

Options for managing salinity in the Murray-Darling Basin under reduced rainfall

David Adamson¹, Peggy Schrobback¹, John Quiggin¹

¹Risk and Sustainable Management Group, School of Economics, The University of Queensland

Introduction

The Murray-Darling Basin (MDB) covers over 1 million km² and is located in four states in eastern Australia and the Australian Capital Territory. The MDB produces over 40% of Australia's total gross value of agricultural production, has over three quarters of the total irrigated land in Australia, utilises 70% of Australia's irrigation water and supplies drinking water for Adelaide (ABS 2007).

The management of water allocation and water quality in the MDB has been a major policy concern for state and federal governments. In 1992 the Murray-Darling Basin Commission (MDBC), replacing the earlier River Murray Commission was established to provide a mechanism for enacting the MDB Agreement. Part of the agreement is to ensure that the water quality at Adelaide is less than 800 EC, 95% of the time. Recently the MDB has experienced some of the lowest recorded rainfall in the last 100 years (MDBC 2007a), resulting in re-examination of administrative arrangements for the MDB and greater national focus in addressing the complex situation facing the communities in the MDB.

The aim of this paper is to examine the implications for the basin and Adelaide's potable water supply from an increased frequency of drought. A range of options for mitigating salinity under changed climatic conditions are considered.

Modelling uncertainty under climatic stress

Adamson et al (2007) adopted a state-contingent production approach (Chambers and Quiggin 2000) to model irrigation systems in the MDB. The model optimises economic return by choosing between 13 production systems that use alternative levels of inputs and delivery differing outputs (yield) that respond to the availability of land, labour, capital, water volume and water quality (salinity) by three states of nature (normal, dry and wet).

Economic returns are calculated for 20 regions: 18 catchments, Adelaide and a 'flow to the sea'. The last two allow for the representation of water quality arriving at Adelaide and a proxy value for environmental flows. By determining the yield response to salinity thresholds and explicitly defining the negative externalities from return flows carrying salt, the interaction between upstream use and downstream yield impacts can be examined. The model can be solved either: sequentially where flows of water and salt from the headwaters of the basin are tracked to the mouth of the MDB in South Australia (this approach allows for the examination of current management and policy by standard linear programming methods); or by a dynamic non-linear approach where the model effectively solves backwards (this allows for the formulation of national policy for the benefit of the greatest number).

The model's datasets and production systems are continually being refined to reflect reality and currently the 2004/05 salt extractions of over 430,000 T (MDBC 2006) are being used for this analysis. As the model treats all salt flows in a catchment uniformly it does negate benefits from treating point source salinity pollution.

Results and discussion

To determine the validity of the model, the current climatic conditions have been run where the frequency of the dry state is set at 0.2, the normal state 0.5 and the wet state is 0.3. Here the model estimated that the average water quality for Adelaide was 482 EC, with the normal, dry and wet state providing potable water at 499 EC, 537 EC and 416 EC respectively. By switching off the benefits from the mitigation program (i.e. tonnes of salt removed) in the basin, it was estimated that water quality at Adelaide would decrease as salinity increased to

596 EC on average, with a salinity level of 600 EC in the normal state, 751 EC in the dry state and 485 EC in the wet state. This suggests that the benefits from the salinity mitigation program would be around 114 EC on average, with benefits ranging from 101 EC in a normal year, 214 EC in a dry year and only 69EC in a wet year. These figures are roughly within the MDBC (2007b) estimations of between 80 and 265 EC. This reduction in salinity is estimated to be worth \$136 million per annum. As noted by the MDBC (2007b), while the initial effect of drought conditions is to reduce inflows of salt to the system, sustained drought conditions raise the risk of increased salinity.

As the frequency of the dry states is increased (from 0.2 to 0.3 and corresponding decrease to the frequency of wet state) it is expected that salinity levels would rise to 607 EC on average, with a range of 484 EC, 948 EC and 406 EC in the normal, dry and wet states respectively. As the frequency of dry states increases the estimated average water available in the system declines by some 1,280 GL of which 365 GL less is available for irrigation and the rest no longer flowing to the sea. Comparing these EC results with Table 5 from the MDBC (2007a) report, it could be suggested that these levels of salinity would violate the threshold level (800 EC) for Adelaide about 23% of the time, rather than the agreed 5%. These results suggest that the movement from the current frequency of droughts to more frequent droughts has a greater impact to the system than switching off mitigation practices under current conditions.

The increased dry periods also cause significant shifts in agricultural production as producers adapt to the increased probability of poor water availability. This reaction is expressed by utilising more land (21,000 Ha extra) as landholders switch to technologies that utilise less water (spreading risk). For instance this would represent an acute shift for the dairy industry, where 300,000 Ha transfers from high water technologies to low water technologies. This shift in technology lowers the economic return on average from \$5,217.2 million to \$4,684.6 million per annum, a decrease of \$532.6 million. This loss could actually be greater because of the interaction between water use and salinity where switching to low water use technologies may no longer remove the salt away from the root zones compounding production losses. In practice this may be reflected in decreased area planted with a periodic over watering to transfer the salt further down the soil profile away from the root stock.

The question then becomes, as average water availability declines by 1,280 GL how best do we overcome this shortfall to reduce salt arriving to Adelaide. Schrobback et al (2008) argues the alternative policy responses to the increased salinity levels can be modelled by: increasing the mitigation works (tonnes of salt being removed); investing in more storage (increasing water flow in each state); changing the release patterns from storages (by altering the volumes of flows by state); adjusting the amount of water available for irrigation; and the ability to totally reallocate water property rights. The aim of these scenarios is to illustrate the impact and scope of alternative options operating in isolation rather than provide a descriptive solution to the problem.

Increasing mitigation

In 2004/05 over 430,000T of salt was removed from the system and for this exercise new mitigation works were assumed to remove an extra 200,000, 300,000 and 400,000 T of salt from the Lower Murray Darling catchment. This is a significant increase from the current extraction capacity and it is likely that by targeting other catchments and key points of salinity pollution that less tonnes of salt could more effectively reach the same outcome. Ideally the mitigation works would have to align with the 'end of valley' targets in the basin (MDBC 2006).

An extra 200,000 T removed reduces the average EC arriving at Adelaide by 75 units and due to the linear relationship for mitigation benefits in Adamson et al (2007) each additional 100,000 T of salt removed from the basin receives a further 34.5 EC reduction to Adelaide's water supply on average. The actual relationship for salinity mitigation benefits is likely to represent a diminishing return curve for each extra unit. As Quiggin (1991) suggests improving water quality upstream means that more water is used downstream thus just

relocating the problem, unless extractions are retained at their current level. This is partly incorporated in the results as the economic return declines for each of the three options as initially a further 200,000T of salt removed increases economic return by \$63 million,

the next 100,000T of salt removed increases economic return by \$24 million, and the last 100,000 T of salt removed only adds an extra \$12 million to economic return.

Despite the increased removal of 200,000, 300,000 and 400,000 the EC in the dry states is expected to still reach 797, 722 and 646 EC respectively. It is expected that only when removing 400,000 T of salt it is likely not to violate the 800 EC thresholds due to daily fluctuations in a dry state year. As the cheapest options for salinity mitigation have already been utilised it is expected that each additional tonne of salt removed would become more expensive through time MDBC (2006).

Increasing storage

The model reflects current storages by describing the probability of a given state (i.e. dams regulate flow to take out the extremities of droughts and floods) but new investment in storage is represented by altering the flow in the each state as more runoff is harvested. Thus more water is harvested in the normal (1,500 GL) and wet states (3,000 GL) where flow now equals 0.9 and 1.0 respectively (was 1.0 and 1.2) for the benefit of the dry state (2,860 GL) which increases to 0.8 from 0.6. This means on average there is now only 15,075 GL on average (15,560 GL in the increased droughts) as water is lost in seepage, evaporation and transfers. The salt load now is no longer state contingent as extra salt become mobilised in the dry and the wet state no longer flushes the soil of excess salt.

Here producers move away from flexible production systems that utilise water use in dry states to systems that require a constant water supply. In this case average annual economic revenue decreases by \$4.5 million to \$4,680 million. While the average salinity falls to 546 EC and in dry state the extra available water reduces the EC to 515, under the threshold for potable water supply for Adelaide.

Realistically the building of extra storages to drought proof the basin may not necessarily increase flows as rainfall has to occur in the right places. The four major storages in the basin (Dartmouth Reservoir, Hume Reservoir, Lake Victoria and Menindee Lakes) hold some 9,352 GL (MDBC 2007a) and we are talking about increasing their capacity around 15% to 30%. Storages in the basin are supplemented by transfers from the Snowy River (over 1,100 GL/annum MDBC (2006) but increased drought pressure and the agreement to re-establish natural flows to the Snowy puts that supply under pressure. It is also unrealistic to assume that extra transfers required to augment storages in the MDB basins would be found easily elsewhere.

Altering flow

The MDB is already a highly modified system especially in the south where the system has moved from a winter to summer dominate flow to meet water demand. This is modelled by increasing the flow in the dry state from 60% of the normal flow up to 65% and 70% at the expense of the wet flow and in this case we are not increasing storages as we do not alter the normal state. This effectively transfers 700 GL and 1,400 GL of flow from the wet to the dry state of nature improving economic return up to \$5,023.1 and \$5,053.8 million per annum on average. This flow management improves the water quality to 547 and 514 EC on average but only to 724 and 588 EC in the dry.

This would suggest that the 1,400 GL transfer from the wet to the dry state of flows would have to occur and as the system is already highly modified, a further smoothing out of yearly flow is likely to compound environmental issues with sedimentation and other factors. Questions concerning the evaporation in storages and issues to meet water flow requirements, in successive years of drought when required would have to be examined.

Reducing irrigation supply

Part of the MDB Agreement was to limit water extractions at 1993/94 development levels and

this is referred to as the Cap. When the model optimises it already does not allocate about 2,900 GL of water under the current dry state and due to reduced water availability when the dry state increases up to 3,250 GL. By reducing the available water for irrigation by 5, 10, 15% roughly 600, 1,200 and 1,800 of water is transferred to the environment to help deal with salinity. This could be achieved by either not meeting general security licences, on-farm water efficiency provided that remaining water goes to the environment, or purchasing water from owners for the environment.

By transferring 600 GL away from irrigation use the economic return increases to \$4,693.4 million (\$8.8 million per annum) as water quality improves but for the next steps the economic return falls to \$4,625.5 million and then \$4,544.5 million as more water is removed. From the results in the dry state it is not until a 15% reduction in the Cap that salinity falls (640 EC) enough to be considered that it would not violate the Adelaide threshold (at 600 GL the dry state is 805 and at 1,200 GL the dry state is 736 EC). This then returns about 3,550, 3,800 and 4,150 GL of extra flow into the basin when the Cap is reduced by 5, 10 and 15% respectively. This flow volume is in line with Jones et al (2002) estimation of 2,000 to 4,000 GL required to return a health flow to the Murray River.

Conclusions

Only limited insight can be drawn from these results and a full costs benefit analysis should be undertaken to compare the effectiveness of each option. From the results summarised in Table 1 and the arguments provided above it can be suggested that readjusting the Cap downwards has significant benefits for the system in the long term. Other options and combinations of strategies could also provide interesting results which would be worth considering because an increasing number of dry states may increase the challenge of ensuring Adelaide's potable water supply.

Table 1 Summary of options

Scenario	\$million	Avg. EC	Dry EC
Drought	\$4,684.6	607.7	948.3
Mitigation (400,000 T)	\$4,783.5	457.6	645.9
Storages	\$4,680.2	546.4	515.4
Flow (1,400 GL)	\$4,779.1	513.8	587.9
CAP (15%) (1,800 GL)	\$4,544.5	472.1	640.0

References

- ABS (2007), Year Book Australia, 2007: Catalogue No. 1301.0, Australian Bureau of Statistics, Canberra.
- Adamson, D., Mallawaarachchi, T. and Quiggin, J. (2007), Water use and salinity in the Murray- Darling Basin: a state-contingent model, *Australian Journal of Agricultural and Resource Economics*, 51, pp.263-281.
- Chambers, R.G. and Quiggin, J. (2000), *Uncertainty, Production, Choice and Agency: The State-Contingent Approach*, Cambridge University Press, New York.
- Jones, G., Hillman, T., Kingsford, R., McMahon, T., Walker, K., Arthington, A., Whittington, J., and Cartwright, S. (2002), Expert Panel Report to the Murray Darling Basin Ministerial Council on the Environmental Flow requirements for the River Murray System.
- MDBC (2007a), Murray-Darling Basin Commission Annual Report 2006–2007, MDBC Publication No. 27/07, Murray-Darling Basin Commission, Canberra.
- MDBC (2007b), Basin Salinity Management Strategy 2005–06 Annual Implementation Report, MDBC Publication No.13/07, Murray-Darling Basin Commission, Canberra.
- MDBC (2006), Basin Salinity Management Strategy 2004–2005 Annual Implementation

Report, MDBC Publication No. 05/06, Murray-Darling Basin Commission, Canberra.
MDBC (2006), Murray-Darling Basin Water Resources Fact Sheet, MBDC, Canberra.
Quiggin, J. (1991), 'Murray River salinity mitigation – engineering and management approaches', *Review of Marketing and Agricultural Economics* 61(1), 1–25.
Schrobback, P., Adamson, D., Quiggin, J. (2008), The options for salinity mitigation in the Murray Darling Basin, 52nd Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra, Australia, 5-8 February 2008.