Water trade and irrigation

Defining property rights to return flows

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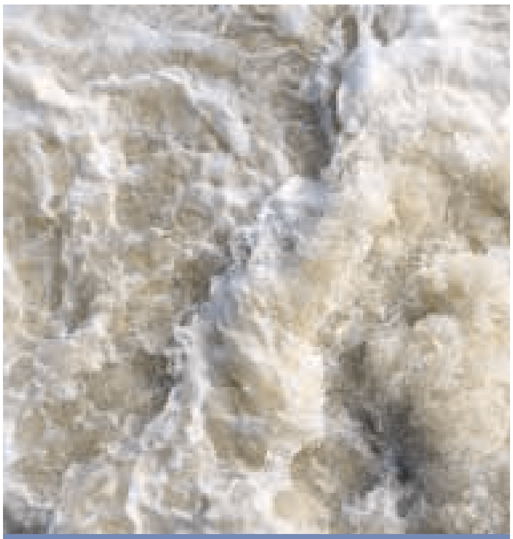

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In 1994, an audit of water use in the Murray Darling Basin showed that if the volume of water diversions continued to increase, river health problems would be exacerbated, the security of water supply for existing irrigators would be diminished, and the reliability of water supply during long droughts would be reduced (MDBMC 1999). The audit highlighted the need to find a balance between extractive and nonextractive uses such as the riverine environment.

The outcome was that a cap was imposed on the volume of water that could be diverted from the rivers. The aim of the cap was to limit further increases in water diversions; it does not constrain new developments. The cap on diversions has effectively made water — as opposed to storage capacity and delivery infrastructure — a scarce resource, thus creating the need for an effective water market. As the demand for water continues to increase, water trading is likely to play a key role in allocating water between competing uses, including the environment.

The implementation of the cap has also encouraged water authorities and irrigators to consider more efficient water delivery and irrigation practices, so that irrigated activity could be expanded even though aggregate allocations are capped.

However, water trade and improvements in irrigation efficiency affect return water flows. These, in turn, affect the quality and volume of water used downstream and the riverine environment more generally. Return flows consist of surface runoff from flood irrigation, irrigation drainage and ground water discharge from irrigation areas that reach the Murray River system.

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Reflecting the large volume of water that is diverted from the Murray River and its tributaries in the upstream irrigation areas and relatively low rates of irrigation efficiency, return flows form a substantial part of water available for downstream users. Further, return flows from irrigation areas with relatively low underlying ground water salt concentrations may provide dilution flows downstream.

Irrigators presently hold an implicit right to return flows in that they can trade or save water without considering the downstream impacts on others (in economics, termed 'externalities') associated with changes in water quality and volume.

Under current institutional arrangements, reductions in the volume of return flows are simply absorbed as an additional diversion above the cap that may be at the expense of desired environmental flows. Hence, the balance between rights to extractive use and environmental flows needs to be specified, with explicit consideration given to rights to return flows.

A simulation model was developed to examine the impact of changes in water allocations and irrigation practices on river flows and salinity as part of a project to evaluate land and water management options in the Murray Darling Basin. Within the modeling framework, the interrelationships between land and water use, vegetation cover, surface and ground water hydrology and agricultural returns are represented.

The model, described in more detail in Bell and Heaney (2000), was developed at ABARE in cooperation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It was initially used to estimate the benefits of improved irrigation efficiency as a tool for salinity management in the Riverland region of South Australia (Heaney, Beare and Bell 2001).

In the analysis presented here, the model was extended to examine the impact of water trade and improvements in irrigation efficiency in the irrigation areas around the Murray River and its major southern tributaries. The geographic area under consideration is shown in map 1.

Return flows and externalities

Trading water between irrigation regions and improvements in irrigation efficiency affect the pattern of surface runoff, irrigation drainage and ground water discharge that, in turn, alters the composition of return flows from irrigation. External benefits or costs arise as return flows affect the quality and quantity of Murray River flows used for irrigation, thus having an impact on users not directly engaged in the trade. The impacts of trade or efficiency changes on return flows depend on the agronomic and hydrological characteristics of each irrigation area and, as a result, may produce external benefits or costs that vary continuously along the Murray River system.

The main quality issue in the Murray River system has been increasing river salinity. The extent to which return flows

Major irrigation areas in the southern Murray Darling Basin

affect the salt concentration of Murray River flows depends on a number of factors.

- Ground water recharge rates and the salinity of the ground water underlying irrigation areas have a major impact on salt concentrations.
- Soils throughout most of the irrigation areas in the southern Murray Darling Basin are shallow.
- The percolation of irrigation water past the root zone has led to a large increase in the rate of recharge into the ground water system.
- The volume of water entering the ground water system is higher in areas with low rates of irrigation efficiency.
- Increased ground water recharge has resulted in rising water tables and increased ground water discharge and saline irrigation drainage.
- The volume of salt transported to the river depends to a large extent on the salinity of the ground water.
- The salinity of ground water discharge in the Murray River and its tributaries is relatively low in the upland catchments.
- Ground water salinity levels tend to increase moving downstream and reach levels approaching sea water in low lying regions of South Australia.

Changes in return flows that result from water trade may have an impact on river salinity. For example, trade that moves water from an irrigation area with relatively low recharge rates and low ground water salinity to a downstream irrigation area with high recharge rates and high ground water salinity can produce a series of impacts on water quality. Immediately downstream of the seller, the transfer may increase stream flows and reduce salt concentration in the Murray River. However, as ground water salinity is higher in the downstream areas, salt concentrations will increase as more salt is transported to the river system.

The salt concentration of Murray River flows may decrease after an improvement in irrigation efficiency if the amount of ground water leakage past the root zone is decreased, thereby decreasing the amount of saline water being transported to the river system.

Volume effects from changes in return flows may occur — for example, if downstream trade moves irrigation water from an area with high volumes of surface water runoff to one with high recharge rates and/or high levels of irrigation efficiency. As a result of the reduction in the surface runoff component of return flows, there will be less water available for users downstream of the source area.

Similarly, an improvement in irrigation efficiency through, for example, paddock landforming and leveling for flood irrigation systems may also reduce the surface water runoff component of return flows. The distribution of the volume impacts along the river will depend on the characteristics of the areas engaged in trade and improving irrigation efficiency.

The impact of changes in the pattern of return flows on water quality resulting from trade has been considered for the Murray River system (MDBC 2001). The Murray Darling Basin Salinity Management Strategy requires that the salinity impacts of interstate water be accounted for by a system of state level debits or credits. In Victoria, high impact areas have been identified and water trade into these areas has been prohibited. In addition, a levy has been introduced on water transferred into the Sunraysia district in the Victorian Mallee near Mildura (Young et al. 2000).

However, there is considerable variation in the indirect effects of changes in return flows between regions and states. An objective of the work presented in this article is to estimate the internal and external benefits of trade in water and improvements in irrigation efficiency. The results provide an indication of the potential economic benefits of developing a consistent institutional framework to account for return flows. These benefits could include direct economic gains from, for example, charges that reflect the cost of changes in river salinity, as well as providing environmental benefits at least cost.

Evaluating changes in return flows

The model was initially used to determine a baseline over a fifty year simulation. The estimated cost of salinity in the baseline scenario is measured as the reduction in economic returns from agricultural and horticultural activities from those that are currently earned. Thus, only costs and/or benefits associated with changes in stream flows, salt concentration and the extent of high water tables from current levels are estimated.

Salt loads and salt concentration of the Murray River are predicted to rise over the next fifty years as a result of both the clearance of native vegetation to facilitate dryland agriculture and the increased mobilisation of salt associated with irrigated agriculture.

The Murray Darling Basin Commission has linked its hydrological modeling to estimates based on cost impacts of incremental increases in salinity. Costs downstream of Morgan, a gauging site on the Murray River below the major irrigation areas, are measured using EC changes in salt concentration at Morgan. (EC, electrical conductivity, is a measure of salinity, calculated as micro-Siemens per centimetre. To obtain EC units, divide mg/L by 0.6.) The analysis considers agricultural, domestic and industrial water uses.

Using the cost functions derived in this model, each unit increase in EC at Morgan is imputed to have a downstream cost of $65 000 (MDBC 1999). This cost is included in the analysis presented here.

The salt concentration at Morgan is projected to increase from 590 EC currently to 700 EC by 2050. This increase in salt concentration is expected to result in a decline in agricultural returns of almost $260 million, in net present value terms (NPV) using a discount rate of 5 per cent, and impose costs to agricultural, urban and industrial water users downstream of Morgan of almost $60 million NPV over the fifty year period.

Two simulations conducted

Two series of simulations were conducted for several major irrigation areas on the Murray River system to examine the property rights issues associated with quality and volume changes in return flows resulting from trade and improvements in irrigation efficiency. For both simulations the internal and external costs or benefits of changes in irrigation allocations and practices are compared with a baseline scenario. Internal (or direct) impacts are derived within the

1 Summary data for the irrigation areas studied

Irrigation area	Main irrigated activities	Water allocation Murray	Water allocation Tributary	ET fraction a	Recharge fraction b	Ground water salinity
		GL	GL	%	%	mg/L
Goulburn–Broken	Pasture, cropping, horticulture	320	853	65	50	1 000
Campaspe	Pasture, cropping	207	75	50	60	5 000
NSW Murray	Pasture, cropping	2 464	0	65	75	2 000
Loddon Barr Creek	Pasture, cropping	163	0	65	75	20 000
Loddon Cohuna	Pasture, cropping	275	0	65	75	3 000
Loddon Tragowel	Pasture, cropping	455	0	55	75	9 725
Murrumbidgee	Pasture, cropping, horticulture	0	2 045	65	80	1 000
Robinvale	Horticulture	31	0	80	100	10 000
Colignan	Horticulture	59	0	80	100	10 000
Mildura	Horticulture	188	0	80	100	25 000
Lindsay	Horticulture	15	0	80	100	30 000
Border – Lock 5	Horticulture	85	0	80	100	25 000
Lock 4 – Lock 3	Horticulture	93	0	80	100	21 000
Lock 3 – Lock 2	Horticulture	71	0	80	100	33 000

a The percentage of irrigation subject to evaporation and transpiration. **b** The percentage of excess water, irrigation water and precipitation less evapotranspiration, that enters the ground water system.

irrigation areas where the action is undertaken, whereas external (or indirect) impacts are those derived downstream of the areas where the action is undertaken. Summary data for the irrigation areas under consideration are listed in table 1.

Baseline

In the baseline simulation a cap on the aggregate volume of water that can be diverted for irrigation is maintained. Over the fifty year simulation period, ground water discharge, and hence river flow, increases as a delayed effect of land clearing. While under the current MDB cap on irrigation diversions an increase in river flows may be shared between irrigators and the environment, it is assumed for simplicity here that all increased river flows are allocated to the environment.

In the alternative simulations, any decline in return irrigation flows resulting from water being traded from a region leads to a reduction in water allocations for downstream users. That is, environmental flows are maintained in preference to allocations to irrigators. However, when river flows increase following the gradual increase in ground water discharge, allocations are restored to their original levels. While this definition of the cap may not be perfectly consistent with the way it is currently managed, it has been used to highlight the potential for water quantity effects under different institutional arrangements.

A permanent trade of 20 gigalitres was assumed in each of the simulations.

The impact of trade without the cap on diversions for irrigation was also considered, to examine the volume and quality impacts of a reduction in return flows separately. The direct and indirect costs and benefits associated with trade were calculated over a fifty year time period to allow the delayed response in salinity impacts in ground water systems to be accounted for.

Trade in irrigation water

In the first series of simulations, bilateral trade from the Goulburn–Broken irrigation area to several downstream destinations is modeled. These trade scenarios are listed in table 2. It should be noted that there is a major irrigation area in New South Wales (NSW Murray) that lies above and below the confluence of the Goulburn and Murray Rivers. The major irrigation offtake is above the confluence and the majority of return flows are below. In the model, NSW Murray is treated as being downstream of the Goulburn–Broken to simplify the model structure.

2 **Trade destination scenarios**

Source	Destination	Net internal benefits	External benefits
		$/ML, NPV	$/ML, NPV
Goulburn –Broken	Robinvale	2 124	–51
	Mildura	2 230	–54
	Lindsay	1 730	99
	Lock 3 – Lock 2 within 2.5 km of Murray River	1 923	–302
	Lock 3 – Lock 2 more than 5 km from Murray River	1 065	129

Irrigation efficiency increased

In the second series of simulations, irrigation efficiency was increased by 5 per cent in the irrigation areas listed in table 1. Here, irrigation efficiency is defined as the proportion of irrigation water extracted from the river that is returned to the atmosphere as evapotranspiration. In horticultural areas such as western Victoria and the South Australian Riverland, irrigation efficiency can approach 75–80 per cent for horticulture (A. Meisner, Department of Environment, Heritage and Aboriginal Affairs, personal communication, November 2000). In areas where there is widespread use of flood irrigation on pasture, irrigation efficiency is around 50 per cent.

With, for example, a 5 per cent increase in irrigation efficiency, a 5 per cent reduction in application rates will achieve the same crop yield. It was assumed that irrigators retain all the water savings and use those savings to expand irrigated production in the region in which the water is saved. Hence, the reduction in surface water runoff, drainage and ground water recharge will be less than 5 per cent. Again, the internal and external costs and benefits were calculated over a fifty year time period.

Results

Trade in irrigation water

Internal benefits accrue to irrigators in the downstream irrigation regions after trade as a result of increased horticultural production (table 2). As the trade moves water to higher valued production (horticulture as opposed to pasture and cropping in the Goulburn–Broken), the benefits to the destination regions exceed the costs of the forgone irrigated production in the Goulburn–Broken.

The internal cost of forgone agricultural production in the Goulburn–Broken catchment from trade is estimated to be $403 a megalitre. (It should be noted, however, that the capital costs associated with expanding irrigated activity are not included in this analysis.) The internal benefit in, for example, the Lock 3 – Lock 2 region is $2326 a megalitre, giving a total net change of $1923 a megalitre. Given current demand and supply conditions and the relatively small volume of water being traded, it is likely that the traded price of water will be close to the observed price of a permanent water entitlement in South Australia. This has been reported to be around $1000–1150 a megalitre (Young et al. 2000).

The external impacts of trade resulting from changes in return flows are a complex interaction of water quality and quantity impacts. The external impacts of water trade on water quality in the Murray River arise from two sources.

First, as the water that would have otherwise been used for irrigation is retained in the river, there is an immediate reduction in salt concentration.

Second, the Goulburn–Broken has relatively low recharge rates and low ground water salinity, whereas the destination areas have high recharge rates and high ground water salinity. Consequently, trading irrigation water from the Goulburn–Broken to the southern horticultural areas changes the pattern of return flows. Further, the external impacts of changes in return flows on water quality in the Murray River vary along the river system.

Trading water from the Goulburn–Broken reduces the amount of irrigation recharge that, over time, reduces the amount of saline ground water discharge reaching the Murray River. The combination of reduced saline discharge and dilution flows after the trade lead to improvements in salt concentration in the Murray River between the Goulburn–Broken and the destinations. The extent to which salt concentration is reduced depends, among other things, on the volume of the reduction in recharge and the underlying ground water salinity in the source region. As a result of the improvement in surface water quality, the productivity of irrigation water increases in the regions between the seller and the buyer.

However, salt concentration downstream of the destination areas increases after trade as the underlying ground water salinity is higher in the downstream irrigation regions and more salt is transported to the river system. Reflective of a ground water salt concentration approaching that of sea water, the negative externality is highest when water is traded to the irrigation area nearest the Murray River in the Lock 3 – Lock 2 region.

These findings indicate that there may be economic gains from attaching site specific conditions to the implicit rights to return flows that reflect the cost associated with downstream changes in river salinity. To fully account for the externalities associated with trade between the Goulburn–Broken and Lock 3 – Lock 2, the price of a permanent water entitlement would need to reflect the cost incurred by downstream water users. Trade between the Goulburn–Broken and Lock 3 – Lock 2 has an associated external cost of around $300 a megalitre as compared with the reported trading prices of around $1000 a megalitre for the region. A charge on traded water could be imposed to internalise this cost.

In contrast, trading water to the irrigation area that is more than 5 kilometres from the Murray River in the Lock 3 – Lock 2 region generates an external benefit over a fifty year time period. As the increase in recharge associated with irrigation is further from the river, it takes longer for the ground water discharge to be transported to the river system, consequently delaying the increase in salt concentration.

An external benefit is also derived when water is traded to the Lindsay region in the Victorian Mallee. The underlying geology of this region is such that ground water discharge is transported away from the river system. Any increase in recharge is therefore not reflected in an increase in salt concentration in the Murray River. A site specific condition attached to trade in this scenario could take the form of a subsidy that would reflect the positive effects on water quality of moving irrigation water to this region.

In the above scenarios where water quality is improved as a result of trade, subsidies could encourage further irrigation development in the Lindsay region and other areas further away from the Murray River, even though there may be greater pumping and capital costs of delivering water to these areas.

Changes in the pattern of return flows after the trade also affect the volume of water available downstream of the Goulburn–Broken. As the traded irrigation water is sourced predominantly from pasture production that generally has low rates of irrigation efficiency, there is a considerable reduction in surface runoff and consequently in the volume of water available for downstream users if environmental flows are to be maintained.

In the trade scenarios presented above, allocations to downstream irrigators were reduced because of losses in return flows. Only when river flows increase through gradual increases in ground water discharge were the allocations restored to original levels. As a result, external effects on downstream users were a combination of changes in water volume and quality.

To examine these effects separately, an additional simulation was conducted — downstream users were allowed to retain their original allocation despite a reduction in return flows. The simulation was conducted for a trade between the Goulburn–Broken and Mildura and compared with the corresponding simulation where environmental flows were maintained. The relative external benefits and costs of downstream changes in salinity concentrations versus water volumes are shown in figure A. The total absolute change in costs has been standardised to 100 per cent.

The impacts of volume changes are only significant immediately downstream of the Goulburn–Broken. The decline in the importance of the volume effects moving downstream reflects the fact that ground water discharge is increasing over time because of the delayed effects of land clearing. This serves to restore allocations to their original levels over time. Thus, the impact of a 20 gigalitre reduction in irrigation in the Goulburn–Broken on the volume of return

A

Indirect trade impacts: water quality and volume

flows compared with the overall increase in ground water discharge becomes smaller moving downstream from the Goulburn–Broken. Downstream impacts of salinity dominate the volume effects, with indirect benefits above Mildura and costs below. The effects below Mildura are predominantly quality rather than volume for two reasons. First, irrigation efficiency levels are high in Mildura, hence the volume of return flows is low. Second, ground water discharge from this region is highly saline.

Improvements in irrigation efficiency

In the scenario presented here, the users undertaking the efficiency improvement retain the right to water they have saved and use it to extend agricultural production. Internal benefits from increased irrigation efficiency are derived from an increase in agricultural revenue stemming from the increased availability of irrigation water. The internal, external and total associated with undertaking improvements in irrigation efficiency are shown for each irrigation area in figure B.

As in the trade scenarios, the external costs and benefits of improved irrigation efficiency are a combination of quality and volume changes in return flows. The impacts of undertaking improvements in efficiency are highly dependent on the characteristics of the irrigation area where the action is undertaken and, as a result, there is considerable variation in the external benefits and costs.

Improved irrigation efficiency leads to quality changes in return flows — the amount of ground water leakage past the root zone is reduced, thereby reducing the volume of discharge of saline water directly into the Murray River. Volume changes in return flows may occur through reductions in the volume of ground water discharge, irrigation drainage and/or surface water runoff.

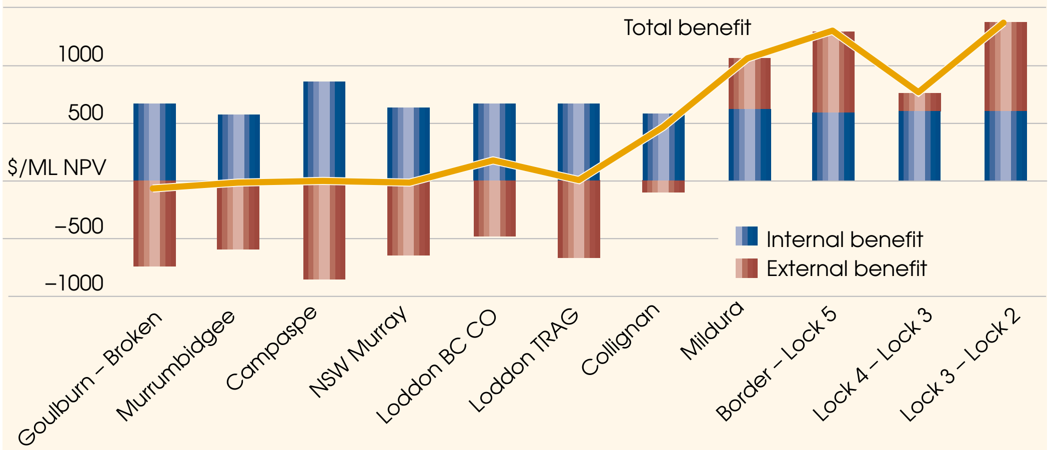
External salinity benefits derived from an improvement in the quality of water are a result of the reduction in saline ground water discharge, thereby reducing the volume of salt load that is transported to the river system. The extent to which a reduction in salt loads and concentration is achieved depends, among other things, on the volume of the reduction in recharge and the underlying ground water salinity.

As a result of the improvement in water quality, agricultural yields and revenue increase. The main driver of the benefit profile is the response time of the ground water aquifer (the time it takes for a change in recharge to be reflected in a change in saline discharge), with ground water aquifers with short response times generating water quality benefits sooner.

External benefits are only derived as a result of improvements in irrigation effi-

B

Indirect trade impacts: water quality and volume



ciency in the lower reaches of the Murray River system where ground water salt concentrations are high and ground water response times are short relative to those in the upper reaches of the system. Improving irrigation efficiency generates external costs in the upper catchments as these areas have large volumes of surface water runoff and low ground water salt concentrations. Return flows from these regions dilute the salt concentration of the Murray River. The improvement in efficiency reduces the surface water runoff component of return flows, thereby imposing costs downstream as water quality is reduced.

The reduction in surface water runoff and irrigation drainage also has immediate implications for downstream users as it leads to a reduction in Murray River flows. Volume impacts of changes to return flows are largest when irrigation efficiency is improved in the upper catchments where the dominant water use is irrigated pasture. Under conditions where environmental flows are maintained, the reduction in return flows reduces the volume of irrigation water available for use in downstream irrigation areas.

Over time, the reduction in ground water discharge will also reduce the volume of Murray River flows. The volume of the reduction in discharge will depend on rates of irrigation efficiency and ground water recharge in the irrigation areas where the improvement is undertaken.

Concluding remarks

As water becomes a more scarce resource in the Murray Darling Basin, the need to establish an efficient water market will become increasingly important. At the same time, there is concern about the impact of rising salinity on water quality and river health. However, establishing an institutional framework that will allow efficient water allocation and that addresses the externalities associated with irrigation and salinity remains an elusive policy goal.

Two problems stem from the lack of property rights associated with return flows. Return flows from some irrigation areas represent a substantial proportion of the total water applied. Downstream irrigators subsequently use these return flows. Furthermore, return flows from some irrigation regions have a major influence on the level of river salinity. Water trade and changes in the water use efficiency can affect the pattern of return flows, affecting both flow volumes and quality.

Water trade can alter the volume of return flows between the source and the destination. Along the Murray, trade downstream generally reduces the volume of return flows. If irrigators retain the full right to water use savings through improved application efficiency, similar impacts on return flows can occur.

The impact of reduced return flow volumes on downstream users depends on whether the current cap on diversions is strictly enforced and allocations are reduced. Alternatively, if intervening downstream users are allowed to retain their allocation then the additional diversions may come at the expense of environmental flows. At the same time, trade and increased water use efficiency has the potential reduce salinity and improve the riverine environment, if the incentives for trade and investment reflect their full economic impact.

In general, the results from the simulation experiments indicate that the magnitude of the external impacts associated with trade that does not take into account return flows is highly site specific. Furthermore, the external impacts of trade on upstream and downstream users vary continuously with location relative to the source and destination of trade. The impact of changes in water use efficiency is the same in this regard. As a consequence, it is infeasible to fully internalise return flow impacts on others through a system of private property rights.

Establishing water regions and administering a set of regulations on water trade and investments in water use efficiency is a potential solution that may improve the overall efficiency of water allocation. These regulations may take the form of either exchange rates or a set of taxes and subsidies on water trade and investments in improved water use efficiency.

For example, if a megalitre of water was saved in the Goulburn–Broken catchment, irrigators may only be entitled to retain the right to a proportion of that saving. The balance may be returned to the river for environmental purposes and/or downstream consumptive use.

Alternatively, there may a region specific tax or subsidy imposed on water use efficiency investments. Further, a transfer of water from the New South Wales Murray to South Australia may attract a tax. This tax might become a subsidy if the water was used in a lower impact area such as Lindsay. This in turn might defray the increased pumping costs of moving the water further from the river. Alternatively, using the exchange rate approach, a proportion of the water traded might be allocated to the environment.

An effective water market in which the arrangements for trade account for salinity impacts may assist in meeting environmental objectives in the Murray River system at least cost. Having appropriate incentives to sourcing water use savings in the right regions can also generate additional economic and environmental benefits. Environmental flows in, for example, the Snowy River may be sourced through the water market and through investment in water use efficiency. Targeting these purchases and investment to regions that reduce salinity discharge and improve water quality may deliver a better policy outcome.

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