# ECONOMIC ASSESSMENT OF WATER TRADE RESTRICTIONS IN THE MURRAY DARLING BASIN*

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## Abstract

Water markets across Australia contain many restrictions and the peak intergovernmental forum, the Council of Australian Governments (CoAG) and others have proposed that water markets should be freed up so that the net contribution that water makes to the economy is increased. Using an model of the southern Murray River Basin system, this paper estimates the cost of existing restrictions and changes in the contribution that water makes to the economy if, at least, the temporary market for water was unrestricted.

The model used is a short-run annual model which assumes that water entitlements are distributed so as to maximise returns in an "average" year. No account is taken of the case for permanent trading driven by underlying opportunities to reconfigure land and water use in the southern Murray River Basin system.

Allowing trade from intraregional only to interregional trade has increased net returns from $2502 million to $2590 million (i.e. an increase of $88 million). When a comparison is made between no restriction, no charges and no spatial exchange rates on free trade to a case when there are restrictions and charges and exchange rates are applicable, the trading restrictions, charges, and spatial exchange rates reduce net returns from $2590 million to $2573 million (i.e. a reduction by $17 million). The exclusion of South Australia, New South Wales and Victoria reduces net returns by $27 million, $31 million and $63 million from water trading in Scenarios C, D and E, respectively. The difference of $10 million, $14 million and $46 million reflect the costs of preventing these states from entering in the water market.

## Introduction

Australia's water resources use and management have been challenged to meeting the often conflicting environmental, social and economic objectives. In the Murray Darling Basin (MDB), for example, changes to land use and river management have led to pressure on the Basin's resources, and concern over water quality and ecosystem health (MDBC, 2001). Over the last 20 years, there has been significant expansion in the areas of agricultural activities, including crops and pasture. This expansion in agriculture has increased the use of irrigation water. In the early 1980s, irrigation water use was about 9000 GL, while in recent years it has exceeded 12000 GL for the whole MDB. There are also concerns that the river system is facing multiple threats, including changes to flow

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regimes, habitat destruction, increased salt and sediment load, loss of connectivity due to structural alterations, unsustainable floodplain management, and the introduction of exotic species (CRCFE, 2003).

State and Federal Governments through the Murray Darling Basin Commission (MDBC) have responded with various measures (including regulatory and economic measures) to tackle these concerns. In 1993, the Murray Darling Basin Ministerial Council (MDBMC) initiated an audit of water use in the MDB. The audit demonstrated that if the volume of water diversions continued to increase, it would exacerbate river health problems, reduce the security of water supply for existing irrigators, and reduce the reliability of water supply during long droughts. This audit resulted in a "cap" on water diversions in the MDB being introduced in 1995 (MDBMC 1995).[1] However, in order to meet the continuing increase in the demand for water and to achieve the environmental and economic sustainability of the Basin, there had to be much greater efficiency in the allocation and use of the limited water resources.[2]

In July 1997, the MDBMC agreed to maintain the cap which restricted future extractive usage of water while allowing for adjustments for annual streamflow and climate changes. New irrigation development could only occur by sourcing water from existing extractive users. Imposition of the cap made irrigators and irrigation authorities realize the impacts of the scarcity of water for irrigation, particularly in some regions of the basin. Water trading was seen as an efficient mechanism to facilitate water resources allocated to higher-value uses. Its importance has been recognised by the Council of Australian Governments (COAG) Water Reform Agenda. Among other things, a key objective of the Agenda is to encourage water use to achieve its highest value among both consumptive and non-consumptive uses, and ensure that the use is ecologically sustainable. As a result, it required to develop and implement comprehensive and consistent systems of water entitlements, which were "backed by the separation of water property rights from land title and clear specification of entitlements in terms of ownership, volume, reliability, transferability and, if applicable, quality" (COAG, 1994). Environment was also recognized as a legitimate water user (Crase et al., 2004).

As a first step, the COAG through its establishment of the National Water Initiative (NWI), committed $500 million over five years to address the issues of over allocation. This is expected to recover around 500 GL of water for environmental flows (COAG, 2004). One of the COAG objectives is to achieve an efficient water market structure and expand markets to their widest practical geographical scope, enabling increased returns from water use. This involves reviewing various water entitlement products, pricing policies, exchange rates and trading rules with a view to ensuring consistency and

[1] An interim Cap was imposed in June 1995. Following an independent review of equity issues (Setting the Cap - Report of the Independent Audit Group - November 1996) permanent Cap for NSW, Victoria and South Australia was implemented from 1 July 1997. For NSW and Victoria, the Cap is defined as "The volume of water that would have been diverted under 1993/94 levels of development." For Queensland (a moratorium on further development in place since September 2000) and ACT which together divert less than 7% of total water being diverted in the Basin, the Cap arrangements are still being worked out.

[2] Water allocation is the sharing of water between water users, by whatever means and mechanisms (Taylor, 2002).

compatibility within and across jurisdictions. Another important objective is to establish effective economic incentives, such as best practice water pricing by applying the principles of 'user pays' and 'full cost recovery' to the cost of delivery, planning, and environmental impact where appropriate (COAG, 2003).

In the Southern River Murray System, emerging water markets have increased irrigators' flexibility in managing risk and allowed the relocation of water to more profitable uses. However, wide variations in institutional arrangements among States and significant impediments to market development suggest suggests that the full benefits of water markets are yet to be realised. At the moment, rights to the use of rural water are not fully specified and vary considerably among different jurisdictions. Access rights to water are often called water property rights. In general, property is associated with ownership whereas rights to water have historically been rights to access not own the water. This has led to a range of difficulties in managing both the volume and the quality of flows, and in the establishment of markets for irrigation water. Water trading in the southern connected MDB is particularly constrained by a plethora of differing water access rights and supply agreements (BDA Group, 2003; Shi, 2005).

This paper reviews the progress in water market development in each state as at May 2006 and discusses institutional restrictions and barriers in (both temporary and permanent) water trading within and among several catchments of the southern MDB. A model is developed to estimate the gains from water trading and the impact of these institutional, administrative and spatial restrictions and of the financial disincentives.

## Progress in water trading

*Water access rights and water markets*

In the MDB, states under their legislation provide water users conditional statutory entitlements to access water. The MDBC manages the River Murray system and advises the MDBMC on matters related to the use of water, land and other environmental resources of the basin. It provides bulk water services to NSW, Victoria and South Australia through its water business, River Murray Water. States then provide conditional statutory entitlements to access water to users. In the past, however, these water entitlements were tied to the land on which the water could be used but not allowed to transfer separately from the land. However, over the past decade, this link between land and water has gradually and progressively been broken, allowing water to be traded as an asset separate to land, enabling it to move to higher-value uses (ACIL Tasman (2004).

The last decade has also seen significant progress in the development of water markets as a key instrument in achieving the objective of more efficient and sustainable use of water resources. The development of these markets has generated considerable benefits from the transfer of water from low-value to high-value uses (ACIL Tasman, 2004; Young et al., 2006). However, the extent of actual trades on a permanent basis has been relatively modest. For example, in states like NSW and Victoria that have the largest irrigation sectors and where arrangements for trade have the longest history, annual permanent trade is commonly of the order of less than 1% of total entitlements. In contrast, temporary trade has grown significantly to represent as much as 10-20 % of allocations

(Peterson et al. 2004).[3] However, the volume of net interregional trade ('trade-out' minus 'trade-in') in seasonal allocations remains small and varies across irrigation districts from year to year (Heaney et al., 2005). Nevertheless, water trading has raised the value of water use in the basin (Young et al., 2000) and enhanced its contribution in the economy. For example, Peterson et al. (2004) examined the likely economic effects of expanding water trade among irrigators in the southern MDB and found that allowing both intra- and inter-regional water trade among irrigators substantially lessens the impact of reducing water availability on gross regional product.

*Variation in access rights*

Despite significant benefits of water trade to the national economy, there are still impediments to interstate trade. There is variation in allocation of water access rights in the three states of the southern Murray Darling Basin. In NSW, the water supply is far less secure, and rules for adjusting entitlements in circumstances of low water supply have been incorporated into two types of entitlement systems. As a result, there are two major types of irrigators – 'high security' and 'general security' irrigators. High security entitlement holders receive all of their water in all but the driest years. While for general security entitlements holders, the allocation varies according to the water available in the general security allocation pool and they are allowed to carry over or overdraw in some years. In NSW, around 10 per cent of entitlements are high security while the remainder has a yield of around 80 per cent of entitlements (Heaney, 2005). In contrast, Victoria has a relatively conservative water allocation system where irrigators' water entitlements are referred to as 'water rights' and 'private diversion licenses'.[4] Water right entitlement is relatively secure and available in all but the driest seasons. Private diversion licenses entitle holders to take and use water direct from regulated systems. Both water rights and diversion licenses are able to qualify for 'sales water'[5] which is excess water within a bulk entitlement to that required to meet basic entitlements in the current and following years offered as a proportion of the basic entitlement. It therefore represents an additional medium-security entitlement to water right and diversion license holders (ACIL Tasman 2004) and depends on the amount of water in storage, less a provision for the following year's water right. South Australia has the most conservative allocation regime of the three states and has issued only high-security licenses (Crase et al., 2004). Nominal entitlements in Victoria and SA have a yield of around 95-100 per cent. Further, there is difference in the storage to allocation ratio in NSW and Victoria. As a result, supply reliabilities can be affected significantly by climatic conditions (Heaney 2005).

[3] Trade in water entitlements or permanent trade is the transfer of the ongoing right to access water for the term of the right. Trade in seasonal water allocations or temporary transfer is the transfer of some or all of the water allocated in accordance with the entitlement for the current irrigation season or for an agreed number of seasons (Heaney et al., 2005).

[4] In addition, Victoria is about to introduce a medium security water entitlement which is made available depending on prevalent seasonal conditions.

[5] Under current arrangement, sales water is not a formal entitlement in Victoria. It is attached to water right or diversion license and cannot be traded separately. However, the Victorian Government White Paper (2004) has proposed to unbundle sales water into a separate, legally recognised and independently tradable entitlement.

Different state-based legislation makes it difficult, if not impossible, to address some interstate water management issues (e.g., to alter water access rights to enhance environmental flows). Whereas some state laws provide for compensation to the alteration of water access rights under certain circumstances, some do not. For example, in NSW, access rights are guaranteed for up to 10 years under their various arrangements, and changes within that period can attract compensation rights. On the contrary, in Victoria, some access rights may be altered without compensation at any time a stream flow management plan is changed while others may not be permanently altered and would have to be bought from their owner (MDBMC 2002).

*Administrative and regulatory variation*
In addition, there is variation in the management regimes of different irrigation authorities. In the NSW southern MDB, there are three main irrigation water providers. Murrumbidgee Irrigation Limited, Coleambally Irrigation Co-operative and Murray Irrigation source their bulk water supplies from NSW StateWater, which is responsible for storage, management, operation and ownership of the state's water (Heaney et al., 2004). In Victoria, there are five main water providers. Each of the providers is a statuary authority with sole responsibility to deliver water to its customers holding water entitlements. Goulburn-Murray Water[6] accounts for 90 percent of all entitlements used for irrigation (NCC 2003). In SA, most irrigation water is managed by three irrigation trusts, namely Central Irrigation Trust, Renmark Irrigation Trust and Sunlands Irrigation Trust Inc. (Heaney et al., 2004).

Trade within and between irrigation districts has been constrained by administrative and regulatory arrangements. These restrictions appear to be imposed for a variety of reasons including (Peterson et al., 2004): hydrological limitations to water movement; environmental impacts of changing the current patterns of the supply and use of water; concerns of stranded assets[7]; and social and economic adjustment costs associated with water being exported from particular districts. Many of these restrictions have been imposed to simply retain water within an irrigation system. For example, the Central Irrigation Trust in SA has put a 2% cumulative limit on permanent entitlement trade out of the trust's districts in an attempt to protect regional interests. Excessive water allocation is seen as an incentive for future investment in the regions. Goesch (2001) argues that some irrigation authorities impose restrictions to protect against the prospect of stranded assets, to maintain the economic viability of the region because of expectations of higher water prices in the future.

The reasons for administrative restrictions vary between regions. For example, in NSW, Murrumbidgee Irrigation uses a variety of trade rules to manage MIA compliance with the MDB Cap. Murray Irrigation prohibits permanent trade out of the region because the authorities view surplus water as an incentive to encourage new investors into the region. In Victoria, Goulburn-Murray Water restricts trade out on the basis of the potential for

[6] Goulburn-Murray Water is divided into the Shepparton, Central Goulburn, Rochester-Campaspe, Pyramid-Boort, Murray Valley and Torrumbarry irrigation districts.
[7] A situation where an irrigation authority is faced with large fixed infrastructure costs and a declining customer base.

external third party impacts and some concern over stranded assets. First Mildura Irrigation Trust prohibits transfers from low salinity impact zones to high salinity impact zones on either a temporary or permanent basis (Bell and Blias, 2002). In South Australia, trust boards formulate most rules affecting water trading, although government regulations apply in the few government irrigation districts awaiting privatization (Peterson et al. 2004).

At a state level, water authorities in Victoria can refuse permanent trade out of area if annual net transfers exceed 2 per cent of water rights in that area (following the National Water Initiative, this limit will be extended to 4 per cent in June 2006). Further, Victoria may ban interstate temporary trade following the end of the irrigation season. This measure is designed to prevent temporary transfers of unused water from Victoria to NSW at a low cost later in the irrigation season. Such a transfer may reduce water availability in Victoria in the following season or result in the water being introduced at higher prices by speculators during the peak demand period of the following season (Bell and Blias, 2002). In NSW, state water transfer principles exist from which management committees determine trading rules (Cleary, 2001 paraphrased in Bell and Blias, 2002). Interstate trading is allowed between the Murray and Murrumbidgee and South Australia or Victoria. Temporary trades with South Australia and Victoria are subject to constraints associated with the Barmah Choke[8].

*Other constraints in trade*
Some physical congestion constraints[9] also preclude trade between some regions. The NSW Water Allocation Plan 2003-2004 provided a restriction on temporary (annual) trades between the valleys of the Murray and the Murrumbidgee Rivers at the start of the 2003-2004 seasons due to low water availability (DIPNR 2003, p.14). This restriction was later relaxed in 2005 however when there was a significant improvement in the available water resources. Similarly, Goulburn-Murray Water (GMW) does not permit the trade of more than 30 per cent of an irrigator’s sales water. If GMW irrigators trade sales water, their total use and trade of sales water is restricted to 30 per cent. This means irrigators can only transfer 30 per cent of their allocation. As well, transfers to NSW close on 28th of February. Direct trading is also prohibited between certain subdistricts within an irrigation district and from certain trading districts within an irrigation district to other irrigation districts. For example, irrigators in the Greater Goulburn subdistrict are not permitted to trade directly with irrigators from the Murray Irrigation district and vice versa. Further, in some irrigation districts, water use standards apply that penalize irrigators for exceeding certain irrigation volumes per hectare during an irrigation season (Appels et al., 2004).

There is also the issue of thin markets due to unmotivated market participants. Just as some buyers are reluctant to buy because of uncertainty about future security of the

[8] The Murray River channel narrows at an area known as the *Barmah choke* because of its limited capacity to carry flows. The water flow capacity of the channel is about 8500 ML per day.
[9] The most significant rive channel constraints on the River Murray is the Barmah Choke, through which the flow capacity is reduced to around 8500 megaliters per day to prevent flooding of the surrounding red gum forest. As a result, downstream trades are only possible if they are offset by upstream trades.

entitlements, some sellers might be reluctant to sell because they foresee increasing scarcity of water in the future and so ‘hoard’ their water (Gaffney, 1997 paraphrased in Hassall & Asociates, 2002). In a similar manner, this kind of uncertainty could motivate some buyers to ‘speculate’ in water in the expectation of capital gains.

It is to be noted that trade does not always result in gains, especially when negative externalities are considered. The externalities or third party effects can be of particular concern if the water market comprises a significant reallocation mechanism for resources. Third party effects primarily occur owing to the difficulty in defining property rights in water with precision and well-defined property rights are important in ensuring productive use. In the presence of externalities and asymmetric information between market participants, it is unlikely that a competitive market will generate maximum benefits from trade (Bell, 2001). The Murray Darling Basin Commission has established an exchange rate among states to deal with the third party impact issues. The application of an exchange rate enables the volume and reliability characteristics of the water entitlement to be converted from those of the seller’s State to those of the buyer’s State, including accounting for losses incurred in delivering the water. Exchange rates can be used to minimise adverse impacts on other entitlement holders. Trades from upstream diverters from NSW to Victoria and from Victoria to SA have a 1.0 exchange rate, which means that 100 percent of the entitlement can be transferred down-stream. But transfers from SA to the upstream states of Victoria and NSW have an exchange rate of 0.9 so that only 90 percent of the entitlement can be transferred. Thus, the capacity of the lower river to continue to dilute the salinity will be protected. To integrate the program with the basin initiative, all transfers must meet a no-net-detriment-to-the-environment standard and must be consistent with environmental flows set for the Murray (Young et al., 2000).

Water trade affects return flows that, in turn, affect the quantity and quality of water used downstream. The impact of return flows on water quality is location specific. The extent to which return flows affect water quality depends on a number of factors including groundwater recharge rates and the groundwater salinity underlying the irrigation areas. Trade that moves water from an irrigation area with relatively low recharge rates and low groundwater salinity to a downstream irrigation area with high recharge rates and high groundwater salinity can produce a series of impacts on water quality (Beare and Heaney, 2002).

*Financial cost variation*

Another reason for less interregional water trading is variation in water charges by different irrigation water providers. Generally, irrigators face a two-part tariff comprised of a fixed access fee and a variable consumption charge based on the volume of water delivered. There is considerable variation between regions in the proportion of fixed and variable charges. In regions where fixed charges are an excessively large component of delivery charges, they may distort trading patterns by moving an irrigator out of business. On the other hand, in the regions where delivery charges are based mainly on the variable component, it is likely that these fees include the costs directly associated with the volume of water delivered as well as a significant share of the capital and overhead costs of delivery (Goesch, 2001; Heaney et al., 2004). Further, the fixed fee that they do charge tends to be collected through an annual access fee. In both cases, irrigators are not liable for any outstanding fixed costs when water is traded out of the system, leaving those remaining to face higher charges. Depending on the outcomes from interregional trade, therefore, the way in which the supply authority recoups its revenue differential could have a significant impact on regional income and further distort trading patterns (Goesch, 2001). As noted by Heaney et al. (2005) “where a utility adopts an inappropriate pricing model, such as one that allocated fixed costs to variable charge…the average cost of delivery may rise in source regions, while in the destination region, average cost may fall. These artificial conditions of decreasing and increasing costs can distort the spatial pattern of trade and result in movement of water into lower returning activities”.

The costs associated with temporary water trades include State Government, agency, water authority fees or agent commission. The costs associated with temporary water trades for SA, NSW and Victoria include application fees, technical assessment fees and other charges. The application fees for temporary water trades in SA are larger than the other two states. The application fee for NSW and Victoria is up to $75 while the same fee for SA is up to $300 along with the local irrigation authority or trust’s fee (MIL Water Trading Ready Reckoner, 2006). In SA, there is also variation in different irrigation authorities’ fee structures. Renmark Irrigation Trust (RIT) does not charge additional fees while the Central Irrigation Trust (CIT) charges a fee of $250 for both the purchase and sale in a temporary water trade. In SA, the technical assessment fee is up to $200 while in NSW and Victoria there is no technical assessment fee (Carmel Schmidt, SA Department of Primary Industries and Resources, personal communication April, 2006).

There is also variation in other charges among the three states. For example, authorities in the Murrumbidgee charge a buyer a transfer fee of $75 where water is traded out of the region while a seller is responsible to pay $110 on the sale of a listed parcel of water. Buyers are also charged a commission of 3.3% on the sum of the water sold, along with any water authority transfer fees. Western Murray charges $55 per trade for both buying and selling while Murray Irrigation Limited does not charge any fee whether an irrigators buys or sells water.[10]

In Victoria, temporary and permanent water trading is facilitated by Watermove, Waterfind and the Water Exchange and also a network of water brokers and private trading arrangements. Watermove conducts water exchanges for all water trading zones

[10] Variation in state water allocations and the speed of development in removing water trade restrictions imposed can result in uncertainty among irrigators/investors and in future development. A high level of uncertainty can have a significant impact in reducing investment and undermine incentives for development. Dixit and Pindyck (1994) demonstrate that various sources of uncertainty about future profits such as tax and regulatory policies have much more important effects on investment that does the overall level of interest. From a future investment point of view, it is also critical that uncertainty in water allocation is reduced through more consistent water allocation rights and a simple water charging regime across the states and irrigation authorities.

where trading rules have been defined.[11] A fee is deducted from payments made to successful sellers. The fee includes: a) 3% of the total sale value achieved at exchange; or b) $50 minimum fee; or c) $500 maximum fee or $1.70 per ML sold if the volume of water offered for sale is reduced during an exchange, or the maximum fee, whichever is the lower.

In the case of interstate trade, sellers are required to pay the transfer fees set by the selling authority which vary between $65 and $75. Further, there is an exchange rate mechanism applicable in certain irrigation authorities. For example, when an irrigator in Murray Irrigation Limited buys water from a source external to Murray Irrigation and transfers it into the company's area of operation for use, a 10% loss factor applies. Similarly, rights being traded upstream of the junction of the Murray and Darling Rivers are reduced by 10%.

*Temporary trading status*

Whilst water market reforms have been slow with respect to trade in permanent water rights with spatial restriction (discussed above) still exist, temporary water markets have been more broadly embraced by water service providers, irrigators, local communities and policy makers, as shown in Figure 1. The widespread uptake of temporary trade is evidenced by the public water exchanges that now exist to facilitate exchange in seasonal water allocations by providing a public notice board, and sometimes a clearing house, for such trades (Brennan, forthcoming). These water exchanges bring buyers and sellers together on a regular basis and thereby reduce the extent of potential asymmetry in bargaining power between market participants (Bell and Blias, 2002). The largest of these public clearing houses is Watermove, which began as the Northern Water Exchange that covered temporary trade in the large irrigation districts on the Victorian side of the Murray, and the Goulburn Valley, its major Victorian tributary (Brennan, forthcoming).

[11] A trading zone is defined by a combination of political, administrative, and physical considerations. State and hydrological boundaries are always respected.

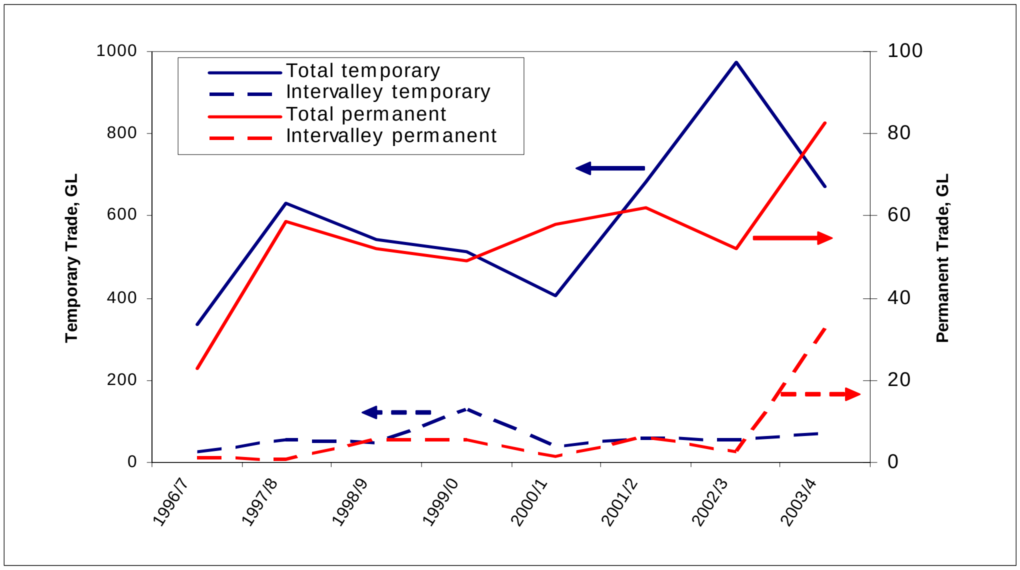



**Figure 1: Annual Water Trade Volume in the Southern MDB**
Source: MDBC (2005).

In the light of the above discussion, it can be summarized that many of the barriers discussed above though applicable to permanent trade, do have implications for temporary trading, and interstate trading including spatial constraints and financial barriers in the form of differences in water fees and charges along with maximum tradable water allocation. The focus of this analysis is on temporary trading, therefore only the relevant spatial, administrative constraints and financial barriers (disincentives) are considered in this paper. The costs of these constraints and disincentives are estimated for each catchment in the MDB by extending a modeling framework developed to estimate the value of irrigation water in 12 agricultural activities across the southern MDB (as shown in Figure 2) and estimating cost of environmental flows under various water acquisition strategies (Qureshi et al., forthcoming). It is to be noted that this modeling framework does not account for environmental flows water allocation and costs of their acquisition.

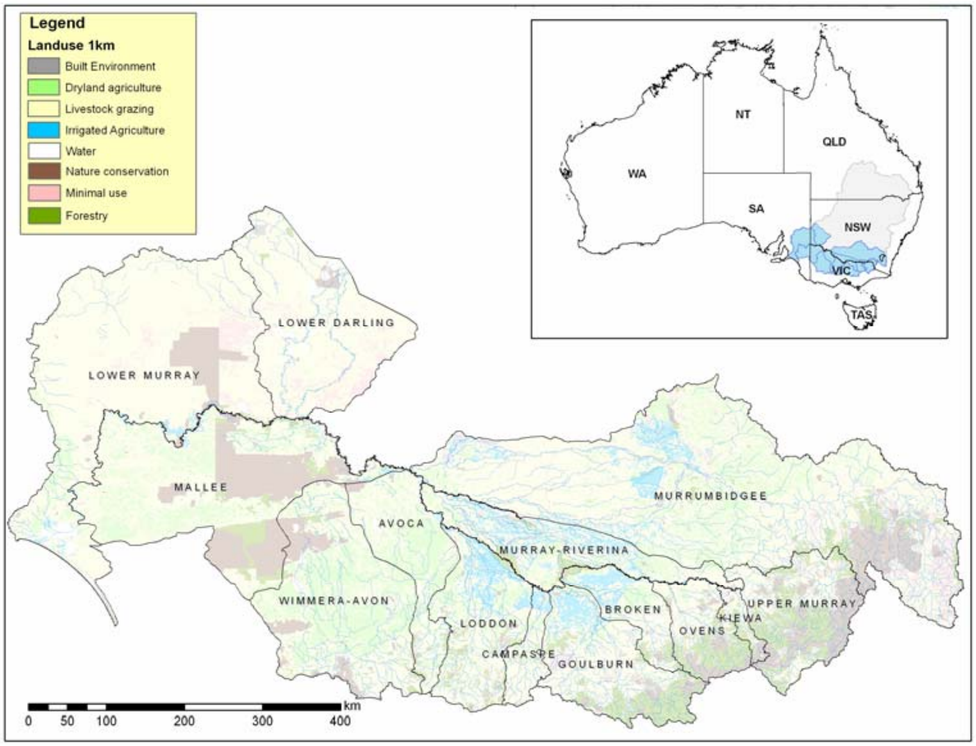



Figure 2 Location map of Southern Murray Darling Basin, Australia

**Modelling framework**

The overall objective of this irrigation water demand (optimisation) model is to maximise the expected net revenue from water use for regional irrigation areas subject to a number of land, water and agronomic constraints discussed below. Each region is treated as though it were a decision maker attempting to maximise economic returns from producing irrigated crops and releasing for dryland activity if it is more profitable to sell water in temporary intra-regional water markets than it is to irrigate. Stochastic water availability, effective rain and irrigation requirements are treated as states of nature and weighted by probabilities as derived from historical observations. These states are included in the model to understand how irrigators will respond when they face extreme weather conditions that have an affect on rainfall, irrigation requirements and water allocations. The model is used to estimate expected values of these variables accounting for risk involved in the agricultural activities.

This is a short term planning horizon model with an assumption that no capital investment can take place, i.e. irrigators cannot invest in capital and allocate more land and water to the activities which result in high expected net return in the short term. Therefore, changes in fixed costs may not influence production decisions because the total cost remains the same irrespective of the quantity of water used. In contrast, changes in variable costs may affect production decisions. Irrigators facing an increase in variable costs may be able to reduce the resultant impact of the cost increase on profits by reducing the amount of the input used and/or substituting other inputs (Appels *et al*. 2004).

The net revenue from all regions for each state of nature is equal to the aggregate revenue from these regions minus variable costs, water supply costs and water charges. The expected net revenue (*ExpR*) from these regions is obtained by weighting the net revenues from these regions by their probabilities in each state of nature and aggregating to get total expected net revenue from the basin:

$$ExpR = \sum_{s} \Pr_{s} \left( \sum_{r} \sum_{j} P_{rj}\, Yld_{rj}\, A_{srj} - \sum_{r} \sum_{j} OC_{rj}\, A_{srj} - \sum_{r} \sum_{j} WCh_{r}\, A_{srj}\, w_{srj} \right) \qquad (1)$$

where

| | |
|---|---|
| *s* | State of nature |
| *r* | Irrigation demand sites (regions) |
| *j* | Cropping activities |
| *Pr* | Probability of water allocations/supply |
| *P* | Crop price ($/ha) |
| *Yld* | Actual yield (t/ha) |
| *A* | Harvested area (ha) – the decision variables |
| *OC* | Other cost ($/ha) |
| *WCh* | Water charge in different regions ($/ML) |
| *w* | Water used (ML/ha) |

***Stochastic rainfall and water supply***

Five states of nature have been used to reflect the overall temporal pattern of water availability for consumptive uses in the different regions of the basin. Historical rainfall data reveals that in extreme low rainfall cases, regions received about 35 per cent less rainfall than an average year rainfall while in a slightly better year, regions receive 25 per cent less. The expected rainfall value is used for each region across the Basin. In calculating water supply across states of nature, administrative water allocation rules are taken into account allowing for the system capacity to be stored and, hence, shifted towards drier years.

The spatial distribution of water allocations were calculated from a combination of the changed MDBC simulation runs and information from Bryan and Marvanek (2004). The MDBC figures give the allocation at each diversion point. The analysis by Bryan and Marvanek (2004) is used to characterise differences in water demand related to evapotranspiration and effective rainfall across regions and years. The result is a cumulative distribution of allocations for these catchments that was plotted and the 10, 30, 50, 70 and 90 percentile points of the distribution calculated (Qureshi et al., forthcoming).

The expected allocations for the whole basin were compared with actual usage of water for irrigation in catchments of the southern MDB and it was found these allocations are higher than the actual usage data which was close to the $10^{th}$ percentile. For consistency and for estimating financial returns and the true value of irrigation water, expected values were multiplied by the allocations at the various percentile points on the distribution by a factor which resulted in values that were approximately equal to the actual water usage plus an allowance for the channel conveyance losses for each catchment. Hence, approximate values of water use for several points on a frequency distribution were obtained. It is to be noted that this frequency distribution is based on the assumption that the frequency distribution of water use is equal to the frequency distribution of water allocation for all catchments and for all years (including droughts and wet periods) (Qureshi et al., forthcoming).

***Evapotranspiration (water-yield) function***

The water requirements of a crop depend on physical factors, such as climate, soils and crop characteristics. At low water application rates an additional unit of water results in a substantial yield increase but the marginal product of water quickly declines at higher water levels. Beyond a certain level of water application, crop yields suffer due to lack of aeration in the root zone and the marginal product of water becomes negative (de Fraiture and Perry (2003). The model assumes that output is a function of water only (i.e. water yield response function) and no contribution of land and capital is considered in the analysis, i.e. the elasticity of substitution between water and land/capital is zero.

The evapotranspiration requirement of irrigation in the model is based on spatial water use data, taken from Bryan and Marvanek (2004). The coefficients used in evapotranspiration functions were derived by combining field data on yield and water requirements from Bryan and Marvanek (2004) and the slope of the FAO crop yield response function (Doorenbos and Kassam, 1979). This information has been used to estimate a yield response function to total irrigation water and rainfall for the agricultural activities in the Basin, represented by equation (2).[12]

$$Y_{srj} = f\left(ET_{srj}\right) = a_{rj} + b_{rj} ET_{srj} + c_{rj} ET^{2}_{srj} \qquad (2)$$

Where

| | | |
|---|---|---|
| $Y$ | = | yield in tonnes per hectare |
| $ET$ | = | total quantity of water used by the crop including irrigation water and effective rainfall (ML/ha) |
| $a$ | = | intercept of the yield response functions (t/ha) |
| $b$ | = | slope coefficient of the yield response functions (t/ML) |
| $c$ | = | other (quadratic) coefficient of yield response function (t.ha/ML$^2$) |

The irrigation water requirement for each activity in each region varies from year to year because both the evapotranspiration requirement and the rainfall vary. The irrigation water requirement of plants takes into account the contribution towards evapotranspiration by rainfall, as well as an allowance for irrigation system efficiency losses and leaching requirement to control any salinity build up in the soil (Skews, 2002). Crop water (quadratic) production functions of grape (for example) for selected

12 It is to be noted that the yield response function is general and can incorporate any change in crop water use in other regions. For example, in a region with high/low rainfall and with different soil type, crop production will be different in that region. These functions are important in determining the final results of the analysis (Qureshi et al., 2006).

catchments are shown in Figure 3. These production functions show contribution of both effective rainfall and irrigation water. Greater contribution of rainfall requires less irrigation requirement and vice versa. Effective rainfall[13] is subtracted from potential evapotranspiration to calculate the net irrigation requirement of plants for each state of nature (Qureshi et al., forthcoming).

Conceptually, an irrigator can improve application efficiency by using deficit irrigation, moving water from low value to high value irrigation activities, substituting capital for water, or ultimately, by withdrawing irrigation and leaving land for dryland production. Deficit irrigation (an irrigation scheduling technique) has been adopted in a number of agricultural activities in Australia. For example, in grapes, water deficit is applied during the post-set period to minimise competition between ripening berries and vegetative growth (McCarthy, 2000). Deficit irrigation may reduce yield of some crops and result in less yield but in some crops it can improve the quality of the product. As a result of deficit irrigation, more areas can be irrigated. It is possible that the decreased benefits due to deficit irrigation could be lower than the profit gained from the increased area resulting in an overall net increase of profit. Mainuddin et al. (1997) showed that in the case of lower availability of water, deficit irrigation can increase the overall net benefit. However, the level of deficit irrigation depends on the type of crops. In general, pulses, oilseeds, cereals (except rice) and grapes are tolerant to water stress to some extent. Rice is very sensitive to water stress particularly at the flowering and the second half of the vegetative period (head development) (Doorenbos and Kassam, 1979). Limited stress can be applied to rice without significant yield loss during the early part of the vegetative stage (which increases tillering) and at the late stage which keeps the field dry during harvesting.

The current model allows deficit irrigation subject to a certain threshold of minimum water requirements for each agricultural activity. For example, rice cannot be grown if the irrigation water is less than 80% of its maximum evapotranspiration requirement. However, this model does not allow further increases in irrigation efficiency with capital investments due to short term analysis. Later, the model is modified to include a small improvement in irrigation efficiency through better irrigation management (such as better soil scheduling and regular monitoring of the existing system) with increased variable cost.

***Major water and land constraints***

*Irrigation water use accounting and basin water constraint*

Water availability constraint is of the general form:

$$\sum_{j} w_{srj} A_{srj} \le (1 - CLoss) \times TotWatR_{sr} \qquad \forall r, s \qquad (3)$$

This constraint ensures that the sum of the amount of water required by all crops $j$ in a region $r$ will not exceed the total amount of water available for that region ($TotWatR_{sr}$) after conveyance losses ($CLoss$) which includes loss in the river channel on its way to the region as well as loss in the delivery canals and fields on its way from the river to the

13 Effective rainfall is the rainfall that is utilised by the crop depending on a number of factors including days (months) a crop occupies in a year.

crop. Later this local constraint on individual catchments is released to examine impact of water trading across the Basin. Here, these regions are categorized into two groups, namely ‘trading regions’ and ‘non trading regions’. A ‘trading region’ can buy or sell water from/to other trading regions while ‘non trading regions’ cannot participate in the market.[14] A subset called ‘restricted trading regions’ is formed of the ‘trading regions’ where a region can enter or exit from this subset or its allowable water for trading can be increased or decreased depending on the policy scenario.

*Irrigated Land Constraints*

The equations for land availability constraints are of the form:

$$\sum_j A_{srj} \leq TotLand_r \qquad \forall\ s, r \tag{5}$$

where *TotLand* is the total available area for irrigation (ha). The land constraint ensures that for each state *s*, the sum of the land areas required by all regions *r* and crops *j* will not exceed the total available area for irrigation.

*Dryland constraint*

This constraint is used to release irrigated land towards dryland activity (Dryland) if not economic to irrigate as shown in the following equation:

$$Dryland_{sr} = LandR_r - \sum_j A_{srj} \quad \forall\ s, r \tag{7}$$

This land constraint ensures that for each state, the sum of the land areas of the crops converted to dryland and used for irrigation will not exceed the area available for irrigation land ($LandR_r$) in that region. Initially, dryland production is zero since only the irrigated portion is modeled. This equation, however, allows conversion to dryland if the cost of water makes the conversion profitable.

*Temporary and permanent activities land constraint*

Here, a fixed land constraint (8a) is imposed on permanent activities (*jp*) which can neither expand nor contract in the short term. Temporary activities (*jt*) are allowed to take land from other temporary activities if it is economically viable to expand, as shown in equation (8b).

$$A_{srj} = Area_{rj} \qquad if \quad jp \qquad \forall\ s, r, j \tag{8a}$$

$$\sum_j A_{srj} \leq \sum_j Area_{rj} \quad if \quad jt \qquad \forall\ s, r \tag{8b}$$

[14] Non trading regions which include Upper Murray, Kiewa and WimAvon catchments are excluded from the ‘Murray River Trading System’ non trading regions. The first two catchments are not part of the regulated trading system while the last catchment ‘WimAvon’ does not have any physical linkage with the other catchments and its rivers do not discharge into the Murray River, rather, they enter terminal lake systems and cannot be part of the trading system. Their economic contribution in the basin remains the same in all the scenarios.

Temporary activities can release land for dry land activity if it is not economically viable to irrigate along with reduction in irrigation water application and producing less yield (t/ha). Minimum area constraint is imposed on the temporary activities to prevent disappearance of activities with poor economic performance. A similar but opposite maximum irrigated land constraint is imposed to ensure that production does not exceed the reasonable demand in the short term.

Minimum irrigated land area constraints are included because survey data (Bryan and Marvanek 2004; ABARE 2003) reveal that some areas produce irrigated crops even in years when this would appear to be unprofitable. This may be because all resources, particularly water and labour, are not perfectly mobile and thus are not imputed using the full market value of alternative uses. The constraints are a way of representing rigidities in water markets that arise as the result of administrative and biophysical constraints to water trade.

The permanent activities can only decrease water use through deficit irrigation and producing less quantity comparing to their maximum yield.[15] The idea is to ensure that permanent crops such as vines and citrus cannot expand from year to year, given that significant capital investment would be required that is only possible in the long-run. In contrast, areas of low value crops such as pasture that typically are expanded in high water availability years with existing excess capacity of capital such as irrigation are allowed to expand. Temporary activities include oilseeds, cereals, legumes, pasture for beef, pasture for dairy, pasture for sheep and vegetables while permanent activities include deciduous fruits, citrus fruits and grapes. Rice is included as a permanent activity because it cannot be grown other than in specific areas and on specific soil types (Appels 2004).

***Solution algorithm***

A non linear programming (NLP) structure is used instead of the more common linear programming approach primarily because of the nonlinearities involved in the agricultural activities production functions as well as multiplication of two variables (i.e. net revenue per hectare and irrigation area under each crop and region) in calculation of total net revenue from each crop in each region. The model has been coded in the modelling language of the General Algebraic Modelling System (GAMS) (Brooke *et al*. 2004). A complete model specification is available in the source GAMS code on request.

## Model results and discussion

[15] Less quantity through deficit irrigation can result in high quality output that can attract a premium price. For example, the price received for grapes ($/t) depends on quantity (yield t/ha) as well as on quality. The price received includes bonuses or penalties based on baume (a system of measuring the sugar content of grape juice by its density and one baume is equal to approximately 1.75% sugar in the juice). Generally, an increase in yield is associated with a decline in quality, which is ultimately reflected in a lower price for additional units (Qureshi et al. 2006). However, net irrigation water cannot be reduced below their thresholds (as mentioned above) which are essential for different activities. Any reduction below the thresholds can result in significant damage to both quantity and quality of those activities.

In the model, it is assumed that the water usage is equal to the stochastic water allocated to or available for that region.[16] A baseline application involves a set of simulations structured to assess the economic rent to investigate water demand, economic return and crop mix changes that could be expected across catchments when irrigators face stochastic rainfall and water allocations due to uncertain weather conditions across a range of market conditions. Initially in the analysis, only intraregional trade is allowed (where irrigators can sell/buy to/from other irrigators in the same region but interregional water trading is not allowed) and optimal land and water use is determined and a comparison is made with the given land and water for each catchment.

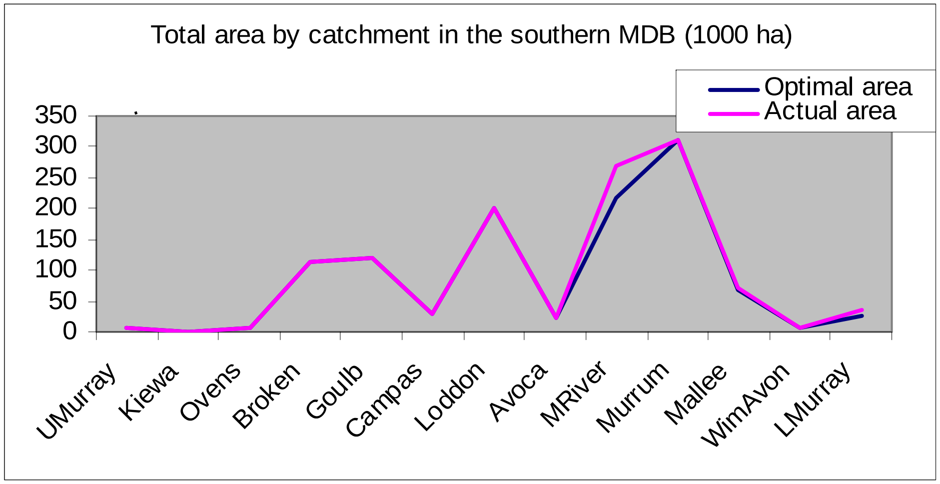
Figure 2 presents the expected optimal area and water usage for each crop and region when only intraregional trade is allowed as simulated in the model. Model results indicate that the expected optimal area is 99% of the given area. Avoca, MRiver, Mallee, WimAvon and Lower Murray are the catchments where optimal irrigation areas are less compared to their actual areas, i.e. by 2%, 20%, 3%, 11% and 26%, respectively. This is because of the relatively more profitable activities that result in greater return of each additional unit of water and scarcity of water in these two catchments. Pasture for sheep production and oilseeds are the activities where estimated optimal area is significantly lower than the actual areas. This appears to be caused by their poor economic performance compared to other activities.

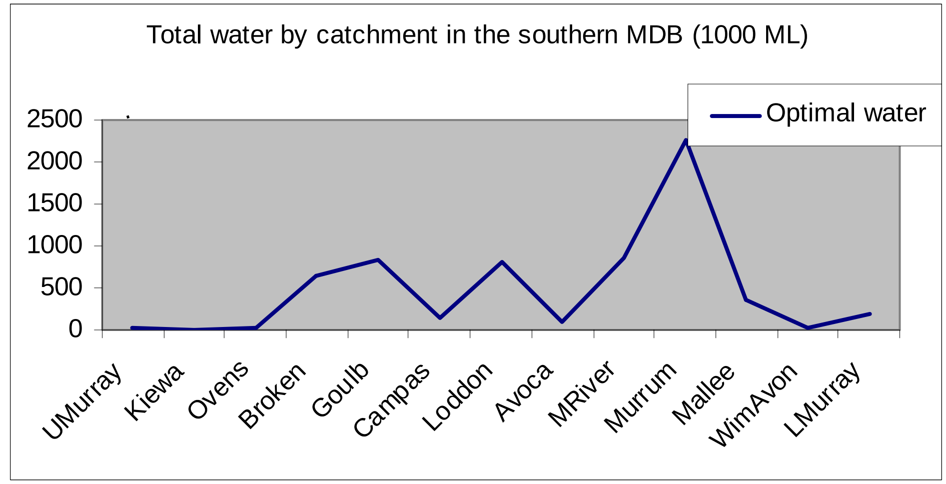
Total expected water use for irrigation in the whole Basin (when only intraregional water trading is allowed) is estimated at 6257 GL while total expected net return is estimated at $2502 million, as shown in Table 1. A summary of the expected water available and water usage by each catchment along with the expected shadow price of water, expected net returns per ha and per ML is also presented in Table 1. All the catchments fully utilized their allocated/given water. Murrumbidgee remains the highest water user followed by Murray River and Goulburn. The shadow prices of Mallee, WimAvon and Lower Murray are $156, $120 and $117, respectively. Net revenue per hectare and per ML are also highest in these three catchments.

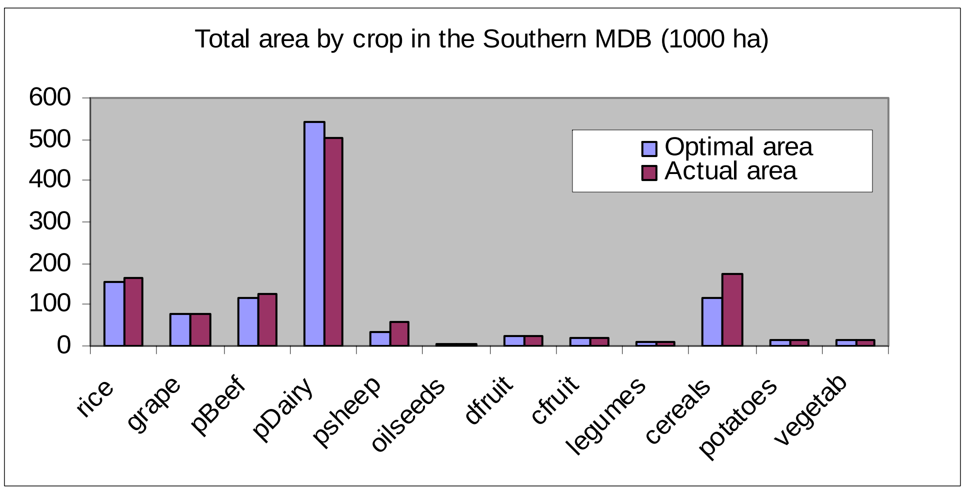
The weighted average shadow price of the basin under each state of nature is also estimated by multiplying the proportion of water use in each catchment by each catchment's shadow price and adding them together. The expected weighted average shadow price of water in the basin varies from $42 to $21/ML indicating that irrigators in the basin are willing to pay up to $42/ML when they face extremely low water allocations compared to the state of nature when there are very high allocations and the irrigators are not willing to pay more than $21/ML. These figures also indicate the willingness of the irrigators in the basin to pay higher premiums for more secure water.

[16] Water charges, charging strategies, and rules for security of supply all differ from region to region, and are under review in response to water reform (COAG 2004; Heaney et al. 2004). Heaney et al. (2004) sourced current water charges (including fixed fee and variable fee) applicable in nine irrigation regions by the relevant authorities. These water charges are used for the catchments where these irrigation areas are located and for the remaining four catchments water charges similar to their adjacent catchments are used in the analysis.

Figure 2 Expected optimal areas and their comparison with actual areas by catchment and crop along with expected water usage by catchment and crop



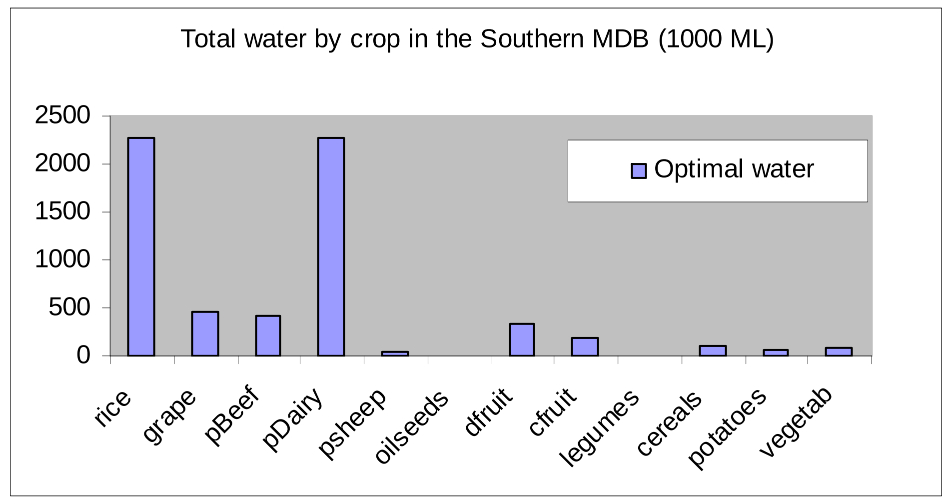



Table 1: Expected land/water use, net return and shadow price of water usage in different regions

| Catchment | Irrigation use (%) | Water use (ML) | Water shadow price ($) | Net revenue (000 $)[a] | $/ha | $/ML |
|---|---|---|---|---|---|---|
| UMurray | 1.00 | 20412 | 10 | 5375 | 944 | 263 |
| Kiewa | 1.00 | 3543 | 14 | 859 | 919 | 243 |
| Ovens | 1.00 | 14768 | 20 | 11617 | 1472 | 787 |
| Broken | 1.00 | 654248 | 9 | 232701 | 2064 | 356 |
| Goulb | 1.00 | 840427 | 6 | 287120 | 2388 | 342 |
| Campas | 1.00 | 132001 | 12 | 58529 | 1949 | 443 |
| Loddon | 1.00 | 799605 | 12 | 245081 | 1212 | 307 |
| Avoca | 0.98 | 104537 | 22 | 77036 | 3440 | 737 |
| Mriver | 0.80 | 853084 | 32 | 190114 | 865 | 219 |
| Murrum | 1.00 | 2271415 | 12 | 430350 | 1379 | 189 |
| Mallee | 0.97 | 346583 | 156 | 660807 | 9719 | 1906 |
| WimAvon | 0.89 | 31900 | 120 | 46133 | 9308 | 1445 |
| Lmurray | 0.74 | 184335 | 117 | 256383 | 9645 | 1388 |
| Total | | 6256858 | | 2502105 | | |

a In the case of Avoca, Mallee, WimAvon and LMurray, both irrigated and dryland revenues are included because these catchments released some portion of their irrigated land towards dryland.

**Model based policy analysis**

The purpose of this study is estimating cost of interregional water trade restrictions across the catchments and their impact on the Basin's net revenue. The model is used to examine the impact of the following five scenarios:

A. Baseline run when *water trading is allowed across the basin catchments* without any institutional/administrative constraints or financial disincentives or exchange rate mechanism except an upper limit on maximum water trade-in allowed.[17]

B. *Water trading is allowed across the basin catchments* but irrigators in Victoria can sell up to 30 per cent of their water allocation while irrigators in Murrumbidgee can sell up to 75 per cent of their allocation along with an upper limit on the maximum water trade-in allowed restriction across the catchments; All administrative/application, irrigation authority and State fees and charges on water trading are applicable along with water exchange rate mechanism;

C. *Water trading is allowed only in Victoria and NSW catchments* (i.e. Lower Murray catchment of South Australia does not participate in the water market). The Victorian irrigators can sell up to 30 per cent of their water allocation while irrigators in Murrumbidgee catchment can sell up to 75 per cent of their allocation. All administrative/application, irrigation authority and State fees and charges on water trading are applicable along with an upper limit on maximum water trade-in allowed restriction on the trading catchments;

D. *Water trading is allowed only in Victoria and South Australia catchments* (i.e. NSW catchments do not participate in the water market). The Victorian irrigators can sell up to 30 per cent of their water allocation while irrigators in the

[17] The maximum upper limit is imposed on water trading to address the channel capacity constraint.

Murrumbidgee catchment can sell up to 75 per cent of their allocation. All administrative/application, irrigation authority and State fees and charges on water trading are applicable along with an upper limit on the maximum water trade-in allowed restriction on the trading catchments;

E. *Water trading is allowed only in South Australia and NSW catchments* (i.e. Victorian catchments do not participate in the water market). Irrigators in the Murrumbidgee catchment can sell up to 75 per cent of their allocation. All administrative/application, irrigation authority and State fees and charges on water trading are applicable along with an upper limit on maximum water trade-in allowed restriction on the trading catchments;

Scenarios B to E are compared against Scenario A and costs of the additional restrictions in each scenario are estimated. In the baseline policy run Scenario A (when interregional water trading is allowed across the basin and the irrigators face no institutional or administrative constraint or financial disincentives), total expected water use in the whole Basin remains the same, i.e. 6257 GL while total expected net return is estimated at $2590 million (i.e. a gain of $88 million as a result of interregional water trading) shown in Table 2. A summary of expected areas under irrigation, water available, water use and proportion of water along with expected net returns per ha and per ML for each catchment is also presented in Table 2. As a result of water trading, the results indicate that Ovens, Avoca, Murray River, Mallee and Lower Murray catchments increase significantly their water usage while Broken and Goulburn reduce their water usage, i.e. by 25% and 40%, respectively. Lower Murray releases 13% of its irrigated area towards dryland production due to more profitable activities dominating and the scarcity of water in the region. The reader is reminded that the three catchments of Upper Murray, Kiewa and WimAvon are not part of the trading system, therefore, their water usage remains the same as before trading along with their economic contribution towards total net revenue of the Basin.

Table 2: Expected irrigated land/water use and net return of water usage in Scenario A across the regions

| Catchment | Irrigation Use (%) | Water available (ML) | Water use (ML) | Water use proportion | Net revenue (000 $) | $/ha | $/ML |
|---|---|---|---|---|---|---|---|
| UMurray | 1.00 | 20412 | 20412 | 1.00 | 5375 | 944 | 263 |
| Kiewa | 1.00 | 3543 | 3543 | 1.00 | 859 | 919 | 243 |
| Ovens | 1.00 | 14768 | 20675 | 1.40 | 12130 | 1537 | 587 |
| Broken | 1.00 | 654248 | 490883 | 0.75 | 223825 | 1986 | 456 |
| Goulb | 1.00 | 840427 | 503336 | 0.60 | 271942 | 2261 | 540 |
| Campas | 1.00 | 132001 | 134457 | 1.02 | 58610 | 1952 | 436 |
| Loddon | 1.00 | 799605 | 778004 | 0.97 | 243273 | 1203 | 313 |
| Avoca | 1.00 | 104537 | 129791 | 1.24 | 79101 | 3473 | 609 |
| MRiver | 0.96 | 853084 | 1194318 | 1.40 | 234441 | 899 | 196 |
| Murrum | 1.00 | 2271415 | 2247180 | 0.99 | 430968 | 1381 | 192 |
| Mallee | 0.99 | 346583 | 452082 | 1.30 | 707891 | 10144 | 1566 |
| WimAvon | 0.89 | 31900 | 31900 | 1.00 | 46133 | 9308 | 1445 |
| LMurray | 0.87 | 184335 | 250275 | 1.36 | 275574 | 8896 | 1100 |
| Total | | 6256858 | 6256856 | | 2590122 | | |

The model is used to estimate the impact of Scenarios B and C. In Scenario B, the impact on water trading is estimated when irrigators in Victorian catchments and Murrumbidgee catchment in NSW are only allowed to sell up to 30% and 75% of their water allocation, respectively. Later, state fees and charges on water trading as well as a water exchange rate mechanism are also included in the model to examine both collective as well as individual impact of water trade restrictions and financial disincentives. Some fees and charges are based on the number of transactions that take place in a catchment. Depending on the economic performance and size of a catchment, the volume of transactions varies across the catchments, as shown in Table 3. A negative figure indicates that a region traded-out water while a positive figure indicates that a region traded-in water as a result of trading. The results of three Scenarios indicate that the transaction took place in all the catchments in Scenarios A and B. LMurray catchment did not participate in Scenario C because of the exclusion of South Australia and resulted in zero trade. Similarly, the two catchments of NSW did not participate in Scenario D while the seven catchments of Victoria did not participate in Scenario E and resulted in zero water trade. The reader is reminded that the maximum allowable water that can be traded in a region remain in the model which forces a region to trade in only up to the threshold no matter how much irrigators in that region are willing to pay for an additional unit of water. The expected volume of water traded in these scenarios varies between 341 GL to 546 GL. The volume of water traded is lower than the intrastate trading volumes but close to the interstate trading volumes, shown above in Figure 1.

Table 3 Expected volume of water traded in/out of the trading regions in each scenario

| Catchment | Volume of water traded Scenario A | Volume of water traded Scenario B | Volume of water traded Scenario C | Volume of water traded Scenario D | Volume of water traded Scenario E |
|---|---|---|---|---|---|
| Ovens | 5907 | 5907 | 5907 | 5907 | 0 |
| Broken | -163365 | -164085 | -152054 | -89082 | 0 |
| Goulb | -337091 | -252128 | -252128 | -252128 | 0 |
| Campas | 2457 | -3663 | -659 | 21082 | 0 |
| Loddon | -21600 | -48464 | -28350 | 107076 | 0 |
| Avoca | 25254 | 22198 | 23995 | 29779 | 0 |
| MRiver | 341234 | 341234 | 341234 | 0 | 299362 |
| Murrum | -24235 | -70665 | -43432 | 0 | -351304 |
| Mallee | 105500 | 105121 | 105487 | 106957 | 0 |
| LMurray | 65940 | 64545 | 0 | 70409 | 51942 |
| Total | 546292 | 539005 | 476623 | 341210 | 351304 |

The historical size of transaction in the trading regions by individual irrigators varies between zero to hundreds or thousands.[18] Following the local water trading observations, a conservative size of 20 ML per transaction is considered appropriate and used to estimate number of transactions in each scenario, as shown in Table 4. After determining

[18] Young et al. (2000) estimated volume of permanent trades from the commencement of the inter-state trading trial by origin and destination and found that 51 trades took place and a total of 9.8 GL of water was traded. These figures indicate that on average across the basin the size of water traded was about 185 ML per. As far as the temporary or seasonal water trading is concerned, the size of transactions was much smaller. According to the Murray Irrigation Limited, average size of a transaction in the region was 145 ML while in the Goulburn Murray water trading regions, average size of a transaction was about 20.

optimal water usage and the number of the transactions that took place in each catchment, the costs of water trading are included. A post optimality analysis is carried out again using GEMPACK software package and net revenue is estimated for each catchment as well as impact on the total basin net revenue for each scenario. Table 4 also presents change in volume of water use and net revenue per ML of water in each catchment. As far as the water trading out is concerned, Broken and Goulburn are the two catchments which lose significant portion of their water allocations while Mriver, Malle and LMurray catchments trade in water significantly in all the three scenarios, except LMurray in case of Scenario C where it does not participate in the water market. The net revenues per ML of the regions which increase their water usage resulted in lower net returns per ML. For example, water usages of Broken and Goulburn have increased while their net revenues per ML have decreased from \$456 and \$540 to \$454 and \$468, respectively. Similarly, the net revenue of LMurray has increased from \$1082 and \$1088 in Scenario D and B to \$1388 in Scenario C when this region was not allowed to take part in the water trading.

Table 4: Expected change in water usage (proportion), number of transactions and net returns ($/ML) in major trading regions in each scenario

| Catchment | Scenario A | | | Scenario B | | | Scenario C | | | Scenario D | | | Scenario E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Change in water use (%) | Number of transactions | Net revenue ($/ML)* | Change in water use (%) | Number of transactions | Net revenue ($/ML) | Change in water use (%) | Number of transactions | Net revenue ($/ML) | Change in water use (%) | Number of transactions | Net revenue ($/ML) | Change in water use (%) | Number of transactions | Net revenue ($/ML) |
| Broken | -0.25 | -8168 | 456 | -0.25 | -8204 | 454 | -0.23 | -7603 | 445 | -0.14 | -4454 | 402 | 0 | 0 | 356 |
| Goulb | -0.40 | -16855 | 540 | -0.30 | -12606 | 468 | -0.30 | -12606 | 468 | -0.3 | -12606 | 468 | 0 | 0 | 342 |
| Campas | 0.02 | 123 | 436 | -0.03 | -183 | 453 | 0.00 | -33 | 444 | 0.16 | 1054 | 390 | 0 | 0 | 443 |
| Loddon | -0.03 | -1080 | 313 | -0.06 | -2423 | 321 | -0.04 | -1418 | 314 | 0.13 | 5354 | 277 | 0 | 0 | 307 |
| Avoca | 0.24 | 1263 | 609 | 0.21 | 1110 | 620 | 0.23 | 1200 | 612 | 0.28 | 1489 | 589 | 0 | 0 | 737 |
| Mriver | 0.40 | 17062 | 196 | 0.40 | 17062 | 191 | 0.40 | 17062 | 191 | 0 | 0 | 219 | 0.35 | 14968 | 192 |
| Murrum | -0.01 | -1212 | 192 | -0.03 | -3533 | 194 | -0.02 | -2172 | 193 | 0 | 0 | 189 | -0.15 | -17565 | 211 |
| Mallee | 0.30 | 5275 | 1566 | 0.30 | 5256 | 1564 | 0.30 | 5274 | 1562 | 0.31 | 5348 | 1557 | 0 | 0 | 1906 |
| Lmurray | 0.36 | 3297 | 1100 | 0.35 | 3227 | 1088 | 0.00 | 0 | 1388 | 0.38 | 3520 | 1082 | 0.28 | 2597 | 1161 |

*Net revenue in Scenario A shows average return per ML without including transaction costs related to water trading

Net returns on the basin wide are also estimated to examine impact of the regulatory regimes and of financial disincentives under each scenario, as shown in Table 5. Due to the imposition of the upper limit out of water trading in a region and inclusion of exchange fees and charges, net return has reduced from $2590 million of Scenario A to $2573 million in Scenario B, $2563 million in Scenario C, $2559 million in Scenario D and $2528 million in Scenario E. The opportunity cost of all these restrictions is $17 million in Scenario B, $27 million in Scenario C, $31 million in Scenario D and $63 million in Scenario E. Comparing the last three scenarios (C, D and E, where one of the three states is excluded from the trading market in each case) with Scenario B (where all three states participated in the market), the figures indicate that exclusion of LMurray catchment costs $10 million. These costs have increased to $14 million and $46 million when first NSW catchments and then Victorian catchments are excluded from the water market. Other than the impact of administrative and regulatory constraints, the individual impact of exchange fees and charges are also estimated for these scenarios which are $16.34 million, $11.26 million, $5.05 million and $6.06 million, respectively.

The gains estimated above as a result of free water trade in Scenario A compared to the other scenarios (where restrictions are imposed in water trading along with exchange rate and charges and fees on water trading) are lower than the gains shown in previous studies on free trade in the Basin (Peterson et al., 2004). This is due to a number of reasons. For example, in the current study a partial analysis approach is adopted rather a computable general equilibrium modeling approach adopted in the previous studies where impacts on other industries and sectors are also linked and included. Further, the current study is a short term analysis and estimates expected gains as a result of variation in rainfall and water allocations and any new investment is not allowed. It is to be noted that the estimates of the costs due to restrictions, exchange rates and charges and as a result gains due to free trade are for one year only and removal of these restrictions will result in further gains over the years ahead. Further, it is noted that many gains will come from permanent water trading and investment in new industries.

Table 5: Total expected water use, net returns and opportunity cost of restriction in each scenario

| | Scenario A | Scenario B | Scenario C | Scenario D | Scenario E |
|---|---|---|---|---|---|
| Net return ($1000) | 2590120 | 2573113 | 2563138 | 2559111 | 2527544 |
| Opportunity cost ($1000) | N/A | 17007 | 26983 | 31010 | 62576 |
| Cost of exchange fees and charges ($1000) | | 16342 | 11264 | 5052 | 6057 |

**Conclusions**

In this paper, the optimization model is used to estimate the expected economic value of irrigated water for each agricultural activity in the basin. The model provides estimates of costs of water trade along with the costs of institutional and administrative constraints, financial disincentives and spatial restrictions as well as a restriction on maximum allowable water for trading in each region across the basin. The results of the optimisation model indicate that the framework can provide robust information about the cost of temporary water trading restrictions to inform policy makers in dealing with water management issues.

The Murrumbidgee catchment in NSW remains the highest water user followed by the Murray River and Goulburn catchments. When there was no water trading, the estimated expected shadow prices in the Mallee, WimAvon and Lower Murray are $156, $120 and $117 per ML, respectively. Net revenues per hectare and per ML are also highest in these catchments. The expected weighted average shadow price of water in the basin varies from $42 to $21/ML indicating that irrigators in the basin are willing to pay up to $42/ML when they face extremely low water allocations, compared to the state of nature when there are very high allocations and they are willing to pay up to $21 for each additional unit of water.

Allowing free trade between regions has increased the net returns. Ovens, Avoca, Murray River, Mallee and Lower Murray catchments increase their water usage significantly while Broken and Goulburn reduce their water usage by 25% and 40%, respectively. Lower Murray releases 13% of its irrigated area towards dryland production due to more profitable activities dominant and due to scarcity of water in the region.

The institutional and administrative restrictions, financial expenses and exchange rate constraints reduce net returns from $2590 million in Scenario A to $2573 million in Scenario B. Preventing SA, NSW and Vic catchments in Scenarios C, D and E, respectively, further reduces the net returns to $2563 million, $2559 million and $2528 million. The opportunity cost of Scenario B is $17 million while the opportunity cost of Scenario C, D and E is $27 million, $31 million and $63 million, respectively. The difference of $10 million, $14 million and $46 million reflects the costs of not allowing SA, NSW and Vic, respectively from entering in the water market. The individual impact of exchange fees and charges are also estimated for these scenarios which are $16.34 million, $11.26 million, $5.05 million and $6.06 million, respectively.

The gains estimated in Scenario A as a result of free water trade compared to all the respective scenarios are lower than the gains shown in previous studies on free trade in the Basin. This is due to the fact that this study adopted a partial analysis approach rather than a computable general equilibrium modeling approach adopted in the previous studies of water trading. Further, the current study is a short term analysis and estimates expected gains as a result of variation in rainfall and water allocations and any new investment is not allowed. Also, the gains as a result of free trade are for one year only and removal of these restrictions will result in further gains over the years ahead. This means the continuation of these restrictions will continue imposing even greater costs to the basin in the future.

The analysis demonstrates that including expected rainfall and water allocation is suited to exploring general bounds and most likely outcomes of decision making under a wide range of conditions and is thus well suited to policy development. The intent in the future is to further develop and use this modelling capacity to, amongst other things, test the efficacy of alternative decision making strategies, and water management. The size of water trading transactions is critical in estimating total cost. It is planned to extend the analysis to account for varying size of water transactions. It is also planned to examine impact of a constant water charging regime on water trading across the catchments.

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