Opportunities for achieving water savings throughout the Murray-Darling Basin

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Abstract Demand for water from the rivers of the Murray-Darling Basin (MDB) continues to increase, despite a Cap on diversions being in place since 1996. Previous and ongoing efforts to improve water use efficiency within the Basin have focused primarily on engineering solutions, in particular through reducing losses from seepage, leakage and evaporation within the distribution system, including by upgrading channels or replacing them with pipes. Water trading is enabling water to be moved from low value to high value enterprises consistent with market demand. On many properties the instillation of improved water reticulation and application systems, including replacing some of the flood and furrow systems with sprinkler, trickler and micro-drip systems, is also achieving significant savings. A model was constructed to explore the potential for achieving further on-farm savings within the MDB through increased adoption of best management practices aided by low and high levels of investment. Despite significant limitations in the underlying data, it was shown that savings in excess of 900 GL per annum can be achieved on irrigated farms in the Basin, under reasonable time frames, and plausible scenarios for farm investment and the adoption of new technologies. Savings of this magnitude have the potential to provide a significant incentive to develop and implement policies that could bring them into being.

Keywords: *Water use efficiency; Land use; Policy framework; Modelling*

1. INTRODUCTION

The demand for water in the Murray-Darling River Basin (MDB) has never been greater, even though a Cap on diversions has been in place since 1996. In some valleys water entitlements frequently exceed the amount of available water, this mis-match not yet fully addressed through the water allocation system. Competing uses of water include meeting existing requirements of irrigators in the dairy, cotton, rice, horticultural and other rural industries, of rural townships within the Basin, and the increasing demands for environmental flows to improve the health of the river systems and associated wetlands, and to incrementally restore water flow within the Snowy River to 28 *per cent* of its original rate. In addition there is an expectation that the value of production from irrigation within the MDB will continue to increase as water moves to higher value rural industries. With constrained water supplies, expansion over the past decade has been in part dependent on improved WUE.

In this paper we explore the potential for achieving further on-farm savings within the MDB through increased adoption of best management practices. We then discuss how a policy framework and underlying models can help policy makers and others in considering options for future use of water throughout the MDB. More details on the policy options are described by Beynon *et al*. (2002).

2. WATER USE WITHIN THE MDB

The MDB covers an area of 1,058,800 km^2. Within the Basin the Murray flows for 2,530 km from its source at Forest Hill in the Snowy Mountains, and the Murray and Darling Rivers flow for 3,577 km from Condamine in Queensland. The Basin covers 14 *per cent* of the area of Australia, and includes 38.1 *per cent* of the farms (ABS 2000-01).

The total area of crops and pastures irrigated in the MDB is 1,725,598 ha. This is 68.9 *per cent* of the total area of irrigated crops and pastures in Australia. There are 16,796 farms with irrigated crops and/or pastures, which is 31.4 *per cent* of the total number of farms in the Basin (ABS 2000-01). Over 95 *per cent* of water use in the Basin is for rural and irrigation purposes (MDBMC 1995).

Australia has the highest variability in rainfall and run-off in the world (McMahon *et al*. 1992). This variability is primarily due to the influence of the El Niño – Southern Oscillation (ENSO), and is reflected in the variable flow of the Murray River. The long-term average run-off reaching the River is 11,250 GL, but this may vary from around 2,500 in a very dry year to 40,000 GL in a very wet year (MDBC 2001). On average, one year in 15 will have a run-off of less than 2,500 GL.

Use of water over the whole MDB from 1996/97 to 1999/2000 was as follows (MDBC 2001; Beynon *et* *al*. 2002): New South Wales on average took 57.6 *per cent*, Victoria took 32.7 *per cent*, and South Australia, Queensland and the Australian Capital Territory together accounted for less than 10 *per cent*. The three major river systems were the Murray (32 *per cent*), the Murrumbidgee (22 *per cent*) and the Goulburn (15 *per cent*), these accounting for 62 *per cent* of total water use.

3. LAND USE WITHIN THE MDB

There are many types of water users in the MDB, each having different requirements for water supply security (Close 1989). At one extreme are the cotton growers on the Darling system with large off-river storages who are opportunistic users of water. Next are the rice growers and irrigators of other cash crops who prefer to use the water when it is available rather than maintain large reserves. Dairy farmers are more sensitive to risk since reducing the size of herds or buying feed during droughts involves considerable expense. At the other extreme are irrigators of horticultural crops such as vines and fruit trees and urban water consumers whose security of supply is of great importance and for whom a failure of supply would be catastrophic.

Rice growing is concentrated in New South Wales, dairy farming is predominant in Victoria, and horticulture and domestic water supply are the major uses in South Australia. Because of these differences in water use, the attitudes of the three States to risk and security of supply differ considerably (Close 1989). Given the different water requirements and attitudes to risk of each of these industry groups, their efficiency of water use has to be considered separately.

ABS data on the areas of crops and pastures irrigated within each local government area and river system within the MDB exist for 1996. These were downloaded from the National Land & Water Resources (NLWRA) web site. As can be seen from Table 1, the dominant land uses are pasture, cotton and cereals, including rice. However, there is also a wide diversity of high value enterprises targeted at niche markets that is starting to emerge.

4. ASSESSING WATER USE BY CROPS

Potential water savings on farms may be estimated from a) the areas in different pastures and crops throughout the Basin, b) estimates of the quantity of water provided to these crops, and c) the savings that could be achieved through adopting Best (or near-optimal given existing knowledge and technology) Management Practices (BMPs).

Table 1. Land and water use within the MDB (derived from ABS 1996 data)

Crop type	Area (%)	Water used (%)
Pasture (annual and perennial	41	44
Cotton	17	18
Cereals	18	14
Other annual crops (incl. rice)	17	16
Fruit and vegetables	7	8

The data on areas in crops and pasture were combined with best estimates of water application rates for the crops within each system, based on field experiments and farm surveys. Even within crop types, application rates were generally higher in the more arid regions where evaporation rates werer highest. Water application rates using BMPs were also obtained from these sources. Different levels of adoption of BMPs were assumed.

Other *ad hoc* data collected were on enterprise structure, typical WUE measures, and gross margins and prospects for investment in WUE. Although surrounded by enormous variability, the total diversions for irrigated agriculture fluctuate around 11,000 GL per annum depending on climatic conditions, this being used to irrigate some 1,600 ha on average over some 10,600 irrigation farms. In addition, some 2,800 GL of groundwater are extracted. Aggregate figures such as these are presented here for perspective only.

5. ANALYTICAL FRAMEWORK

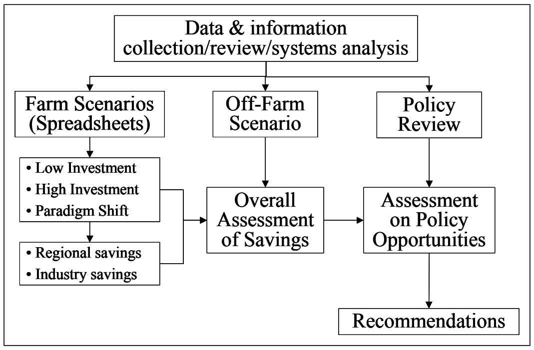

Figure 1. Structure of the analysis

An analytical framework was developed in response to a brief provided by the Murray-Darling Basin Commission (MDBC) to scope the level of water savings that may be achieved from improved water use efficiency. The selected sequence and nature of the scenario analyses undertaken (Figure 1), made it possible to obtain an insight into the scale of potential water gains that could be achieved, including by industry and by region, consistent with our brief. Even so, as this was a scoping study we have not delved into the detail of outcomes by region and industry in this analysis – that is for a later stage of the overall project.

6. TECHNICAL AND POLICY SCENARIOS

In order to explore the extent of the technical possibilities for improvement in WUE, four scenarios were considered using a spreadsheet model. Each scenario depends upon a specific policy position. Thus, each scenario also gives pointers to the type of policies that may be required if the rate of adoption of technological change is to be modified. All scenarios involve investment in either financial and/or management terms:

- Low investment by all irrigators using current technology but improving management;
- High investment with all irrigators adopting new technology and associated management regimes;
- Significant investments to reduce in-storage and transmission losses; and
- A structural or paradigm shift instigated by significant changes in policy to accelerated adoption of latest technology and improved management.

Scenario 1: *Low Investment On-Farm* describes what could be gained from improved WUE if all irrigation farmers invested in improvements that required little or no capital expenditure, but rather changes in management regimes including labour used. That is, for the purpose of this analysis it is assumed that existing broad production systems and enterprise mixes would be continued, but that gains would be made by adopting improved management regimes including current ‘best practice’. A number of other assumptions must be made, including that there is no adoption of new technology (see Scenario 2), the distribution of usage (ML/ha) is relatively stable across the Basin for each commodity, and that policies remained unchanged. The aim is simply to apply better management outcomes to the MDB and then to recalculate total water usage. A 50 *per cent* adoption rate and no negative impacts on yields were assumed.

Scenario 2: *High Investment On-Farm* describes a situation in which a reasonably high adoption of available technology becomes appropriate through applying the results arising from recent scientific R&D. The analysis provides insight into the potential gains from improving WUE without radical changes and assumes a willingness and capacity on the part of producers to invest in the latest technologies which also implies new management regimes. Again, a 50 *per cent* adoption rate and no negative impacts on yields were assumed.

Scenario 3: *Water Use Efficiency Gains Off-Farm* describes a situation where significant investment is undertaken to reduce water losses beyond the farm gate. Significant amounts of water are lost during the transmission of water to farms. These losses arise through seepage and leakage from storages and channels, evaporation from storages and channels, the need to fill pipes and channels to generate flows to irrigators, outfalls and escapes from irrigation districts, and losses at the point of farm intake. In addition, apparent losses arise through poor (or no) metering, Aging assets of water utilities create high maintenance costs and increased risk of transmission losses.

Scenario 4: *Paradigm Shift in Policies and Practices On- and Off-Farm* describes a situation of structural change in both policies and practices for irrigated agriculture. It is assumed that there is extensive innovation in management and policies, technological change and adoption of new and more sustainable production systems, which act to transform irrigation industries and communities. Developments considered are, for example, changes in technologies and management systems for all the major irrigated crops, the handling of water on-farm and throughout the distribution system, and the management of water quality, salinity and waste water. It also assumes that new technologies capable of applying water more efficiently are used properly, whilst being aware that this is currently often not the case. Scenario 4 describes change within a better policy environment, with more certainty in the investment environment. As a result we extended the Scenario 2 situation to assume an adoption rate of 80 *per cent,* and that there was some increase in water prices in real terms for the pasture sector of around 10 *per cent* over a ten year period to demonstrate possible impacts of price increases.

7. RESULTS OF SCENARIO ANALYSES

The preceding scenarios outlined some reasonable and feasible ways to improve water use efficiency.

The numbers presented are, and always will be for this type of analysis, only indicative. Improvement in the collection, storage and analysis of data on the area of land used for irrigation and the actual (ie metered) quantities of water applied to that land would help, but would not necessarily improve the confidence of the calculations. To improve that we would need significantly better knowledge of factors such as farm total costs, profitability, world commodity prices, extent of the complementarity of farm enterprises, actual adoption rates by farm type by location, and so on. It is likely that we will never have information of such a high quality and currency. However, we can make educated and considered assessments and recommendations of likely trends, including providing some idea of the possible size of those trends and outcomes.

Table 2 shows results of the Low Investment scenario and the sensitivity to changes in adoption rates. The table also shows that about half of the potential gains are to be made the pasture sector and in NSW. The small values for SA reflect the modest size of its irrigation sector, and the nature of its mix of agronomic cultures, reflecting the fact that most of its irrigation is in perennial crops (fruit and grapes) rather than broadacre annual crops.

Table 3 shows the results of the off-farm scenario. The values in the State and Basin summary were determined by estimating what would have been the conveyancing loss (ML) in each water delivery system if the maximum loss was set at 15 *per cent*. Those that already had conveyancing efficiencies of 85 *per cent* were assumed to already be operating at or near peak efficiency. The difference in water lost between assuming the current efficiency (if less than 85 *per cent*) and a conveyancing efficiency of 85 *per cent* was then calculated for each system. Total 'feasible savings' and weighted averages for conveyancing losses were then calculated for each State and for the whole Basin as shown in Table 4. This analysis does not include the potential savings from large scale public investments such as the proposed pipeline for the Anabranch which would save 46 GL and the Lake Menindee improvements which would save 20GL. Clearly, across the Basin there will be other examples where public investment in particular could lead to large savings.

Table 4 provides a summary of the key results from the scenarios. It would appear that opportunities for WUE gains, both technically and managerially, may be substantial at the farm level ranging from around 1,000 Gl to 2,500 GL per annum. Technical, geographic and logistical barriers to improving WUE between river systems and in various reaches within individual rivers, reduce these possibilities for gains. Gains may be further reduced due to issues related to the ability and willingness of land holders and managers, and other water users, to bring about change.

With radical changes in production and management systems, involving a 'paradigm shift' in ways in which water is used, it is estimated that after ten years around 3,000 GL annually could possibly be 'freed-up' for other uses. This would provide significant environmental and resource health benefits as a bonus. This is possible through improving the efficiency of existing systems, use of radical new technologies, changes in the infrastructure investments of water managers and the behaviour of water users, and changes in the location of irrigation areas. The potential to make gains in WUE varies considerably across regions of the Basin and within each industry. In addition, the capacity of irrigators to move to higher levels of efficiency depends on their ability to make sufficient financial gains to make the necessary investments profitable.

In summary, relatively low levels of investment, particularly changes in management on-farm, may result in a 7-8 *per cent* reduction in water use over ten years, compared with existing management on the current areas of irrigation. A higher investment in WUE on-farm (over 10 years) may yield around 10 *per cent* across the Basin. If policies were put in place to improve the adoption rate of 50 *per cent* assumed in the analysis, then substantially more gains (ie around 20 *per cent*) could be made. This would be further enhanced by gains off-farm. Through accelerating the ongoing renewal processes for existing infrastructure we could feasibly reduce water use by around 25 *per cent* over ten years (Table 3). To date we have not analysed what a radical change in policy, including measures such as changing property rights, might lead to. Under current legislative arrangements those who invest to save water own those savings. As a consequence, these private gains would not result in water for alternative uses, but would instead be used to further expand irrigation in the MDB.

8. DISCUSSION OF POLICY OPTIONS

The analyses in this study highlighted considerable potential to save water in the MDB, ranging from improved irrigation infrastructure to reduce often significant losses through seepage, leakage and evaporation within the distribution systems, to more

Table 2. Water Gains from Low Investment by Crop type by State (GL)

Commodity	Qld	NSW	Vic	SA	Total	% of Total
Pasture	11.2	373.6	537.9	12.5	935.3	50.8
Cereal	7.6	154.0	10.1	.06	172.2	9.4
Vegetables	1.8	9.9	4.5	3.9	20.0	1.0
Fruit	1.3	9.5	13.2	12.1	36.1	2.0
Grapes	0.2	9.3	14.6	11.3	35.5	2.0
Cotton	67.5	216.5	-	-	284.0	15.4
Other Crops (incl rice)	77.7	622.1	10.7	2.4	357.0	19.4
Total if 100% adoption	167.4	1,038.9	590.9	42.8	**1,840.1**	100.0
Total if 50% adoption	**83.7**	**519.9**	**295.5**	**21.4**	**920.0**	**-**
Total if 20% adoption	33.5	207.8	118.2	8.6	**368.0**	-
State % of Total	9.1	56.5	32.1	2.3	100.0	-

Table 3. Mean deliveries, conveyancing losses and feasible savings, by State and Basin (1)

Based on data from ANCID (2000, 2001)

State	Mean 'extractions' (ML)	Conveyancing losses (ML)	Conveyancing losses (%)	Feasible (2) savings (ML) $E_{c>}$= 80%	Feasible (2) savings (ML) $E_{c>}$= 85%
Queensland	223,649	57,465	25.7%	22,294	29,426
New South Wales	3,072,027	636,108	20.7%	36,533	178,138
Victoria	3,383,848	877,924	25.9%	238,412	379,301
South Australia (3)	111,891	29,972	16.5%	4,907	7,137
Totals and (weighted means)	**6,861,415**	**1,601,468**	**(23.3%)**	**302,146**	**594,003**

(1) Percentages in the table are weighted for the relevant amount of water within each System

(2) Target improvements are zero in those systems that have less than the target 15% or 20% loss

(3) The data for South Australia are not based on accurate estimates of conveyancing loss.

Table 4. Summary of Water Gains from Several Scenarios (GL)[1]

Combinations of Actions to Improve WUE	GL	% of Diversions [2]	% of (Diversions + Groundwater)
Low Investment On-Farm (50% adoption rate)	920	8	7
High Investment On-Farm (50% adoption rate)	1,240	11	9
Paradigm Shift in Policy [3]	2,500	23	18
Off-Farm	594	5	4
Low Investment On-Farm + Off-Farm	1,514	14	11
High Investment On-Farm + Off-Farm	1,834	17	13
Paradigm Shift in Policy [3] + Off-Farm	3,094	28	22

[1] While these figures are presented as additive results of actions to improve WUE, the combined effect in some situations may not necessarily be additive. The reason is that some actions are common to the range of scenarios presented and are therefore not mutually exclusive. The above results are therefore for indicative purposes only.

[2] Assuming an annual diversion of say 11,000 GL. This excludes the 2,800 GL of groundwater allocations.

[3] Composed of an 80 *per cent* adoption of high investment on-farm plus changes in water prices.

efficient use of water on farms. Such information is of value to policy makers, who urgently require advice as to the magnitude of possible savings. Despite the substantial deficiencies in the data and the simple structure of the models, it is clear that large water savings can be achieved to satisfy the demands of environmental flows, ensure that the demand for water by irrigators and others can at least be met in the majority of seasons, and allow for ongoing structural adjustment within irrigated agriculture as even more water is diverted to higher value uses. A discussion of policy options and economic instruments to achieve this is beyond the scope of this paper; see for example Beynon *et al*. (2002).

Irrigation practices are still largely a legacy of past policies and attitudes. Despite substantial policy reform, the mood in many irrigation communities continues to be one of uncertainty and caution about policy settings, particularly with respect to water reforms. Many irrigators report that they are unwilling to discount risks in this environment and will not invest on a large scale in upgrading their irrigation infrastructure and practices. It is also acknowledged that as some irrigators move towards best practice their water usage will increase.

Success in improving WUE is very much about the investment environment in which farmers operate (Beynon *et al*. 2002). The investment environment can be characterised by externalities and failures in capital markets, in the use and management of natural resources, in water distribution and delivery systems, and in bureaucracies and government. Irrigation may reduce the level of production risk through diminishing the exposure to adverse seasons. However, capital requirements and investment risk to upgrade irrigation practices are often large and beyond the scope of individuals. Time frames for investment are long and generally beyond the vision of financial institutions. Water infrastructure investments will require significant expenditure in order to capture some of the opportunities to improve infrastructure performance.

The next phase of the overall study will focus on, *inter alia*, a more detailed appraisal of land and water resources within the Basin, and how they are and could be used. Disincentives for individuals, communities and water authorities to change management practices, and upgrade existing irrigation infrastructure will also be examined. Whilst some will rightly argue that many of the easier and less costly initiatives are either already underway or completed, the fact remains that a lot more can be done, and that the economic incentives and technological capacity to make such changes will also improve. Aligning an analytical framework with the proposed policy framework of Beynon *et al*. (2002) offers opportunities for near-optimal decisions to be made on rational grounds.

9. ACKNOWLEDGMENTS

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