The Australian Journal of Agricultural and Resource Economics, 43:1, pp. 69–89

Issues in defining property rights to improve Australian water markets

D. Brennan and M. Scoccimarro*

This article discusses the key practical issues associated with defining property rights to water use, in the context of broadening the scope of the market for transferable water entitlements. In particular, the third party impacts of water trade and the need for improved water trading rules are discussed. Some of the issues associated with defining the reliability of water rights, including the design of appropriate dam management policies, are also discussed. The article concludes with some positive suggestions for the policy debate.

1. Introduction

As a consequence of the micro-economic reform agenda adopted by the Council of Australian Governments, the water industry of the lower Murray–Darling Basin is undergoing considerable policy review. In principle, the concept of a broad-ranging inter-state water market has been embraced by the Council of Australian Governments, but the transition to market-based allocation mechanisms has been slow. While political issues abound, there are also serious practical problems associated with the transition process, due to the difficulty in defining property rights to water. As ARMCANZ points out, a necessary condition for an effective water market is the careful definition of formal property rights to water, that need to be clearly specified in terms of volume, reliability, transferability and quality (ARMCANZ 1995).

The inherent common property nature of river flows complicates the definition of property rights to water. Even in the case of irrigated agriculture, where the benefits from water use are purely private, the mechanisms of water delivery do not provide perfectly excludable rights, resulting in the potential for externality problems when water is transferred between users. For example, the process of water delivery may provide in-stream benefits

* D. Brennan, Department of Agricultural Economics, University of Sydney and M. Scoccimarro, Centre for Integrated Catchment Assessment and Management, Australian National University, Canberra.

for other users such as the maintenance of river health in particular locations, or may cause external costs associated with changing groundwater levels in the vicinity of the diversion. The potential for external effects associated with changing the location of water consumption implies that the definition of non-attenuated rights to water use is difficult and costly.

Another characteristic of river flows in the Australian environment that complicates the definition of water rights is the highly variable nature of flows. Irrigation and hydroelectric dam developments in Australia are not only used to change the seasonal pattern of water consumption, but also to smooth the consumption of water from year to year. Much of the debate about water allocation mechanisms has focused on the management of these dams (e.g. Dudley and Musgrave 1988; Musgrave, Alouze and Dudley 1989; Dudley 1990).

While the process of improving property rights to water is difficult, there is urgency to the reform agenda that is driven by concern for apparent over-exploitation of water resources in the Murray–Darling Basin. A recent audit of water use in the Basin highlighted significant potential for further growth in diversions for agriculture (MDBMC 1995) which, if left unchecked, would threaten the security of existing water use rights, including commercial and residual environmental uses. This concern has prompted the imposition of an interim cap on diversions. However, successful implementation of the cap is ultimately dependent upon parallel water market reforms for a number of reasons.

First, whilst one of the benefits of the proposed cap on diversions is the maintenance of existing residual environmental uses, there is increasing concern that more formalised 'environmental flow' policies are needed. The uncertainty surrounding possible changes in environmental allocations, which has already resulted in a reduction in (off allocation) water normally available to farmers in New South Wales, adds to the existing problems associated with attenuated water rights that are discussed in this article.

Second, the existence of unused 'sleeper' and partially used 'dozer' licences that may come into use as water markets mature, implies that future water consumption is bound to increase as a result of trade, even if no more licences are issued. The potential growth in on-farm storage development raises similar issues. Studies predict that there is a potential for water diversions to increase by a further 14.5 per cent under existing allocation policies (MDBMC 1995). In clarifying rights to trade water, policy-makers need to account for this potential increase in water consumption. There is a conflict between the preservation of the rights embodied in existing licences, and the preservation of the water diversion targets set by the cap.

The aim of this article is to review the practical issues associated with defining property rights to water use. The discussion presented here is set in the context of water use in the lower Murray–Darling Basin. In the following section, a background into water resource uses in the lower Murray–Darling Basin is presented, in which we highlight the dominant uses of water and the nature of existing water rights. The subsequent discussion of problems associated with defining water rights is divided into two parts, to which we broadly refer as the *spatial* and the *temporal* dimensions of the problem. First, the experience of overseas and Australian policy-makers in dealing with the spatial externalities associated with water diversion and consumption are discussed. The second part of the discussion focuses on some of the issues associated with managing the year-to-year reliability of water allocations, including methods of dam management. We conclude with some positive suggestions for the policy debate.

2. Water use in the lower Murray–Darling Basin: the physical environment

The lower Murray–Darling Basin contains Australia's major river systems, the Murray, Darling and Murrumbidgee (as shown in figure 1). Along these river systems, a series of dams has been constructed for hydroelectric and irrigation purposes. The total capacity of storage structures in the Basin is 16 000 GL, which is 115 per cent (MDBMC 1995) of the average annual discharge from the catchment. The large volumes of storage structures have been used to control the seasonal flow of water from winter–spring

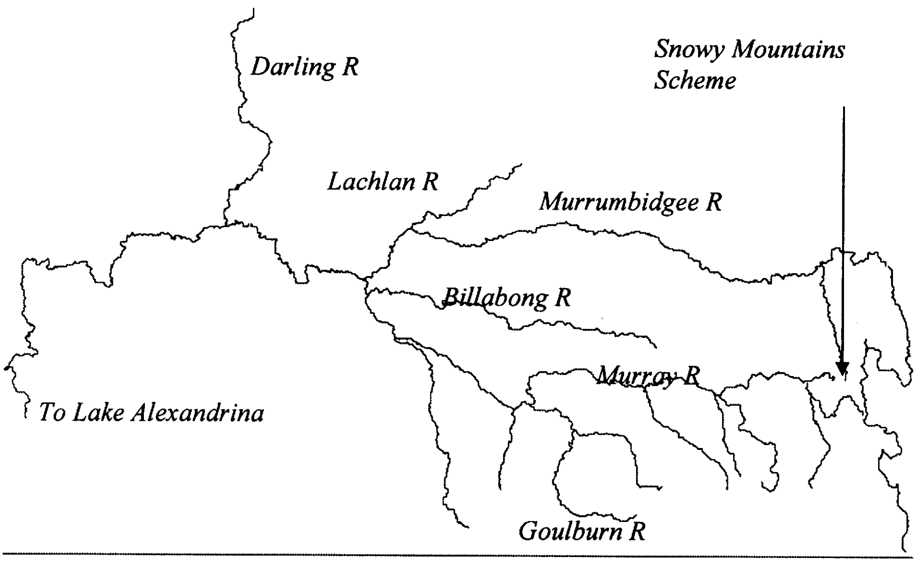

Figure 1 Major rivers within the Southern Murray–Darling Basin

precipitation, to summer–autumn demands for irrigation. The storages are also used to smooth the year-to-year variability of flows in the system. This variation in river flows is extreme compared to river flows in other parts of the world. The ratios for annual variations in maximum to minimum flows range from 3:1 to 15:1 in North America, while in Australia they range from 300:1 to 1000:1. A variation of 10 000:1 has been reported for the Darling River (Powell 1989). The variability of water flows in the Basin implies that property rights cannot be defined in terms of a certain volumetric allocation, but instead, the definition requires reference to the reliability of such rights (Dragun and Gleeson 1989; Randall 1981).

Irrigation is the main consumptive use of water in the lower Basin, and of the yearly average volume of water diverted (10 680 GL), irrigation diversions are around 95 per cent (MDBMC 1995). Other consumptive uses are for urban water supply, and stock and domestic provisions in rural areas. The irrigation industries supported by the Murray and Murrumbidgee River systems in New South Wales, Victoria and South Australia include vineyards, citrus and stonefruit orchards, pasture for dairy and other livestock production, and irrigated cereal crops including rice.

A valuable non-consumptive use of water in the Basin is hydroelectric generation, which uses on average about 2400 GL of water per year (Snowy Mountains Hydro-electric Authority 1993). While on average, the volume of water used for hydroelectric generation is small compared to consumptive uses in agriculture,[1] the waters held in the Snowy Mountains Scheme can provide a significant proportion of irrigation water in years of low rainfall. It appears that the design of the original (public) Snowy Mountains Scheme was partly aimed at providing such security — the volume of storage capacity at Lake Eucumbene is much larger than is required for hydroelectric operation, being equivalent to around 2 years' annual hydroelectric generation (Snowy Mountains Hydro-Electric Authority 1993).

In addition to these commercial uses, there are a number of other demands for water in the Basin, which include the use of in-stream flows for the maintenance of river and riverine health and recreation. Many of the benefits of allocating water for these demands have public good characteristics, for example, the maintenance of biodiversity. Others have identifiable private benefits such as the use of dilution flows to maintain water quality for downstream consumption.

Within the broad range of uses for water in the Basin, there are many different characteristics of water that give value. The private irrigator with a

[1] The main sources of water for the Murray and Murrumbidgee are tributaries below the Snowy Mountains Scheme.

perennial crop values an exclusive use of reliable quantity of water that is available in the summer period. In contrast, owners of hydroelectric generators do not explicitly value the consumption of water. Instead, they value the energy contained in flowing water, as well as the ability to change the timing of water releases from their dams. In other cases, water may have an option value for consumption, such as in the case of wetland management, where water may be used to simulate infrequent natural flooding.

2.1 The policy environment

Agriculture

Water allocation policies have focused on defining diversion rights to irrigators and other commercial users. Since the State Governments hold the constitutional right to water resource management, the policies governing water allocations differ significantly across the Basin. The pricing policies for water delivery differ significantly between the states, with New South Wales government charging irrigators 70 per cent of the regional cost of delivery (on the basis that 30 per cent is a public good) and Victorian government charging irrigators 100 per cent of the cost of delivery. Furthermore, in NSW, the state's share of the operating cost of managing the headwaters is borne by taxpayers and in Victoria, by irrigators (MDBMC 1996).

Water allocation policies and the associated decisions concerning dam management also differ across jurisdictions. For example, quantities of water kept as drought reserves for irrigation along the Murray River vary between Victoria and New South Wales (MDBMC 1995). When determining allocations for the year, Victoria includes a large reserve, being the amount of water that could satisfy irrigation demands in the following year under severe drought conditions. In contrast, New South Wales keeps only small reserves in storages. Consequently, a water right in Victoria has associated with it a much higher level of reliability than a water right of the same volume in New South Wales.[2]

All states have made some progress towards introducing transferable water rights. Temporary markets were introduced in South Australia and New South Wales in 1983 and in Victoria in 1987. More recently, permanent trading of water has been permitted in all three states (Pigram *et al.* 1992). However, there are a significant number of restrictions on transactions in these water markets. The appropriate water authority must approve transactions, and special conditions must be met in order for the trade to be approved. Transactions can

[2] With the exception of specific high security rights for urban and horticultural uses, water rights have a reliability of 70 per cent in NSW. This is contrasted with reliability of 97 per cent in Victoria (MDBMC 1995).

be rejected if the water authority considers that there is a negative externality caused by the trade. Two common third party effects that cause concern are salinity damage and problems caused by overburdening the delivery system in a region. Not all cases require administrative approval, often there are regulatory constraints to trade between regions, made under the auspices of limiting such third party effects. There are also quantity limits placed on permanent trade in Victoria and South Australia (MDBMC 1996). Finally, institutional arrangements vary by state, with the duration of some water markets being all irrigation season, and others only open for a short period at the beginning of the season. While water transfers between farms in different states have not been permitted in the past, an inter-state water trading trial in the Riverina began in 1998 (MDBC 1997).

Hydroelectricity

The rights to use water for hydroelectric generation have been set by regulation, which is partly aimed at protecting downstream irrigators. While the Snowy Mountains Hydro-Electric Scheme may soon be corporatised to coincide with other reforms of the electricity supply industry, it is likely that the corporate scheme will continue to be governed by regulations. Rights to water will probably be set by licences which will specify the hydroelectric authority's ability to 'use, collect, divert, store and release water' (Parer, Egan and Stockdale 1997). Such licences are likely to encompass contractual arrangements to provide water to downstream states in times of drought, but without financial compensation.

Environment

The rights of the environment to water have been residual to commercial developments, and as a consequence, there has been significant damage to riverine ecosystems. The major irrigation releases occur in summer, at a time when many of the riparian ecosystems require low flows. Regulation of river flow has also reduced the frequency and magnitude of flooding in spring, which has serious consequences for ecosystem health and biodiversity (MDBMC 1995).

In cases where there has been recognition of in-stream needs, environmental allocations have been provided for through the operating policy of state water managers, rather than through formal arrangements (Hoey 1995). For example, *ad hoc* management arrangements exist for the Gwydir wetlands and were introduced following the outbreak of toxic blue green algae in the Barwon and Darling Rivers (Blue-Green Algae Task Force 1993). More recently, there has been an increased awareness of the need to define environmental allocations to water, and in the policy environment, there are many examples of recent initiatives in this area. The establishment of the Healthy

Rivers Commission in NSW, and the allocation of formal entitlements to the Barmah Millewa State Forests and to the Macquarie Marshes, reflect the policy trend towards redressing environmental allocations to water (NPWS and DLWC 1996).

3. Spatial dimensions to trading water

While the potential benefits of water trade are well recognised (e.g. ARMCANZ 1995; Randall 1981; Howe, Schurmeier and Shaw 1986), the potential costs associated with changing the spatial location of water consumption are often ignored in the policy arena. The common property nature of water in the delivery system, and the difficulty in clearly defining rights to use, imply that third parties can be affected by such water trades. Further, the public good characteristics of some water uses imply that parties affected by water trades may not always be well represented in the market. The benefits of improving water resource use through market allocation methods will depend on how these issues are dealt with when designing tradable water entitlements.

3.1 Water diversion vs. consumptive use

One of the difficulties in defining property rights to irrigation water is that the net use of water by plants is generally less than the total volume diverted from waterways. While the problems caused by ‘return flows’ are often cited (e.g. Randall 1981; Howe *et al.* 1986; Rosegrant 1995), there is less attention given to possible solutions to the problem in a market setting. Some of the implications of water trade on ‘return flows’, their effect on third parties, and practical methods of dealing with the problem are discussed.

A return flow (generally termed ‘drainage water’ in Australia) is the water associated with a diversion licence that is not consumed, and returns to the hydrological system in the vicinity of the diversion. This return flow may bring positive or negative externalities to neighbouring users, including the environment. A common negative externality associated with this excess water in Australia is the problem of irrigation-induced salinity. The application of water in excess of plant requirements leads to rising groundwater tables, which can bring sub-surface salts to the root zone. Currently, this problem is managed to some extent by restricting trade of water into saline-affected areas[3] (Pigram *et al.* 1992).

[3] The incentive for upstream states to provide regulations to manage salinity has been promoted by the introduction of an inter-state market in salt emissions permits in the Murray–Darling Basin (1992). States earn credits by funding the construction of salt interception schemes or other methods of reducing river salinity and use credits by constructing drainage or allowing other actions which increase salinity (Bain *et al.* 1996).

Not all return flows cause negative externalities (Watson 1996). Farmers can collect and use drainage run-off from neighbouring farms. Return flows may also provide some reduction in salinity through dilution. In some cases, the external effects associated with drainage water are formalised/internalised. One example of this is the licensing of opportunistic water use in the lower Murray swamps, which permits farmers to water a certain area of land with water from drainage channels[4] (Whittle and Philcox 1996). Similar arrangements have evolved in the water markets of Chile and Mexico, where local regions are permitted to use the drainage water created by diversions in that region, but use rights are not formalised (Schleyer 1992).

Potential spillover effects can sometimes be eliminated when transfers are specified in terms of consumptive use. Downstream users of drainage water will be protected if the amount transferred by the initial diverter is limited to consumptive use, and where their source of water is a conveyance system which still contains the 'drainage water' after the transfer. However, in cases where the return flow is normally re-used within a diversion infrastructure, such as within individual irrigation districts, the external benefits of drainage water are lost when the water diversion right is transferred out of the district. Miller (1987) suggests that the restriction of water transfers out of irrigation districts in the United States may be an attempt to internalise the external benefits of drainage water, and that such restrictions may represent a jointly optimal policy for the district.

An additional problem associated with drainage water is that the relative volumes of drainage water (per unit of water diverted) depend on the irrigation technology used. Improvements in irrigation efficiency can result in an increase in the total amount of water consumed from a given volume diverted. Whittlesey and Huffaker (1995) argue that many 'so-called water conservation programs' in the United States have been based on increasing the consumptive use of existing diversions. Such policies do not provide extra water, but merely redistribute drainage water that would otherwise be available for downstream uses, to farmers adopting conservation technologies. Similar problems arise in Australia, where water allocations are enforced by meters on water entering the farm. The farmer appropriates any improvements in efficiency of water use on the farm, to the detriment of downstream users.

In cases where drainage water gives rise to irrigation-induced salinity, the specification of rights to diversion rather than consumption can have

[4] These licences do not, however, guarantee supply, and users have suffered a depreciation of those rights as increased use of laser levelling in the region has reduced the amount of waste water in the drainage channels.

beneficial impacts on third parties. For example, in examining case studies of land forming and reuse systems in NSW, Wall and Marshall (1995) found that farmers could economically recycle up to 15 per cent of the total water applied, because the private benefit of water saved justified the cost of such technologies. Such improvements in irrigation efficiency also bring external benefits in areas where high and rising water tables are causing salinity problems.

However, while the specification of diversion rather than consumption licences may contribute to improved water table management in the lower Murray system, it could create other problems. Widespread adoption of water conservation technologies could have a substantial effect on the total consumptive use of water in the Basin, and thus reduce existing in-stream flows. It is estimated that an average 9500 GL of water was diverted for use on broadacre crops and pastures in NSW and Victoria between 1988 and 1992/93 (MDBMC 1995). Even if only half these broadacre farms adopted such water-saving technology,[5] this could amount to an increase in consumptive use of water by around 700 GL. This figure would represent a significant loss to residual environmental uses; for example, it is seven times the size of the formal allocations given to the Barmah-Millewa forests (Murray Water Entitlement Committee 1996).

3.2 In-stream flows

The allocation of formal rights to the environment is a recent phenomenon and most in-stream uses of water do not have formalised rights. Rather, the rights are residual to the formal rights of commercial uses. While the protection of these 'residual' rights is being promoted by the enforcement of the Murray–Darling Basin cap on diversions (MDBMC 1995), there are many areas where environmental or other in-stream benefits may be eroded. An increased use of on-farm storage which intercepts run-off or diverts high flows, can have an impact on the residual allocation to in-stream uses. The use of on-farm storage in the Basin has more than doubled in the past five years (MDBMC 1995). This has been in response to increased demand from new cotton developments and a desire to reduce variability in supplies. Projections contained in the Water Audit include an increase in off-farm storage capacity of 83 per cent in Queensland and a 32 per cent increase in

[5] There are other factors affecting the adoption of this technology. In some areas re-use systems are not physically feasible as watertables are within two metres of the surface. The benefits of water savings are also affected by the opportunities to sell or re-use the saved water. In a study of the Murrumbidgee irrigation areas, McClintock (1997) found adoption rates of around 40 per cent.

the Darling River in NSW (ibid.). An effective limit on the cap would require that future investments in these on-farm dams be limited. However, in the interests of economic efficiency, the establishment of property rights to diversion of unregulated flows, which could be transferred from irrigated uses downstream, or between farms upstream, could facilitate future expansion in cotton production while keeping water consumption at the cap.[6]

A second example where in-stream rights may be eroded was mentioned in the last section, where it was argued that poorly defined rights to drainage water could increase consumptive use in the Basin, via the adoption of 'water-saving' technology. However, even if it was practical to redefine rights to consumption rather than diversion, to maintain a cap on total consumptive use, this will not always ensure that in-stream benefits are protected. This is because some in-stream uses are location-specific and depend on the volume of flow in the river at that location. Many recreational uses, as well as location of specific riparian uses, fall into this category. When trade occurs from downstream to upstream locations, water flows between the two locations are reduced, and this can threaten location-specific in-stream uses. In some cases, defining flow standards at various key locations along the river system may protect existing in-stream uses. For example, many of the environmental and recreational benefits may be maintained by observation of minimum flow standards.

Similarly, there are physical limits on the maximum amount of water that can be conveyed along river channels. The channel constraints in the Tumut River below Blowering present significant management constraints on the operation of the Snowy-Tumut hydroelectric development. Riparian farmers are protected by law from flooding that could arise if channel constraints are exceeded. Another important channel constraint in the Murray system is the Barmah Choke, which limits the rate of delivery of water to irrigation areas in Victoria (Close 1989). Thus, trade between regions either side of the Barmah Choke has physical limitations.

One method of protecting residual rights is to formalise them so that they have the same 'status' as the water rights held by commercial uses. It has been suggested that environmental managers should be given formal environmental allocations with which they can determine optimal use of water between competing environmental objectives (Rosegrant and Gazmuri-S 1995; Collins and Scoccimarro 1995). These environmental managers could participate in the water market, selling water during

[6] The Department of Land Conservation has recently released a discussion paper which proposes volumetric allocations be applied to users of unregulated rivers and that dams with less than 7 Ml capacity be licensed (DLWC 1998).

droughts at high prices, then using the funds to buy more water in periods of lower prices, to meet the high but infrequent watering requirements of riparian environments.

Formalised 'bulk environmental allocations' have been trialled in NSW and Victoria (Doolan and Fitzpatrick 1995; Knights, Fitzgerald and Denham 1995). These so-called environmental contingency allowances can be used by the manager to meet a range of environmental needs. For example, volumes of water can be reserved in the dam and released to meet specified but unpredictable critical river health problems (Taskforce on COAG Water Policy Reform 1996). Additional measures in New South Wales are to provide for the passage of flows through storages (without being stored), so as to replicate somewhat the natural pattern of flows.

Ecologists have raised a number of concerns arising from their experience with managing such environmental water allocations. These include the lack of experience and lack of information to determine the appropriate use of water (Doolan and Fitzpatrick 1995) and the need for an experimental adaptive approach (Knights, Fitzgerald and Denham 1995). One example that highlights uncertainty in managing environmental allocation is the case of the Barmah-Millewa red gum forests. For these forests, there is a formal annual entitlement of 50 GL per forest, which can be carried over between years (Murray Water Entitlement Committee 1996). So far, this environmental allocation has not been drawn upon, because environmental managers have yet to determine how to use the water allocated to the forests (ibid.).

3.3 Jointness in infrastructure costs

Another feature of water delivery systems that would need attention in a market-based system is the jointness of infrastructure. Most of the costs associated with this infrastructure, including the costs of maintenance and replacement of structures and, in many systems, the costs of water lost in wetting the delivery channels are not use-related. Any reduction in the volume of water delivered through a particular system will raise the average costs of the water delivery infrastructure for the remaining irrigators; however, a range of possible pricing mechanisms for joint cost recovery are possible. In South Australia, purchasers of water from government irrigation areas must pay a levy of approximately $7.50/ML per year (Challen and Petch 1997). This effects a 'compensation payment' to users in the area of origin (maintaining the existing revenue base for infrastructure maintenance) and promotes pricing signals that discourage movements of water out of the region. While this creates an imbalance in water resource use at the margin, the lumpiness in investment decisions for water delivery infrastructure implies that such pricing mechanisms will not necessarily be sub-optimal over the longer term.

The problems associated with pricing and investment in irrigation infrastructure are important issues in a market setting, especially given the depreciated state of current irrigation infrastructure.[7] Whilst a full discussion of these problems was considered to be beyond the scope of this article,[8] they are raised here in order to highlight a potential source of continued resistance to expanding the spatial boundaries of trade. Experience in the United States indicates that this resistance can be driven by both economic and political arguments. Miller (1987) argues that the common practice of restricting trade outside local irrigation areas in the United States may be a jointly optimal arrangement, because of the impact on water delivery infrastructure. Rosegrant (1995) reports that the restrictions on water trade (which, in California, is limited to about 20 per cent of consumptive use rights) are also driven by political and social concerns relating to the impact on regional economies.

3.4 Transactions costs associated with trading water resources

Clearly, one of the main issues associated with broadening the scope of trade on the water market in the Murray–Darling Basin is the problem of protecting third parties. Relaxation of current restrictions to trade will inevitably affect the welfare of other water users, and will require that there is careful consideration of the appropriate mechanisms for regulating trade.[9]

Important lessons can be learned from the experience in overseas markets. The reliance on judicial procedures to protect the interests of third parties has been a serious impediment to trade in some areas of the United States (Ditwiler 1975; Young 1986). However, the degree to which water transactions are caught up in the judicial system varies between states, as do transactions costs, which have been estimated to range between 2 and 20 per cent of the value of water (Colby 1990; Hearne and Easter 1997). The use of case-by-case determination of water trading permits, e.g. as used in

[7] Love (1994) suggests that about $600m needs to be spent over the next thirty years on upgrading infrastructure within the southern Basin.

[8] The interested reader should refer to Watson (1996) and Alaouze and Whelan (1996) for discussions of this topic.

[9] While a number of reviews of trading arrangements have been undertaken in previous years (see for example Pigram and Hooper 1992 and MDBMC 1996), these arrangements are in a process of transition due to water policy changes.

California (Rosegrant 1995) can be compared with more liberal water trading policies adopted in other states, which incorporate simple transfer rules aimed at protecting third parties whilst reducing 'policy-induced' transactions costs. In New Mexico, for example, transferable water quantities are determined utilising standard formulae together with historical and secondary data (Rosegrant and Gazmuri-S 1995). Similarly, in Wyoming the state authorities approve temporary transfers on the presumption that 50 per cent of diverted water is consumptively used, and is therefore available for trade (ibid.).

It is clear that some of the localised externality problems created by poorly defined rights to drainage water could be improved by specifying rights to consumptive use and creating a market in the return flows (Randall 1981). However, at a practical level, the enforcement of consumptive use can involve additional costs over a diversion right. If consumptive use were to be enforced by metering, it would require metering the diversion at the farm intake channel and the return flow in the drainage channel. This would not only double the cost of metering, but measurement of drainage would be prone to errors due to rainfall run-off and seepage from other areas.

However, not all third party effects can be solved by redefining rights as consumptive use and effecting a market in return flows. This is because the return flows can provide localised in-stream (public good) uses. Where these are important, it might be possible to set minimum and maximum flow targets along particular reaches, which would represent a standard against which trade permits could be issued.

It is important that proponents of water markets recognise the other costs associated with trade on such markets when determining the gains from expanding existing water markets. Challen and Petch (1997) provide evidence to suggest that thin trading on the South Australian water market has resulted in significant market price dispersion, indicating that the reliance on markets to allocate water efficiently may have been overstated. These costs together with the potential for errors in designing rights to protect third parties may imply that the net benefits of market allocation methods for water are significantly reduced.

4. The temporal dimension to the water market — defining rights to volume and reliability

In the regulated river systems of the lower Murray–Darling Basin, there has been significant investment in inter-year storage capacity to stabilise the annual allocation of water. This is extreme in Victoria, where the capacity is 3 times the annual average inflow (Alaouze and Whelan 1996), although dam managers in NSW also follow carryover policies. There has been much contention as to the efficiency of centrally controlled management of these dams, and whether end users are being supplied with the privately optimal level of inter-temporal water storage (e.g. Dudley 1988; Musgrave, Alaouze and Dudley 1989). Clearly, the privately optimal assessment of the yield/reliability trade-off implicit in dam management is likely to differ between individuals. This is not only due to differences in risk preferences, but also due to heterogeneous demands, such as the difference between irrigators with perennial and annual plantings. In this section, we discuss dam management alternatives and associated rights to water consumption.

4.1 Centrally managed dams and associated rights

One method of allocating water rights is based on centrally managed dams, where irrigators have rights specified to releases from the dam. All decisions about the management of the dams, in terms of the yield and reliability of releases, are determined by the policy of the central dam management. An important distinction must be made between the concept of central dam management and the policies that have been traditionally applied by central dam managers. Many critics of central dam management have based their criticisms on existing policies, rather than on the concept of centralised management (e.g. Musgrave *et al.* 1989; ARMCANZ 1995).

Dam management policies in each state are determined by policies relating to the underlying water rights. With the exception of special high security licences for horticulturists in NSW, water rights in Australia have been based on across-the-board single reliability rules in all states in the lower Basin. In NSW and Victoria, the 'surplus' water that is available after water rights are met is available for use by irrigators, but rights to use this 'extra' water are tied to the underlying irrigation rights held by the farmer. Under these single reliability rules, farmers are unable to tailor their water allocations according to their own demand for reliability. In contrast, it has been suggested that several types of rights be specified, according to different levels of reliability, so that farmers could purchase a portfolio of release rights according to their needs (e.g. Musgrave and Leseur 1973; Randall 1981; Alaouze 1991).

Alaouze (1991) proposes one type of design, where water is divided proportionately amongst different groups of rights. The more reliable group of rights are allocated a consistently larger share, so that some minimum level is exceeded with a high degree of reliability. However, this proportional sharing basis also means that those with 'reliable' rights end up being allocated large amounts of water that has no marginal value to them.

Howe *et al.* (1986) provide a comparison of such a 'proportional rights' doctrine, with the 'priority doctrine' that is evident in some US states. The priority doctrine evolved with the gradual development of irrigated agriculture in the western United States, where new users of water within a particular system were only allowed access if they did not affect the reliability of rights to prior appropriators of water. In times of low river flow, those with 'senior' rights are entitled to a specific volume of water to the exclusion of those with 'junior' rights (Ditwiler 1975). As Howe *et al.* (1986) argue, priority rights are more effective when users are not alike, but have the disadvantage of being more difficult to organise a market for, because rights are not homogeneous. While proportional rights to river flow (either natural flow or dam releases) are easier to administer in a market setting because they are homogeneous, they have the disadvantage of requiring sensitive users to hold extra shares that are not used in all seasonal conditions. In the circumstances of the lower Murray–Darling Basin, users are very different and there is considerable variability in the annual supply of water (even under regulated systems). Thus, it would appear that the 'priority doctrine' would be a better system for the design of release rights from centrally administered dams. Such a system could be administered by adhering to a few discrete reliability levels, and farmers could buy a portfolio of such rights to tailor their demands for reliability. Conceptually, the market would reveal the premiums and discounts associated with different levels of reliability. Enlightened administrators could trade in rights of different reliabilities, and make associated changes to dam management, in order to achieve a supply of rights on the market that reflect the socially optimal reliability/yield trade-off.

4.2 Rights to a share of dam capacity

An alternative method of water allocation has been proposed which allows individual irrigators to control their own reliability by managing a share of the dam (e.g. Dudley and Musgrave 1988). Under 'capacity sharing', individuals are assigned rights to a share in the capacity of a dam, and to a share of the natural inflows to that dam. Those individuals requiring a more reliable supply would carry over more water from one year to the next, keeping their share more full, and extracting less on average. A more opportunistic water user could adopt a less conservative carry-over policy, and enjoy a higher but less reliable yield of water. In this way, each individual user tailors their consumption of water according to their own risk preferences.

While there are some obvious benefits associated with giving farmers more autonomy in managing inter-temporal reliability, the operation of a capacity-sharing system would require very detailed institutional arrangements in order to function effectively. In addition to the market in dam space, there would need to be an associated spot market for water, and clearly defined rights to inflows. Moreover, while the aim of the capacity-sharing institution is to make water users independent of each other (Dudley and Musgrave 1988; DLWC 1998; NERA 1994), the physical reality is that they are interdependent. As an example of such interdependency, the conservative operator will have a large frequency of 'spills' which would increase the volume of water flowing into the capacity shares of the less conservative users in the dam. The management of this water, which yields a positive value to a neighbouring cell or downstream user, has not been dealt with adequately in the literature on capacity sharing. For example, Dudley and Musgrave (1988) treat the distribution of this water as a positive externality that is not included in the decision-making processes of individual share holders. However, unless a market mechanism is used to allocate this 'internal spill', the water will not be allocated efficiently, except if all the other users place the same value on the external benefit. Moreover, forfeiture of inflow once a capacity share is full does not give the conservative user a true indication of the value of its capacity share, which would have long-term resource allocation implications.

There are other reasons why a capacity-sharing policy would also require a clearly defined spot market for water. In a large dam that caters for a large geographical area, the climatic risk faced by different irrigation districts would not be perfectly correlated. Thus, even when the risk preferences of two individuals are the same, and they place the same value on a stored volume of water, they will be in disequilibrium whenever their realised water demand in a particular season differs according to their local rainfall pattern. A spot market for water would allow the seasonal value of water use to be equated at the margin.

4.3 Capacity sharing or release sharing?

One of the problems of centrally managed dams and release rights could be overcome by changing to a set of priority-based rights. Alternatively, even with proportional sharing, a better functioning seasonal spot market for water would ensure a more efficient allocation of water in the event of temporal variation in water availability.

The problems associated with capacity sharing could be overcome by stronger definition of property rights. This requires more than a specification of rights to dam capacity (and an associated rental market) and specification of rights to inflow. It requires also a specification of rights to water held in the dam (a market in spills and releases). One of the most important advantages of a capacity-sharing system (if such a system is administratively feasible) is that the risk associated with water rights does not have to be specified. In contrast, the design of a priority-based system of release rights requires specification of a volume and an associated level of reliability (probability that the volume is available). There are a number of reasons why the specification of reliability may be difficult. In addition to the potential problem of climate change, the ability of hydrologists to accurately forecast water volume and availability may be questioned, not just because of complexities of the hydrological system, but also because of problems in monitoring and enforcing consumptive water use. The capacity-sharing institution places the burden of uncertainty on the individual, rather than the central authority.

Whatever method of dam management is used, decisions are dependent upon reliable inflow estimates. Such estimates require assessment of the highly variable inflows of the catchments supplying the dam, including the multitude of tributary inflows, and the contributions of upstream hydro-electric operations to dam inflows. Whilst the central authority may not be able to supply perfect information (and may therefore suffer from liability as noted above), the information required for making dam management decisions relies on the specialist skills of hydrologists and systems modellers. Thus there may be important economies associated with the information required for effective dam management, which would be better managed by a central authority who can invest in expert hydrological modelling.

No matter which dam management policy is used, the spatial problems of administering water markets will not be avoided. The spatial problems bring transactions costs that cannot be ignored, and necessarily reduce the net gains from trade. They also affect the appropriateness of alternative systems of rights. In a release-sharing context, the presence of costly market transactions provides more reason for tailoring rights as priority-based rather than proportional rights, because it obviates the need for short-term transactions. The presence of transactions costs will also affect the functioning of markets associated with a capacity-sharing system, but to the extent that it emphasises individual autonomy, it may also facilitate less reliance on short-term transactions than the existing system of proportional release rights.

5. Conclusion

While Randall (1981) heralded the maturation of the Australian water industry over a decade ago, it was the 1995 announcement of the ‘cap’ that really marked the end to the expansionary phase of the water industry in the Murray–Darling Basin. More than ever before, there is a need to address water market reform as a means of reallocating water between existing uses.

These water markets need to go beyond the limited intra-regional ones that currently operate, to allow for broader transfers within the Basin.

However, in view of the many problems associated with defining property rights to water, the slow rate of progress in water market reform is not that surprising. There are some situations where restricting trade might be justified, because of the externality problems associated with water transfers and the costs associated with administering efficient and fair solutions to these third party effects. However, it is our contention that the debate cannot effectively proceed unless there is some attempt to quantify the importance of these third party effects, and the transactions costs associated with alternative market and regulatory mechanisms.

We have highlighted a number of strategies that could be adopted to minimise the externality problems associated with market mechanisms. For example, the definition of rights to consumptive use (rather than diversions) is a possible solution to many of the 'return flow' problems associated with water trade. However, the costs of administering such a solution (which would require monitoring of diversions and return flows) may not justify the policy. An alternative system could involve the design of rules of thumb to protect third parties, such as 'generalised formulae' for converting diversions to consumptive use.

Similarly, the appropriate type of dam management depends on the costs associated with operating centralised versus decentralised schemes. Further, since alternative management policies have different requirements for associated markets (such as spot markets in water and dam space), the transactions costs associated with spatial trading will also affect the suitability of alternative dam management systems.

Ultimately, the appropriateness of alternative mechanisms for water allocation can only be judged by empirical examination. It is impossible to costlessly assign perfect property rights to water. The trade-offs between alternative allocation mechanisms cannot be made without considering the complete system — both the spatial and the temporal dimensions to water use — at the catchment level. Indeed, our discussion has highlighted that many of the issues surrounding the redefinition of property rights for water relate to interdependencies between different users. The complexity of the river system and the many competing and conflicting demands for water resources imply that an interdisciplinary research effort could contribute significantly to the process of market reform. A system-wide planning approach would enable water resource managers to assess the impact of proposed policy changes on all parties, accounting for the sometimes complementary and sometimes conflicting nature of demands for water. It could also facilitate a co-ordinated approach to water resource management between jurisdictions.

References

Agriculture and Resource Management Council of Australia and New Zealand Standing Committee on Agriculture and Resource Management (ARMCANZ) 1995, *Water Allocations and Entitlements: A National Framework for the Implementation of Property Rights in Water, Policy Position Paper for discussion with stakeholders in developing and implementing systems of water allocations and entitlements*, Taskforce on COAG Water Reform, Occasional Paper Number 1, Canberra.

Alaouze, C. 1991, 'Transferable water entitlements which satisfy heterogeneous risk preferences', *Australian Journal of Agricultural Economics*, vol. 35, no. 2, pp. 197–208.

Alaouze, C. and Whelan, S. 1996, 'Economic efficiency and property rights issues in the management of rural water', in Pigram, J. (ed.), *Security and Sustainability in a Mature Water Economy: A Global Perspective,* Water and Economics Consortium: Proceedings of an International Workshop, University of Melbourne, Armidale, NSW, Centre for Water Policy Research, University of New England, Armidale.

Bain, D., Close, A., Milner, H. and Hee, A. 1996, *Striking the Balance: Managing the Water Resources of the Murray–Darling Basin beyond the Year 2000*, Proceedings of the 23rd Hydrology and Water Resources Symposium, Hobart, Tasmania, 21–24 May, pp. 37–41.

Blue-Green Algae Task Force (NSW) 1993, *Blue-Green Algae: Final Report of the Blue-Green Algae Task Force*, Department of Water Resources for the Task Force, Parramatta, NSW.

Challen, R. and Petch A. 1997, 'Price determination and behaviour in the market for irrigation water in South Australia', paper presented to the 41st annual conference of the Australian Agricultural and Resource Economics Society, Gold Coast, January 1997.

Close, A.F. 1989, 'River Murray Water resource planning', in Dandy, G.C. and Simpson, A.R. (eds), *National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability,* AGPS, Canberra.

Colby, B.G. 1990, 'Transactions costs and efficiency in Western water allocation', *American Journal of Agricultural Economics*, vol. 72, no. 5, pp. 1184–92.

Collins, D. and Scoccimarro, M. 1995, 'Economic issues in the creation of environmental water allocations', paper presented to the National Agricultural and Resources Outlook Conference, Canberra, February 1995.

Department of Land and Water Conservation (DLWC) 1998, *Water Sharing in New South Wales — Access and Use: A Discussion Paper*, Department of Land and Water Conservation, Sydney.

Ditwiler, C.D. 1975, 'Water problems and property rights — an economic perspective', *Natural Resources Journal*, vol. 15, no. 4, pp. 663–80.

Doolan, J. and Fitzpatrick, C. 1995, 'Protecting our rivers through property rights and water trading', paper presented to the National Agricultural and Resources Outlook Conference, Canberra, February 1995.

Dragun, A.K. and Gleeson, V. 1989, 'From water law to transferability in New South Wales', *Natural Resources Journal*, vol. 29, no. 3, pp. 645–61.

Dudley, N.J. 1988, 'Volume sharing of reservoir water', *Water Resources Research*, vol. 24, no. 5, pp 641–48.

Dudley, N.J. 1990, 'Alternative institutional arrangements for water supply probabilities and transfers', in Pigram, J. and Hooper, D. (eds), *Transferability of Water Entitlements: Proceedings of an International Seminar and Workshop*, Centre for Water Policy Research, University of New England, Armidale, pp. 79–83.

Dudley, N.J. and Musgrave, W.F. 1988, 'Capacity sharing of water reservoirs', *Water Resources Research*, vol. 24, no. 5, pp. 649–58.

Hearne, R.R. and Easter, K.W. 1997, 'The economic and financial gains from water markets in Chile', *Agricultural Economics*, vol. 15, no. 3, pp. 187–99.

Hoey, D. 1995, 'Implications of environmental flows for land and water management plans in the Murray region', paper presented at the National Agricultural and Resources Outlook Conference, Canberra, February 1995.

Howe, C., Schurmeier, D. and Shaw, W. 1986, 'Innovative approaches to water allocation: the potential for water markets', *Water Resources Research*, vol. 22, no. 4, pp. 439–45.

Knights, P., Fitzgerald, B. and Denham, R. 1995, 'Environmental flow policy development in NSW', paper presented at the National Agricultural and Resources Outlook Conference, Canberra, February 1994.

Love, K. 1994, 'Policy developments and options for irrigation in Victoria's Murray–Darling Basin — revitalising agriculture through sustainable regional development', paper presented at Irrigation Policy Workshop, Focus on Policy Developments and Options for Irrigation in the Lower Murray–Darling Basin, ABARE and CWPR, Mildura, November 1994.

McClintock, A. 1997, 'Irrigated farming on broadacre farms in the southern Murray–Darling Basin', *Australian Farm Surveys Report*, ABARE, Canberra.

Miller, K. 1987, 'The right to use versus the right to sell: spillover effects and constraint on the water rights of irrigation organisation members', *Water Resources Research*, vol. 23, no. 12, pp. 2166–74.

Murray–Darling Basin Commission 1992, *Annual Report*, Murray–Darling Basin Commission, Canberra.

Murray–Darling Basin Commission 1997, *Murray–Darling Basin Moves Closer to Inter-State Water Trading*, media release, Friday, 28 November.

Murray–Darling Basin Ministerial Council 1995, *An Audit of Water Use in the Murray–Darling Basin, Water Use and Healthy River: Working Towards a Balance*, Murray–Darling Ministerial Council, Canbera, ACT.

Murray–Darling Basin Ministerial Council 1996, *Setting the Cap: Report of the Independent Audit Group,* Murray–Darling Ministerial Council, Canberra.

Murray Water Entitlement Committee 1996, *Water Entitlement Bulletin Number 2*, 16 September 1996.

Musgrave, W., Alaouze, C. and Dudley, N. 1989*, Capacity Sharing and its Implications for System Reliability*, Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability, Australian Water Resources Council Conference Series No. 17, Australian Government Printing Service, Canberra.

Musgrave, W.F. and Lesueur, J.F. 1973, 'Large dams and drought', in Lovett, J.V. (ed.), *The Environmental, Economic and Social Significance of Drought*, Angus and Robertson, Sydney.

National Economic Research Associates 1994, *Water Trading in Victoria: Final Report*, London.

National Parks and Wildlife Service and Department of Land and Water Conservation (NPWS and DLWC) 1996, *Macquarie Marshes Management Plan*, NPWS Hurstville and DLWC, Dubbo.

Parer, W., Egan, M. and Stockdale, A. 1997, *Corporatisation of the Snowy Mountains Hydro-electric Scheme*, joint media release by Senator Warwick Parer, Federal Minister for Resources and Energy, Michael Egan, New South Wales Treasurer and Alan Stockdale, Victorian Treasurer.

Pigram, J., Delforce, R., Coelli, M., Norris, V., Antony, G., Anderson, R. and Musgrave, W. 1992, *Transferable Water Entitlements in Australia*, Centre for Water Policy Research, University of New England, Armidale.

Pigram, J.J. and Hooper, B.P. 1992, *Transferability of Water Entitlements*, Proceedings of an international seminar and workshop, the Centre for Water Policy Research, University of New England, Armidale, 4–6 July 1990.

Powell, J.M. 1989, *Watering the Garden State: Water, Land and Community in Victoria, 1834–1988*, Allen and Unwin, Sydney.

Randall, A. 1981, 'Property entitlements and pricing policies for a maturing water economy', *Australian Journal of Agricultural Economics*, vol. 25, no. 3, pp. 195–220.

Rosegrant, M.W. 1995, 'Water transfers in California: potentials and constraints', *Water International*, vol. 20, pp. 72–87.

Rosegrant, M.W. and Gazmuri-S, R. 1995, 'Reforming water allocation policy through markets in tradable water rights: lessons from Chile, Mexico and California', *Cuadernos de Economía*, vol. 32, no. 97, pp. 291–315.

Schleyer, R.G. 1992, 'Chile's market-orientated water policy: institutional aspects and achievements', in Le Moigne, G., Easter, K.W., Ochs, W.J. and Giltner, S. (eds), *Water Policy and Water Markets: Selected Papers and Proceedings from the World Bank's Ninth Annual Irrigation and Drainage Seminar*, Annapolis, Maryland, 8–10 December 1992.

Scoccimarro, M., Beare, S. and Brennan, D. 1997, 'The Snowy River: opportunity costs of introducing environmental flows', *Australian Commodities*, vol. 4, no. 1, pp. 67–78.

Snowy Mountains Hydro-Electric Authority 1993, *Engineering Features of the Snowy Mountains Scheme*, Cooma.

Taskforce on COAG Water Policy Reform 1996, *Waterways, Water Industry Reforms and You*, May 1996.

Wall, L. and Marshall, G. 1995, *Drainage Reuse and Spearpoint Systems: Financial Case Studies in the Berriquin Irrigation District*, Farm Management Report No. 1, Economic Services Unit, NSW Agriculture, Orange.

Watson, A. 1996, 'Conceptual issues in the pricing of water for irrigation', in Pigram, J. (ed.), *Security and Sustainability in a Mature Water Economy: A Global Perspective,* Water and Economics Consortium: Proceedings of an International Workshop, Melbourne, January 1996.

Whittle, J. and Philcox, M. 1996*, Drainage Management Options for the Lower Murray Reclaimed Swamps*, Primary Industries, South Australia.

Whittlesey, N.K. and Huffaker, R.G. 1995, 'Water policy issues for the twenty-first century', *American Journal of Agricultural Economics*, vol. 77, no. 5, pp. 1199–203.

Young, R. 1986, 'Why are there so few transactions among water users?', *American Journal of Agricultural Economics*, vol. 68, pp. 1143–51.