothetically did or did not occur).

Using 1998-99 as the start date for the regression, the model has an R^2 value of 0.90 (Adjusted R^2 value of 0.89); which means that the model explains 90 per cent of the historical variation in water allocation prices.

Technical description of model

A draft version of this report, along with a technical description of the model was provided in-confidence to the two peer reviewers engaged to quality assure this report. Given the confidential nature and intellectual property vested in the model which remains with Aither, the technical description of the model and the model itself remains confidential.

3.2. Caveats

Aither believes that the approach to the modelling presented in this report is fit for purpose in that it is based on economic principles, reflects the underlying available data and focuses on the key drivers of allocation prices in any particular year. However, a number of important caveats apply to the allocation price model and the outputs that it generates. These caveats are presented in Table 3.

It is important to recognise that all modelling is an approximation of reality and is based on best available information at the time. The model should be viewed as providing a relatively robust indication of median annual prices under specific seasonal conditions, and can approximate the potential annual median price impact of the Commonwealth water purchases in any particular year, subject to the points described below.

It is important to understand that the estimate of the Commonwealth's water purchase impact on annual median prices is a stylised modelled effect that is not supposed to reflect actual prices experienced by market participants on a day to day basis. It nevertheless is useful to estimate the overall impact of the Commonwealth's program on an annual basis.

²⁰ See also Bell et al. 2007, Hone et al. 2010, Wheeler et al. 2009 and Zuo et al. 2015 that were used to inform thinking around the ongoing improvement of the modelling approach.

Table 3 Caveats to the allocation price model

Issue	Treatment	Justification	Implications
Estimate of annual median price for whole of sMDB	The allocation price model generates estimates of annual median allocation per ML prices for the whole of sMDB – i.e. it does not generate trading zone specific median allocation prices nor does it account for within season allocation price movements.	In general, water allocation prices tend to equalise across connected trading zones in the sMDB. There may be some instances where local trading constraints create a price differential (e.g. constraints on trade out of the Murrumbidgee system); however, these are hard to model and usually not highly significant. As such, the assumption of a single price generated by the model is appropriate for the purposes of this annualised modelling exercise. This version of the model is not calibrated to address within season allocation price movements or changes to within season climatic conditions. All inputs to the model are based on end of water year outcomes.	Results of the allocation price model need to be interpreted on the basis that they represent whole of sMDB allocation prices and are based on annual outcomes across the course of the year, and do not reflect within season allocation price movements. The price modelling effectively assumes that trade constraints are not binding in any material manner.
Long-term structural water demand	The allocation price model does not account for any long-term structural changes in water demand and the resultant impacts on water allocation prices. The model assumes that underlying demand is stable over the years modelled.	Data to underpin structural changes in demand is either not publically available or is disparately held by individual industries and irrigation corporations across the sMDB. Therefore, the model is not currently calibrated to address any structural changes.	Results of the allocation price model need to be interpreted on the basis that the structure of demand is assumed to be stable. This may reduce the accuracy of the price estimates in assessing the impacts of Commonwealth water purchases. In particular, if entitlement purchases led to adjustment and an exit from irrigation altogether, then this adjustment may ameliorate the impacts of purchases on allocation prices. Our 'short run' approach assumes that there is no adjustment out of irrigation in conjunction with purchases (i.e. irrigators remain connected to the network and could purchase water again if viable to do so).
Sample size	Using 1998-99 as the start date for the model, the model is based on 17 observations (water years).	Given the limited number of years that water allocation trade in the sMDB has existed in a formal sense and accurate price data has been collected, the sample size that the model is based on is relatively small. Based on the paucity of data prior to this date, it is not possible to increase this number of observations (i.e. further back historically) nor in Aither's opinion would this likely improve the accuracy of the model. Similarly, the structure of demand may have changed over this period. However, it was important to include as many data points as possible to ensure the statistical power of the model. Aither has tested the model over the last five to ten years of data only, and it remains statistically significant.	Results of the allocation price model need to be interpreted on the basis that they represent analysis of a smaller than ideal sample size. As future water years conclude, Aither adds actual outcomes to the model, and over time the model has increased in accuracy. It is not possible to add more data points to the analysis.

Issue	Treatment	Justification	Implications
Data quality	Aither has used the most reliable publically available historical data that is available to inform the various inputs to the model.	Aither can only use the best publically available data, and the quality of this data will be an unavoidable limitation of any similar approach to modelling water allocation prices in the sMDB. Aither has made all attempts to quality assure and cross check data where appropriate. Aither also eliminates any \$0 trades and other outliers when estimating observed prices.	The allocation price model provides a reasonable indication of annual median prices but is affected by some of the inaccuracies in recorded allocation prices, particularly prior to 2006-07.
Trade of allocations from Commonwealth water purchases	The model and the future scenarios tested later in this report (Section 4.1) assume that the all water made available to Commonwealth entitlement purchases is not traded on the allocation market (i.e. it is used for environmental purposes only).	At the time of preparing this report, the CEWH had not yet traded any water allocations from its water entitlement portfolio acquired through Commonwealth water purchases in the sMDB. In September 2015, the CEWO announced that it intended to sell up to 20,000 ML of Victorian Goulburn allocations in the 2015-16 water year. This will be the first allocation sale of Commonwealth environmental water in the sMDB to date, and will be the first instance where the Commonwealth will be selling water allocations back to the market and increasing the size of the consumptive pool of water.	The model is capable of factoring in scenarios of allocation trading by the CEWH but it was not within the scope of this report to do so. Results assume no allocation sales by the CEWH in future years.
Carryover	The model does not account for observed water carryover between water years.	Accurate historical carryover volumes are not publically available, so at this stage Aither cannot add this explanatory variable to the model. Furthermore, we found that total allocations in a particular year explain a high proportion of the variability in the observed allocation price, so it was not necessary to make further adjustments for carryover.	Accounting for the practice of carryover could potentially smooth out estimated allocation prices between irrigation seasons and water years because the model would account for the year in which the water was actually used. However, Aither does not believe that the model would be improved significantly if it accounted for or made assumptions about carryover.
Number of entitlement types included	The model does not include a number of smaller sMDB water entitlement types.	Based on the small relative volume of allocations in these smaller sMDB systems, water availability and market outcomes in these smaller systems are unlikely to impact on broader sMDB market outcomes – including price. For this reason, Aither has chosen to exclude allocations to these smaller entitlement types from the model to reduce complexity.	No significant implications.
Value of Australian dollar	The model does not account for shifts in the Australian dollar value between water years.	Aither has undertaken regression analysis of the Australian dollar value against the value of the United States dollar. The analysis showed little or no significant relationship between the value of the Australian dollar and water allocation prices in the sMDB.	No significant implications.

Issue	Treatment	Justification	Implications
Global commodity prices	The model does not account for shifts in commodity prices.	It is commonly accepted that changes in commodity prices in the short and long-term will to some extent affect the value of water for irrigation purposes in the sMDB. Given global population forecasts and climate change impacts within and outside of Australia, there is potential for increased demand for Australian food and fibre products (e.g. dairy, rice, cotton) which may increase commodity prices and thus the value of water entitlements. However, changes in these variables have not been included in the model following testing which showed that they were not statistically significant. In the future, further material changes in these variables could affect observed water demand and allocation prices.	No significant implications.
Changing ownership of entitlements	The model does not account for changes in entitlement ownership in the sMDB.	Historically, tax-effective Managed investment Schemes drove investment in new irrigation developments (e.g. wine grapes, almonds, and olives) across the sMDB. More recently, investors have purchased entitlements with the aim of obtaining returns on allocation sales and capital growth. Aither's economic modelling does not factor in these changes in ownership as it is assumed that water allocations move to the highest value use, as determined by the market. Any underlying changes in the future structure of the demand for water in irrigation may affect the water allocation price in the future.	No significant implications.

Source: Aither 2015.

4. Application of model and results

4.1. Scenarios

A number of scenarios were developed to be tested through the allocation price modelling. These scenarios were developed based primarily on assumptions about future water availability in hypothetical future years. The development and testing of these scenarios allows for an estimate of the potential change in allocation prices under future conditions that may or may not eventuate.

The scenarios were developed to specifically test for the potential allocation price impact of:

- water availability on historical allocation prices
- Commonwealth water purchases on water allocation prices between 2007-08 and 2014-15
- the current volume of Commonwealth water purchases on future water allocation prices
- a hypothetical additional 200 Gigalitres (GL) of Commonwealth water purchases in the sMDB.

These scenarios are described in further detail in the below subsections.

4.1.1. Scenario 1 – Impact of water availability on historical allocation prices

The first scenario was developed to demonstrate the impact that changes to water availability over time have had on historical allocation prices. Testing this scenario involved running the allocation price model over the available time series (1998-99 to 2014-15), and comparing actual and modelled prices for past years to demonstrate the significant impact water availability has on annual median water allocation prices. This modelled scenario is used as the base case for measuring the potential impacts that Commonwealth water purchases have had on allocation prices. See Section 4.2.1 for the results of Scenario 1.

4.1.2. Scenario 2 – Impact of cumulative Commonwealth water purchases on historical allocation prices between 2007-08 to 2014-15

To test the impact that cumulative Commonwealth water purchases have had on historical allocation prices, a second scenario was developed. This scenario compares modelled historical allocation prices (Scenario 1 – base-case) against modelled historical allocation prices if purchases (from 2007-08 to 2014-15) had not occurred and allocations to water purchased by the Commonwealth were still available for consumptive use. This comparison establishes annual price differentials and thus the potential impact of water purchases on historical allocation prices can be estimated. See Section 4.2.2 for the results of Scenario 2.

4.1.3. Scenario 3 – Impact of the current cumulative volume of Commonwealth water purchases on future water allocation prices

To test the impact of the current cumulative volume of Commonwealth water purchases on future water allocation prices, Aither tested the potential impact under a number of hypothetical future water years. These future water years were not developed to represent likely future conditions, but rather to highlight the potential impact of current Commonwealth water purchases on allocation prices if the hypothetical future water year did occur.

The hypothetical future water years tested are based on the outlook for 2015-16 and known past water years – namely:

- expected water availability using water resource manager outlooks for 2015-16 (tracking at ‘dry’ conditions at the time of the analysis)²¹
- repeat of water availability in worst Millennium Drought year (replicating 2008-09 water year)
- repeat of water availability in average year (replicating the 2005-06 water year)
- repeat of water availability in wet year (replicating 2011-12 water year).

To test the potential impact of current Commonwealth water purchases on future allocation prices, Aither ran the above scenarios through the allocation price model twice – once with Commonwealth water purchases and once assuming that Commonwealth water purchases had not occurred. The outputs of this scenario allow the potential impact of current Commonwealth water purchases on future allocation prices to be established.

The outputs of this scenario are used as the base-case for measuring the potential impacts if additional Commonwealth water purchases occur (above that of current volumes). See Section 4.2.3 for the results of Scenario 3.

4.1.4. Scenario 4 – Impact of additional Commonwealth water purchases on future allocation prices

Based on progress to date with recovering water for the environment in the Murray-Darling Basin, there is the potential that further Commonwealth water purchases would be required to meet targets under the Basin Plan. The purchase of additional water for the environment would increase the volume of water held by the Commonwealth Government (above current volumes), and as a result, further reduce the volume of water allocated that is available for consumptive use. As a result of this reduction in consumptive water allocation, any future purchase of water entitlements by the Commonwealth Government in the sMDB is likely to have an additional impact on allocation prices.

Based on the possibility that the Commonwealth Government may need to re-enter the water market in the sMDB to purchase additional water for the environment, Aither developed a plausible scenario to estimate the impact that any further Commonwealth water purchases would have on water allocation prices in future years. To test the potential impact of additional Commonwealth water purchases, Aither replicated a selection of the model runs undertaken for Scenario 3, but assumed that an additional 200 GL of water is purchased by the Commonwealth in the sMDB.²² These purchases would fall within the legislated 1,500 GL cap on water purchases. Aither assumed that this additional water would be purchased on a proportional basis to current entitlements held.

To test the potential impact of additional Commonwealth water purchases on future allocation prices, Aither ran the scenarios developed in Scenario 3 through the allocation price model twice – once with Commonwealth water purchases (including additional volumes of water purchases) and once assuming that Commonwealth water purchases had not occurred. The outputs of this scenario allow

²¹ Note, this scenario and assumptions were developed prior to the October 2015 outlook.

²² Aither checked this assumption with the Commonwealth Department of the Environment. The Department of the Environment indicated that this assumption was plausible if the Commonwealth was required to re-enter the water market in the sMDB. However, we note that this scenario was developed by Aither and we have no knowledge as to whether or not this will actually occur. It is simply posited to explore the impacts if it did occur.

the potential additional and total impact of future Commonwealth water purchases on future water allocation prices in the sMDB to be established. See Section 4.2.4 for the results of Scenario 4.

4.2. Results and discussion

This section presents the results of running the above described four scenarios through the allocation price model. A discussion of the results is also presented.

4.2.1. Scenario 1 – Impact of water availability on historical allocation prices

Scenario 1

Scenario 1 tests the impact that changes to water availability has on historical allocation prices. Testing this scenario involved comparing actual and modelled prices for past years to demonstrate the significant impact that water availability has on annual median allocation prices.

As discussed in Section 2.2, water availability is a major driver of water allocation prices in the sMDB. Figure 6 below plots observed historical allocation prices against the modelled historical allocation prices, total water allocated that is available for consumptive use and water allocated to Commonwealth water purchases. Observed and modelled changes in allocation prices in Figure 6 reinforce the strong correlation between water allocated that is available for consumptive use and water allocation prices.



Note: Prices reported are annual medians and are real – adjusted for inflation based on annual CPI data from the Australian Bureau of Statistics (\$ per ML). The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure 6 Observed and modelled historical water allocation prices against water allocated to all consumptive and Commonwealth purchased entitlements, 1998-99 to 2014-15

As shown in Figure 6, observed allocation prices climbed dramatically from 2005-06 to 2006-07 based on deteriorating water allocated to all entitlements and rainfall.²³ The continuing high prices from

²³ While allocation prices also climbed dramatically in 2002-03, this price rise was primarily due to a 'dryland drought' where poor rainfall eventuated and irrigators were forced to enter the water market to supplement water

2006-07 and 2008-09 reflect the extremely poor water availability experienced during the Millennium drought. While water availability was arguably lower in 2007-08 and 2008-09 than 2006-07, which should push prices higher, rainfall in sMDB growing regions was lower in 2006-07 than the two years following which pushed more irrigators into the market and, thus, drove high prices in the 2006-07 water year.

The subsequent drop in allocation prices from 2010-11 reflects the breaking of the drought and successive wet years (i.e. high water availability in sMDB growing regions). Since 2011-12, allocation prices have been gradually trending upwards, but that increase intensified in 2014-15 with a more marked reduction in water allocated that is available for consumptive use from 2013-14 to 2014-15, than was the case from 2012-13 to 2013-14.

The total volume of water allocated to all entitlements (i.e. including Commonwealth-held water) has been declining since 2012-13, contributing to rising prices over that period of time. Given that the proportion of the total volume of water allocated that is available for consumptive use has fallen since 2008-09 because of Commonwealth water purchases, it is important to understand how allocation prices have reacted (Figure 6). The following section models the extent to which Commonwealth water purchases have impacted historical water allocation prices as compared to broader climatic conditions.

4.2.2. Scenario 2 – Impact of cumulative Commonwealth water purchases on historical allocation prices between 2007-08 to 2014-15

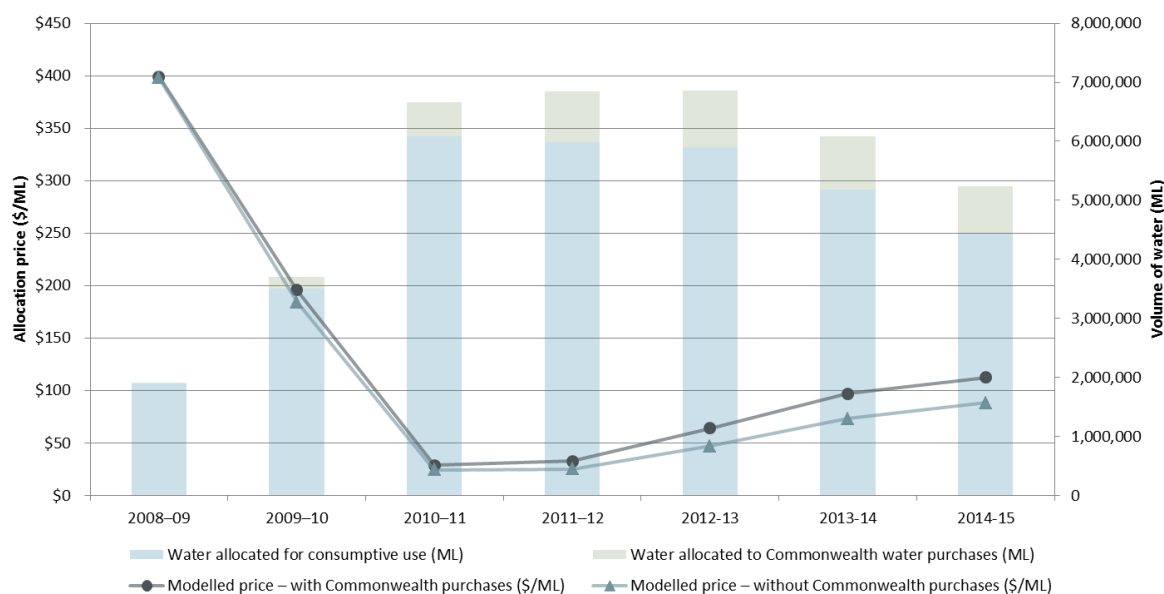
Scenario 2

Scenario 2 tests the potential impact that Commonwealth water purchases have had on historical allocation prices. Testing this scenario involved comparing modelled historical allocation prices (Scenario 1 – base-case) against modelled historical allocation prices if purchases (from 2007-08 to 2014-15) had not occurred and allocations to water purchased by the Commonwealth were still available for consumptive use.

The outputs of this scenario, as presented in Figure 7, show that as the cumulative portfolio of Commonwealth water purchases has increased since 2008-09, the potential price impact in a given year has also increased – reflected by the price difference between the two annual estimates, with and without Commonwealth purchases, in Figure 7. This growth in potential price impact is expected in that as the total volume of water purchases on behalf of the environment by the Commonwealth Government increases, so does the total volume of water being removed from the volume of water allocated that is available for consumptive use (i.e. supply is decreasing as Commonwealth purchases increase).

Figure 7 also highlights the large shifts in allocation prices between years as a result of water availability in comparison to the potential price impact that Commonwealth water purchases have in a given year. As previously explained in Section 4.2.1, the total volume of water allocated to consumptive use has fluctuated substantially and that has primarily driven the large allocation price shifts observed between years. In this context, the potential historical price impact that Commonwealth water purchases have had is relatively modest compared to the impact of drying climatic conditions and the resultant reduction in water availability.

requirements that had been expected to be fulfilled by rainfall (i.e. the observed price does not only reflect the water availability in that year).



Note: The total volume of water allocated to Commonwealth water purchases is reported based on the year to year cumulative portfolio growth (i.e. it is not just purchases in that year).

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure 7 Historical water allocation price impact of Commonwealth water purchases, 2008-09 to 2014-15

The modelling results confirm that Commonwealth water purchases have increased allocation prices above what they would have been had Commonwealth water purchases not occurred. The potential price impact of water purchases have increased in dollar terms year on year as the total cumulative volume of water purchased by the Commonwealth has grown. As stated above, this is expected as the growing portfolio of Commonwealth water purchases has gradually reduced the volume of water allocated that is available for consumptive use (Table 4). Table 4 shows the modelled past impact of Commonwealth water purchases on annual median allocation prices in the sMDB.

The portfolio of Commonwealth water purchases is dominated by higher reliability entitlements which means that as the total volume of water allocated to all entitlements declines (especially allocations to low reliability entitlements), total water allocated to Commonwealth water purchases also declines, but not by as much in percentage terms because the Commonwealth's portfolio has a larger proportion of high reliably entitlements.

These results are consistent with the existing estimates of the impact of Commonwealth water purchases in the sMDB. Elasticity can be calculated for each year in Table 4, showing the percentage change in quantity for a one per cent increase in price. The smaller the elasticity, the larger the price effects of a given reduction in water availability. Between 2010-11 and 2014-15 the estimated elasticity was between -0.5 and -0.7. This is larger than the elasticity of -0.3 estimated by Hone et al. (2010), but smaller than the elasticities of -0.8 to -1.9 estimated by Bell et al. (2007).²⁴ This means that the modelling approach returns a result that likely does not overstate the impact of Commonwealth water purchases in these years.

²⁴ See also Wheler et al. 2009 and Zuo et al. 2015.

Table 4 Historical water allocation price impact of Commonwealth water purchases, 2008-09 to 2014-15

Year	Modelled price – without purchases (\$/ML)	Modelled price – with purchases (\$/ML)	Potential price impact of purchases (\$/ML) ¹	Reduction in consumptive pool as a result of purchases (%)
2008–09	\$398	\$399	\$1	0.3%
2009–10	\$184	\$195	\$11	5%
2010–11	\$24	\$29	\$5	9%
2011–12	\$25	\$33	\$8	13%
2012–13	\$47	\$64	\$17	14%
2013–14	\$73	\$97	\$24	15%
2014–15	\$88	\$112	\$24	15%

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Note: 1) Please see Appendix B for 95 percent confidence intervals of the potential price impact of purchases.

4.2.3. Scenario 3 – Impact of the current cumulative volume of Commonwealth water purchases on future water allocation prices

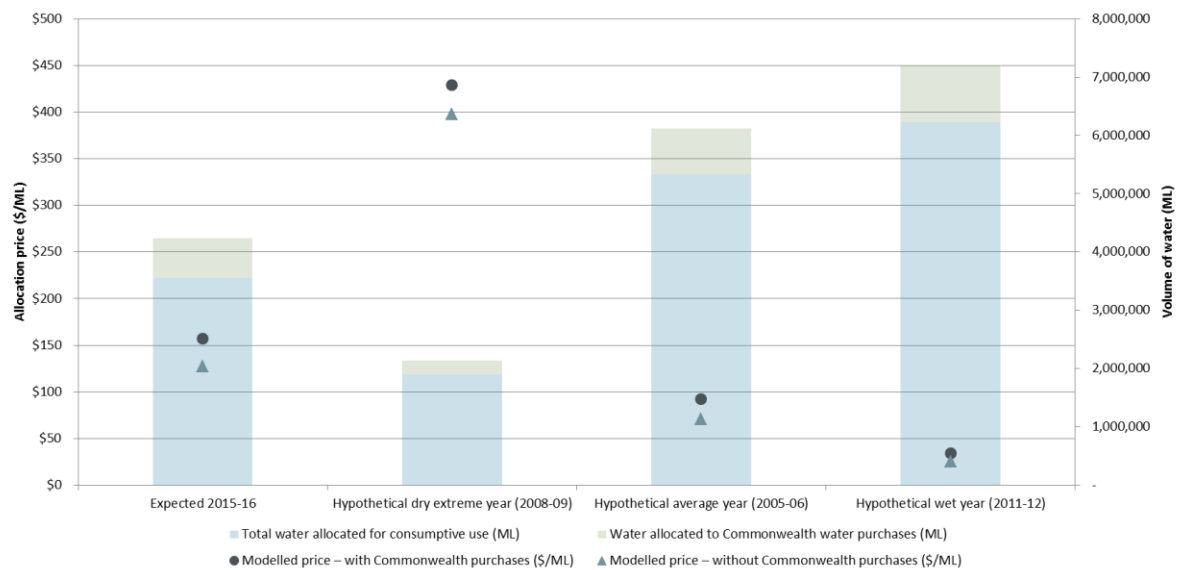
Scenario 3

Scenario 3 tests the impact of current volumes of Commonwealth water purchases on future water allocation prices. Aither tested the following scenarios to examine the impact of current volumes of Commonwealth water purchases on future water allocation prices:

- the expected water availability using state-based water resource manager outlooks for 2015-16 (currently tracking at 'dry' conditions)²⁵
- a repeat of water availability in worst Millennium Drought year (replicating 2008-09 water year)
- a repeat of water availability in average year (replicating the 2005-06 water year)
- a repeat of water availability in wet year (replicating 2011-12 water year).

Figure 8 presents the outputs of these scenarios, and shows that in dollar terms, in years when water allocated to consumptive use is low (dry years), the impact of current Commonwealth water purchases on water allocation prices is higher in dollar terms. Alternatively, in wet years, while the impact of current Commonwealth water purchases in dollar terms is low, as a percentage of total price it is higher.

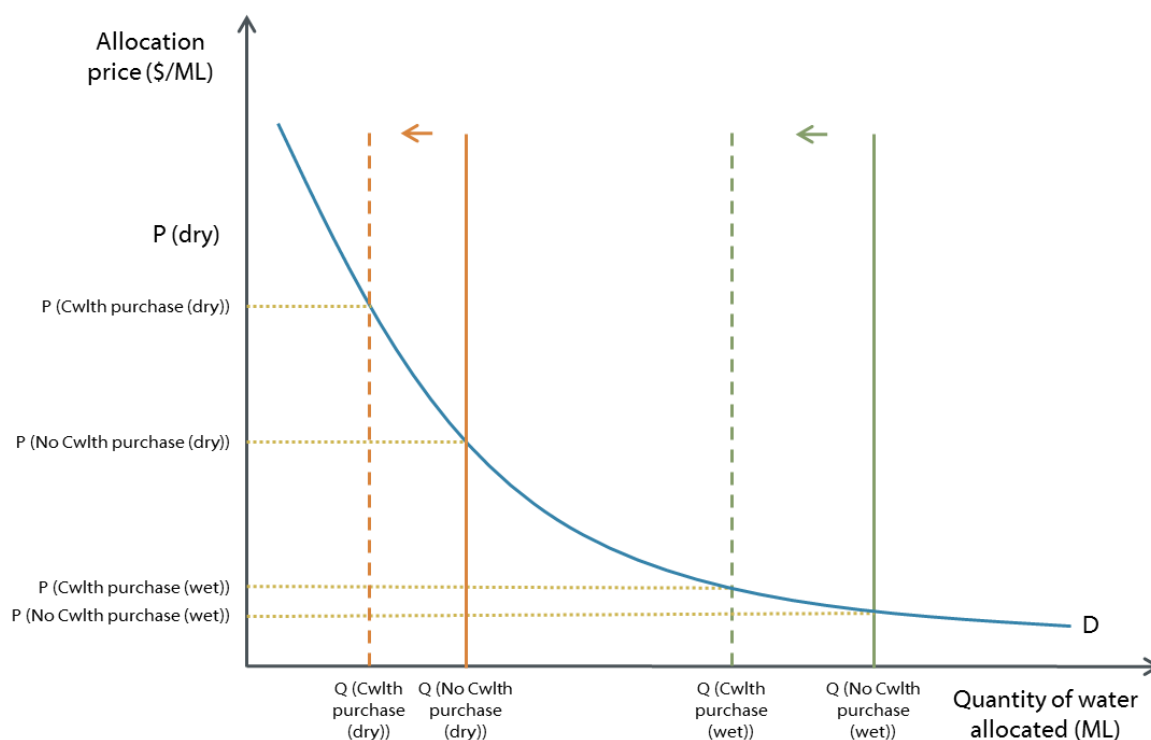
²⁵ Note, this scenario and assumptions were developed prior to the October 2015 outlook.



Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Figure 8 Estimated water allocation price impacts of Commonwealth water purchases for hypothetical future water years

Figure 9 illustrates why in water years when water allocated to consumptive use is low (dry years) the impact of current Commonwealth water purchases on water allocation prices is higher in dollar terms compared to wet years. As the volume of water allocated decreases, the elasticity of demand for water allocations increases and thus the price impact of water allocated to Commonwealth water purchases also increases. However, while the price response increases in dry years, the volume of water allocated to the Commonwealth in dry years also reduces. This means that the difference in volume allocated with and without Commonwealth purchases decreases in dry periods as compared to wet and average conditions, offsetting the higher price elasticity.



Source: Aither 2015.

Figure 9 Impact of Commonwealth water purchases in a dry and wet year

Table 4 provides a detailed breakdown of the estimated water allocation price impacts of current Commonwealth water purchases for hypothetical future water years.

Table 5 Estimated water allocation price impacts of Commonwealth water purchases for hypothetical future water years

Scenario	Modelled price – without purchases (\$/ML)	Modelled price – with purchases (\$/ML)	Potential price impact of purchases (\$/ML) ¹
Expected 2015-16	\$127	\$157	\$30
Repeat of extreme dry year (2008-09)	\$398	\$429	\$31
Repeat of average year (2005-06)	\$71	\$92	\$21
Repeat of wet year (2011-12)	\$25	\$34	\$9

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Note: 1) Please see Appendix B for 95 percent confidence intervals of the potential price impact of purchases.

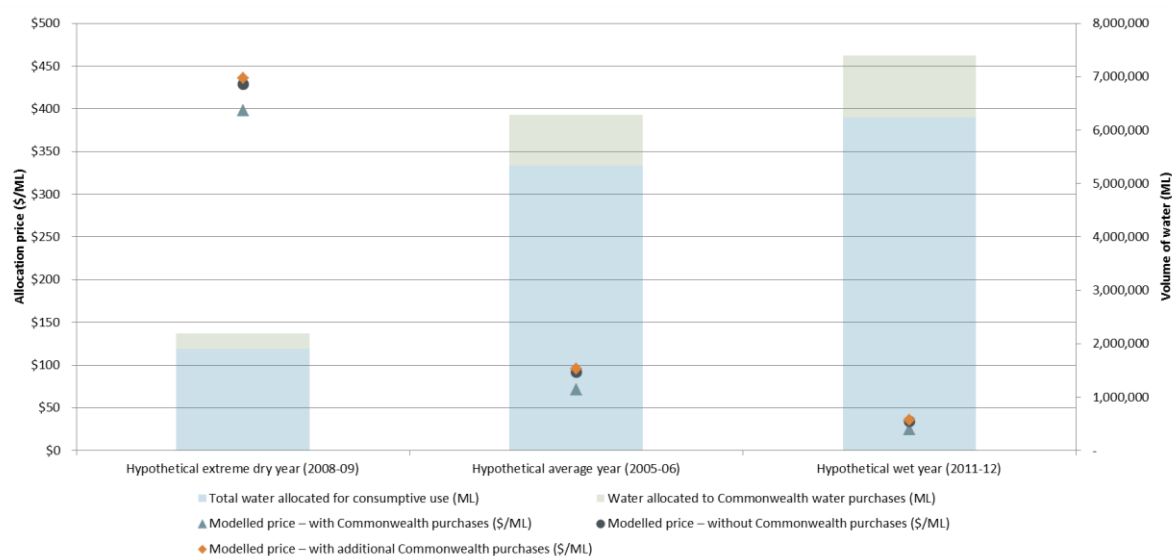
4.2.4. Scenario 4 – Impact of additional Commonwealth water purchases on future allocation prices

Scenario 4

Scenario 4 tests the potential impact of additional Commonwealth water purchases on future allocation prices. Aither tested three of the future hypothetical water years developed in Scenario 3 through the allocation price model twice – once with Commonwealth water purchases (including additional volumes of purchases) and once assuming that Commonwealth water purchases do not occur. The outputs of Scenario 3 are used as a base-case for estimating potential impacts if additional Commonwealth water purchases occurs in the future.

Based on progress to date with recovering water for the environment in the Murray-Darling Basin, there is the potential that further Commonwealth water purchases in the sMDB may be required. To test the potential price impact of these additional Commonwealth water purchases, Aither replicated the model runs also undertaken for Scenario 3.²⁶ For these model runs Aither assumed that the additional 200 GL of water entitlements are purchased by the Commonwealth Government in the sMDB on a proportional basis to the volumes current entitlements held for each entitlement type. All 200 GL of water is assumed to have been purchased before the hypothetical future water year is tested.

The results under an additional purchase scenario for future water years are very similar to that seen under current volumes of Commonwealth water purchases (Figure 10 compared to Figure 8). Only minor price rises in under all hypothetical water years can be attributed to additional 200 GL of Commonwealth water purchases in the sMDB.



Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

²⁶ The expected water availability using water resource manager outlooks for 2015-16 was not tested under Scenario 4 because it is not plausible that the Commonwealth could purchase an additional 200 GL of water in the sMDB before the conclusion of the 2015-16 water year.

Figure 10 Estimated water allocation price impacts of additional Commonwealth water purchases for hypothetical future water years

The price impacts (on top of the impact of current Commonwealth water purchases) of additional water purchased by the Commonwealth Government are presented in Table 5. In comparison to the total potential price impact of current Commonwealth water purchases, the added price impact of additional purchases is relatively small – 2 per cent in a repeat of a dry year, 4 per cent in an average year and 6 per cent in a wet year.

Table 6 Allocation price impacts of additional Commonwealth water purchases for hypothetical future water year

Scenario	Modelled price –without purchases (\$/ML)	Modelled price – with purchases (\$/ML)	Modelled price – with additional purchases(\$/ML)	Potential price impact of additional purchases (\$/ML) ¹
Repeat of extreme dry year (2008-09)	\$398	\$429	\$436	\$7
Repeat of average year (2005-06)	\$71	\$92	\$96	\$4
Repeat of wet year (2011-12)	\$25	\$34	\$36	\$2

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Note: 1) Please see Appendix B for 95 percent confidence intervals of the potential price impact of purchases.

5. Conclusions

Modelling of past water allocation prices since 1998-99 suggests that water availability – including both total water allocated to consumptive use and prevailing climatic conditions (i.e. rainfall) in growing regions – is the primary driver of annual median water allocation prices in the sMDB. Comparing both observed and modelled allocation prices against water allocated that is available for consumptive use has shown very clearly that allocation prices vary dramatically due to inter-annual shifts in water availability.

In parallel to historical movements in water availability and allocation prices, the Commonwealth Government has purchased approximately 996 GL of water entitlements in the major trading zones in the sMDB cumulatively since 2007-08. This water purchased by the Commonwealth is used for environmental purposes and, up to the time of analysis for this report (October 2015), has not been traded back to market participants, whereas prior to purchase it was available to be used in production or sold on the allocation market. In effect, Commonwealth water purchases have reduced the volume of water that is available for consumptive use in any given year. However, Commonwealth purchases do not affect in-crop rainfall, the other key determinant of water allocation prices.

Modelling undertaken for this report suggests that Commonwealth water purchases have had a short-run impact on allocation prices in the sMDB – which has grown over time as the portfolio has grown (although remained relatively consistent over recent years as the portfolio has not grown significantly since 2012-13). In future water years, the water allocated to Commonwealth water purchases will tend to have larger short-run price effects in extreme dry years (\$31 per ML) than wet years (\$9 per ML).

When modelled, hypothetical additional Commonwealth water purchases (200 GL) in the sMDB are only likely to have a marginal price impact in addition to the impact that water allocated to current Commonwealth water purchases is already having.

Overall, modelling suggests that climatic conditions, particularly total water availability, will continue to be a more significant driver of variability in allocation prices across the sMDB compared with the price impact of Commonwealth water purchases.

It is important to note that the price impact estimates presented in this report are short-run impacts, which assume no structural changes to demand for water in sMDB. Over the longer-term, increased water prices could force some irrigators to further adjust or cease production altogether. All else being equal, these price impacts are likely to moderate over time as the irrigation sector continues to adjust to a reduced water volume available for consumptive use. If this structural adjustment occurs (i.e. irrigators ceased to irrigate permanently), the underlying demand for water in the sMDB may decrease, placing downward pressure on allocation prices more generally.

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Appendix A – Peer review comments

Professor Lin Crase - La Trobe University

Background

This review was commissioned to consider the general approach adopted by Aither in its consideration of the supply-side drivers of water allocation prices in the southern Murray-Darling Basin. In addition, the review considered the fit-for-purpose nature of the model developed by Aither; the credibility of model outputs and related data; and the interpretation of results offered by the authors.

Approach

The paper developed by Aither explains the development and application of an empirical model that can be used to estimate likely impacts on water allocation prices. More specially, the model uses data from the previous 17 years to estimate the effects of water availability and climatic factors on water allocation prices. The model is designed at a large scale and does not consider localised market conditions – the unit of analysis is the markets that interact across the entire southern MDB.

The general approach is sound and makes use of the available information. Ideally, more market data would be available but the limit to 17 observations is unavoidable given the longevity of reforms.

The approach is also balanced, insomuch as it is able to unbundle the impacts of buybacks on the allocation market, relative to other drivers. The decision to analyse the possible impacts of additional water purchases as part of this project is also appropriate. Whilst a limit has been placed on buybacks by Government, it seems unlikely that increases in the environmental reserve to meet the ambitions of the MDB Plan will be met without at least some additional entitlement purchases by the Commonwealth.

Fit-for-purpose

As noted above, the data limitations of the model derive from the number of years over which water markets have operated in the basin. The authors have nonetheless undertaken appropriate steps to ensure that the model is capable of generating the information required by the Department – namely to establish the extent to which entitlement purchases materially impact allocation prices in different scenarios.

The assumptions used by Aither are plausible and pragmatic. For example, the authors note that structural change is occurring in the MDB but do not try to ‘second-guess’ the extent or form of that change. This approach means that the results are unlikely to be biased by imposing choices about uncertain future states.

Model outputs and related data

As noted earlier the model generates a high R-square. This is not unexpected given the nature of the model. Importantly, the authors undertake a range of diagnostic tests to validate results. This includes

tests for stationarity, collinearity, heteroscedasticity and trialling alternative functional forms. Each of these tests is competently undertaken and the interpretation of outputs is sound.

Interpretation of results

The results of the modelling support the view that buybacks by the Commonwealth gives rise to impacts on water allocation prices, but these are relatively minor when compared against other factors. Moreover, expanded buyback (as modelled) is unlikely to have dramatic impacts on allocation prices in \$ terms.

The authors are silent on a number of contentious issues, which may or may not be appropriate. For example, the increased activity of so-called 'speculators' is noted but the likely 'smoothing role' of speculation is not addressed. Similarly, no mention is made of the benefits of higher allocation prices for those selling allocation. I leave these topics open for now as they may be considered outside of the engagement by Aither.

Overall, I have few substantive criticisms of the work. I attach a copy of the draft with some suggested modifications to text.

Lin Crase

10th October 2015

Professor Quentin Grafton – Australian National University

Introduction

Detailed comments and suggested revisions, focussed on interpretation and diagnostics of the estimated model, are provided in tracked changes to the document. Based on the information provided by Aither, noting that I did not have access to the data and was not able to undertake a detailed review and quality assurance of the inputs to the model or individual calculations to replicate Aither's analysis, it is my view that their general approach is robust and that their use of the model to compare counterfactuals is appropriate. Further, their results (such as estimated price elasticities) are consistent with the existing literature and what I would expect the likely results would be.

Aither's Estimated Model

As highlighted in their report, Aither has estimated its own econometric model of the water allocation price in the sMDB. This estimated model appears to track the historical data well (with a high adjusted R-squared), as shown in Figure 5. Aither has also tested the model out of sample (see p. 33) and, according to them, it provides 'strong predictive ability' although evidence to support this claim (such as Thiel's U statistic) is not provided. With the exception of: (1) formal test for autocorrelation that would affect the standard errors, but not the coefficients of the estimated parameter estimates and (2) reset statistics for model misspecification, the standard diagnostic tests of their estimated model have been undertaken.

The estimated coefficients are all highly statistically significant from zero (p values less than 0.002) and with the appropriate signs. The model also provides a good historical predictive power for the median annual water allocation price.

Model Outputs

The outputs are appropriate based on their model and also for the questions required by the Department of the Environment. The correct approach, and which Aither has done, is to estimate the effect on median water allocation prices with-and-without CEWH water entitlement holdings. As is appropriate, this comparison should be done under various scenarios (dry, average and wet years) because the magnitude of the effect will differ depending on relative water availability.

Four scenarios are provided in section 4 of the report. In addition to point estimate, confidence intervals should be provided for modelled prices where relevant. Scenario 1 shows the historical water allocation to entitlements is a major driver of water allocation prices. Scenario 2 compares water allocation prices historically. In particular, it assesses the outcome if there had been no water entitlement purchases by the Commonwealth with the actual water allocation prices (with CEWH holdings) over the period 2008-09 to 2014-15. Results are summarised in Table 4 (see p. 24) in both absolute dollar terms and also as a proportion of modelled prices. In recent years, CEWH holdings are estimated to have raised the modelled annual median water allocation price by some 20% or more.

Scenario 3 examines the effect of current volumes of water entitlements held by the CEWH in: expected 2015-16; a repeat of an extreme dry year of 2008-09; a repeat of 'average' year in 2005-06; and repeat of a wet year in 2011-12. As expected, the relative impact on absolute level of prices (in \$) is greatest in a dry year, but the relative impact is greatest in a wet year (26% of modelled allocation price). Scenario 4 replicates Scenario 3, but assumes there is an additional 200Gl/yr of long-term cap equivalent held by the CEWH over and above its current holdings. In this scenario, the effect on the

median annual water allocation price is minimal such that, even in a wet year, the extra increase in allocation price represents 6% of the modelled price.

Interpretations and Conclusions

Aither's outputs show that current holdings of CEWH have moderately raised the median allocation prices in the sMDB. The impact, in relative terms, is highest in wet years, but the absolute price effect (in \$) is greatest in dry years. As noted by Aither, by far the biggest influence or driver of median annual allocation prices is the overall water allocations to water entitlements. In other words, the successive decreases in water allocations from 2012-13 to 2014-15 due to drying conditions explains almost all of the more than doubling of the increase in median allocation prices over that period. Overall, Aither's findings conform to economic theory and, where relevant, are consistent with findings in the literature.

13 October 2015

R. Quentin Grafton

Appendix B – Sensitivity analysis

Table 7 Historical water allocation price impact of Commonwealth water purchases, 2008-09 to 2014-15 – 95 percent confidence limits sensitivity analysis

Year	Potential price impact of purchases (\$/ML) – lower	Potential price impact of purchases (\$/ML)	Potential price impact of purchases (\$/ML) – upper
2008–09	\$1	\$1	\$1
2009–10	\$10	\$11	\$11
2010–11	\$3	\$5	\$6
2011–12	\$5	\$8	\$11
2012-13	\$10	\$17	\$22
2013-14	\$16	\$24	\$29
2014-15	\$18	\$24	\$27

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Table 8 Estimated water allocation price impacts of Commonwealth water purchases for hypothetical future water years – 95 percent confidence limits sensitivity analysis

Scenario	Potential price impact of purchases (\$/ML) – lower	Potential price impact of purchases (\$/ML)	Potential price impact of purchases (\$/ML) – upper
Expected 2015-16	\$25	\$30	\$30
Repeat of extreme dry year (2008-09)	\$23	\$31	\$35
Repeat of average year (2005-06)	\$15	\$21	\$22
Repeat of wet year (2011-12)	\$5	\$9	\$12

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

Table 9 Allocation price impacts of additional Commonwealth water purchases for hypothetical future water year – 95 percent confidence limits sensitivity analysis

Scenario	Potential price impact of additional purchases (\$/ML) – lower	Potential price impact of additional purchases (\$/ML)	Potential price impact of additional purchases (\$/ML) – upper
Repeat of extreme dry year (2008-09)	\$5	\$7	\$7
Repeat of average year (2005-06)	\$4	\$4	\$5
Repeat of wet year (2011-12)	\$1	\$2	\$3

Source: Aither 2015. New South Wales Water Register, South Australian Water Register and Victorian Water Register. Based on Commonwealth water purchase data provided to Aither by the Department of the Environment.

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