Water Policy 11 (2009) 598–614

# Managing groundwater as a common-pool resource: an Australian case study

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**Abstract**

Over-appropriation and degradation of groundwater can result from lack of recognition of, and inappropriate arrangements for, managing groundwater as a common-pool resource. An irrigators group in the Lockyer Valley, South-East Queensland, Australia and the Queensland government are currently working together to address over-exploitation of groundwater through a co-management model designed to be nested within the state and national water reform framework. This paper applies Ostrom's design principles for common-pool resource governance to this proposed co-management framework to strengthen the approach.

*Keywords:* Collaboration; Co-management; Common-pool resource; Design principles; Groundwater; Water resources

## 1. Introduction

Unrestricted access to groundwater has resulted in unsustainable use in the Lockyer Valley—a highly fertile horticulture and fodder growing area located about 80 kilometres west of Brisbane in South-East Queensland, Australia. The situation has been exacerbated by several years of drought. The Queensland Department of Natural Resources and Water (DNRW)[1] and the local irrigators organisation, the Lockyer Water Users Forum (LWUF), are exploring co-management within a regulatory framework to solve groundwater over-extraction problems in the Valley (DNRM, 2005a, pp. 4–5). While there appears to be agreement on the long-term goal of sustainable use of groundwater, some important differences in perspective have been revealed during discussions on the scope of the co-management model in the

[1] This organisation has changed names during the period considered here. In referencing, we use the name extant at the time of each publication cited. When referring to the organisation in the text, the name current at the time of paper submission is used.

doi: 10.2166/wp.2009.076

Valley. No systematic research has been undertaken so far to examine how a sustainable co-management model could work to address over-appropriation issues in the Valley.

A series of studies (Bromley & Cernea, 1989; Ostrom, 1990; McKean, 1992) shows that resource users can self-manage common-pool resources (CPRs), possibly with some minimal support from their governments. Ostrom and others (Ostrom, 1990, 2005, 2006; Ostrom *et al.*, 1999) examined how self-governance of CPRs works effectively in hundreds of local and regional case studies from around the world and developed a self-governance model based on the case study lessons. Weinstein (2000) draws on west-coast Canadian Aboriginal fisheries and the Japanese inshore fishery to illustrate Ostrom's principles for conditions of success and situations that led to failure. While some CPR water management systems have a strong basis in custom, which evolved long before modern governments, others are more recent arrangements in which governments have important roles to play in providing regulatory framing for the arrangements to thrive, and in offering strategic supports to extend the capacities of the self-governing irrigators (e.g. Sarker & Itoh, 2001, 2003). The self-governance model suggests that the development of users' institutions, as well as the design principles that characterize these institutions, is important.

This paper examines the proposed co-management approach for the Lockyer Valley within the context of Ostrom and associates' design principles for self-governing institutional arrangements, and makes recommendations for a robust institutional framework. We argue that the development of effective sharing institutions among groundwater users, supported by the regulating agency and consistent with regulatory requirements, will enhance the sustainability of groundwater use.

This information is derived from four years of participatory action research with the LWUF (a coalition of irrigators), 33 interviews with landholders and water managers to explore their perspectives on water (Baldwin & Ross, 2006; Baldwin, 2008), and a postdoctoral study of CPRs in South-East Queensland (Sarker *et al.*, 2008a,b).

## 2. Groundwater systems as CPRs

A CPR is defined as a large natural or human-made system possessing two key attributes: low excludability of beneficiaries (resource users) and high subtractability of benefits (resource units) (Ostrom *et al*., 1994; Ostrom, 2005). It is very difficult to exclude a potential user from withdrawing groundwater since few jurisdictions have placed limitations on rights to access the water: any user able to reach the water table by manual means (wells) or invest in the cost of a bore can take water. Once a quantity of water is withdrawn (subtracted) it is no longer available to other users. A groundwater user thus exerts a negative externality on other users, which may not be taken into account in maximising personal utility, resulting in withdrawal of too much water. The water is thus easily over-appropriated and Hardin's (1968) 'tragedy of the commons' can occur.

Gordon (1954), Olson (1965) and Hardin (1968) argue that unless an external authority forces users to share their resources equitably, they cannot solve the CPR problems. Bromley & Cernea (1989), Ostrom (1990) and McKean (1992) are critical of the philosophy behind this solution, without rejecting the idea of external authority entirely. Indeed, studies by Ostrom (1990, p. 23), Ostrom *et al.* (1999, p. 278), and Berkes *et al.* (1989, pp. 92–93) demonstrate that privatisation and government regulation have ironically invoked more overappropriation and degradation of resources in many cases. Fenny *et al.* (1998, p. 87) argue that '[s]ocieties have the capacity to construct and enforce rules and norms that

constrain the behaviour of individuals'. This capacity is important in avoiding over-appropriation of a CPR. Van Vugt (2002, p. 783) refers to natural resource management as a social dilemma of conflict between the short-term self-interest of users and the long-term collective interest of the user community. He suggests that an 'alternative community model' can foster self-restraint among users provided they feel attached to their community.

As noted earlier, Ostrom and collaborators argue that individuals in many cases can cope successfully with over-exploitation of the commons by formulating self-governing institutions, and identify a set of underlying design principles that contribute to robust and enduring arrangements. They also note that governments have important roles to play to make self-governance work. Similarly, Pretty (2003, pp. 1912–1914) observes that communities can collaborate in managing a CPR sustainably but, since they do not always have specialised skills needed to manage the resources, they may need support from a higher level of authority for better knowledge of resource management.

## 3. Australian context

Approximately 10–15% of Australia's groundwater management units are judged to be over-allocated, and groundwater use increased by 58% from 1983 to 2000 (NLWRA, 2001, p. 64). Information on groundwater use is limited in availability and reliability, with only 14% of groundwater management units having some or all water use metered (NLWRA, 2001, p. 64).

In Australia, landholders hold the property rights to their agricultural land, usually freehold, and in some regions under long-term leasehold. In Queensland, as in other states, 'all rights to the use, flow and control of all water'—including groundwater—are vested in the State (Water Act, 2000, s19). Legislation provides that persons may take 'subartesian water for any purpose unless there is a moratorium notice or a water resource plan that limits or alters the water that may be taken. . .' (Water Act, 2000, s20 (6)). Thus, unless there are specific prohibitions, landholders can access the water that flows under their private land.

McKay (2007) explains the history to these arrangements. Application of English common law to groundwater in 19th century Australia gave individual landowners unlimited access to groundwater under their land. In the 20th century, groundwater was held completely by the Crown, with each state devising independent licensing and management systems for surface and groundwater. In practice, states allowed unlimited access to water for decades, without a cap on the number of bores or the quantity of water extracted (McKay, 2007). Where management did occur, groundwater was often managed independently from surface water and based on imprecise crop/area formulae (Evans, 2001, cited in McKay, 2007), as well as 'inaccurate understandings of the sustainable yield of the aquifer, poor measurements and lack of metering' (McKay, 2007, p. 324). This historical legacy had contributed to the current unsustainable practices around the country by the time national water reforms were introduced in 1996. Since then, states have been addressing this issue in a more coordinated fashion as a result of fiscal incentives and time-bound targets; however, there are still many challenges ahead owing to 'regional diversity in legal systems and quality standards as well as conflicts between private interest and public welfare' (McKay, 2005, p. 35).

The Council of Australian Governments'[2] Water Reform Agenda in 1994 and Australia's National Water Initiative in 2004 aim to restore systems that are presently over-allocated or overused to extraction

[2] The Council of Australian Governments is comprised of the federal and state governments. It provides a co-ordination mechanism across jurisdictional boundaries, for issues of national interest including water.

levels that are environmentally sustainable, to use community partnerships to promote transparency, and to ensure information is available to all sectors at key decision points (Commonwealth of Australia, 2004, p. 20). The state governments have responsibility for implementing the Initiative.

The State of Western Australia has pointed out two key characteristics of self-management for water in the Australian context; namely, 'self-management can only exist within a framework of government setting strategy, policy and regulation and licensing' and 'at a minimum the [irrigation] organisation is accountable for its regulatory performance' (GWA, 2006, p. 7). In New South Wales (NSW), the Department of Water and Energy is responsible for granting entitlements based on sustainable yield of both surface and groundwater[3]. Since 1995 almost all irrigation areas and districts in NSW, previously controlled by the state government, have gradually become privately owned, with the 'shareholders' of the corporation being the landowner irrigators within the district. Individual irrigators have shares in the licences which belong to the corporation. The major objective was to strengthen irrigators by providing them with local control of the irrigation facilities to ensure long-term financial viability and environmental sustainability (MJA, 2004; GWA, 2006). Pigram & Mulligan (1991) call this 'privatised self-management'. This observation frames our case study, consistent with Ostrom's view that robust self-governing institutions need to be nested within a larger policy context.

## 4. The Lockyer Valley case study

The Lockyer Valley is an area of almost 3,000 square kilometres with a population just over 30,000. It has a mean annual rainfall of 776 millimetres, with higher falls on the surrounding ranges. Owing to over-use of surface waters and the ephemeral nature of the streams, agriculture in the Valley (mainly fruit, vegetables and lucerne[4]) relies heavily on the extraction of groundwater stored in alluvial aquifers[5] (see Figure 1). Irrigation bores have been drilled in increasing numbers since the early 1940s, with over 1,500 bores estimated to be currently servicing the Valley (DNRM, 2003). Market demand for a continuous supply of fruit and vegetables has put additional pressure on irrigators to over-extract groundwater.

Resource use continues to surpass the estimated sustainable yield and, consequently, the Valley is now recognized as a stressed groundwater area (DNRM, 2005a). Historically there has been an estimated annual groundwater withdrawal of up to 74,000 ML, although groundwater storage in the alluvial aquifers is estimated at a safe annual yield of from 27,000 ML/year (DNRM 2005a, p. 11). Reduced availability of groundwater as a result of over-extraction combined with lack of recharge due to the effects of drought has resulted in decreased extraction and hence decreased production (DNRM, 2005a). It is estimated that at least one-third of productive land has been withdrawn temporarily from cultivation

[3] The terms 'sustainable yield' and 'environmentally sustainable level of extraction' of a natural system are used interchangeably in the Australian context. The National Water Initiative defines 'environmentally sustainable level of extraction' as 'the level of water extraction from a particular system (such as a groundwater or surface water system) that, if exceeded, would compromise key environmental assets, or ecosystem functions and the productive base of the resource' (AWR, 2005).

[4] Lucerne is the term used for alfalfa in Australia.

[5] A type of aquifer formed from deposited sand and silt particles.

due to lack of water. Meanwhile, the over-appropriation has exacerbated salinity in some aquifers, as highly saline water seeps in from adjacent sandstone areas to replace the higher quality water taken from alluvial aquifers. This has reduced the area of farmland that can be irrigated with groundwater.

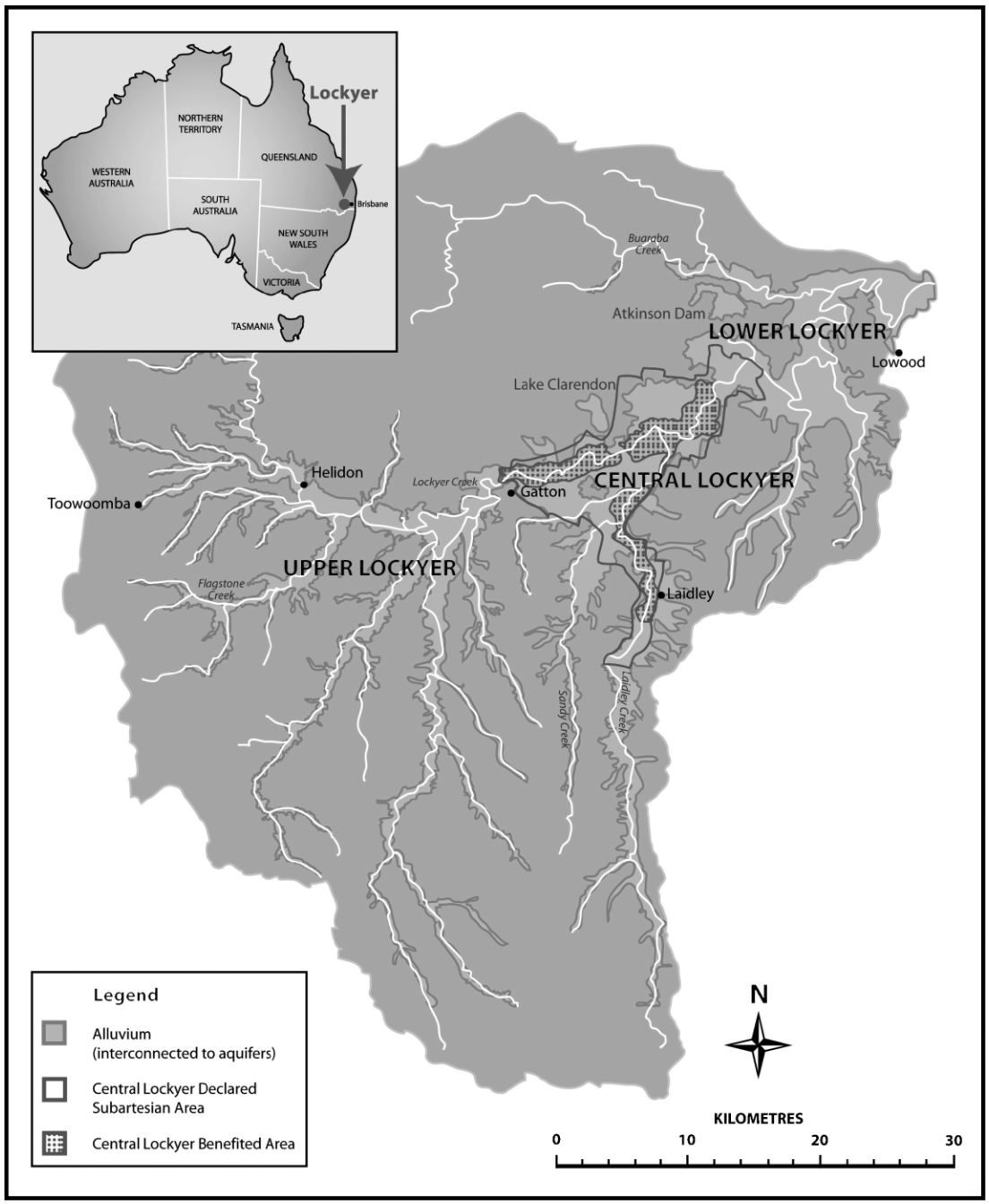


Fig. 1. Map of Lockyer Valley illustrating groundwater areas (Source: Queensland Department of Natural Resources and Water).

There is significant connectivity between surface water and groundwater in parts of the catchment. Surface water recharges the aquifers owing to the porosity of soils and stream beds. Due to the drawdown of the aquifers there is little or no surface water available for irrigation. Thus, unregulated groundwater development will impact further on surface water reliability and environmental flows (DNRM, 2005b; DNRMW, 2006).

In 2005, the Queensland Government released a discussion paper which identified the Lockyer Valley as a stressed groundwater area and proposed the declaration of the whole Valley as a sub-artesian area, as a basis for regulation of aquifer use (DNRM, 2005a). In contrast to other heavily used groundwater areas of Queensland, only a portion of the Central Lockyer groundwater area is regulated through licensing with extraction limits on individual bores under state legislation. Only licensed bores have been identified, are registered with government, and are required to be metered. Currently there are no institutional mechanisms in place to manage groundwater withdrawal by the remaining two-thirds of the irrigators (including some of the largest landholders) in the areas known as the Upper, Lower and some parts of the Central Lockyer (see Figure 1). As a result, there is no accurate data on the number of bores in the entire area, nor of their take.

In Queensland, one mechanism for implementing the National Water Initiative is through a two stage water planning process: a Water Resource Plan (WRP) followed by a more detailed Resource Operation Plan (ROP). The state government completed the first stage of water planning in the Moreton region, which includes the Lockyer, in mid 2007. The Water Resource (Moreton) Plan 2007 defines availability of water in the plan area, provides a framework for managing water sustainably, its extraction and water allocations and, where practicable, aims to reverse degradation that has occurred in natural ecosystems. Specific management rules will be in the ROP which is currently in the process of development; the concepts raised in this paper are intended to inform the ROP development. To prevent deterioration of groundwater resources, a moratorium on further groundwater bore development was instituted in 2005 and the Plan does not allow for further increase in the average volume of groundwater to be taken from the area.

Early in the planning process, the local irrigators' association, the Lockyer Water Users Forum (LWUF), began negotiating with the Queensland government to allow a 'co-management' approach to groundwater to apply across the Lockyer. This was motivated largely by a desire to avoid a regulatory approach being imposed by government that did not reflect grower interests and was potentially inflexible, and by their need for a sense of control over a resource that is key to their livelihood.

## 5. The Lockyer Water Users Forum 'co-management' framework

There is a history of competition between Valley farmers because of the nature of horticultural markets (Brimblecombe, undated). Irrigators formed LWUF in December 2001 with 17 (now 18) member groups representing irrigators in sub-catchments. LWUF became an incorporated association in June 2002, helping to bring competing interests together, identify the consequences of the individual actions upon others, and use self-managing practices to influence the future of farming (Brimblecombe, undated). Organisers invited a variety of other stakeholders to monthly meetings to provide support and direction to the decision making process. This assisted in developing a bond with the DNRW, and stronger connections with local governments and the regional natural resource management body, SEQ

Catchments (SEQC)[6] (Brimblecombe, undated). SEQC works in conjunction with local governments, urban and rural industries, community groups, landcare groups[7], environmental groups, landowners and Aboriginal Traditional Owners[8] to implement its government-endorsed regional strategy and action plan (SEQWCG, 2005). SEQC supports LWUF with advice, organisational and facilitation expertise.

Through a series of facilitated meetings, some with DNRW, a proposal for self-regulation of the entire Valley (now referred to as the 'co-management' approach) was developed through 2005 and 2006. The initial LWUF proposal was that government would provide an overall allocation to each of 18 management areas within the Lockyer, formalised in the ROP. All irrigation bores would be licensed, metered and monitored. A Board of Management to comprise LWUF members, SEQC, and possibly government would administer the system, with meters owned and monitored by the Board (LWUF, 2006). Irrigators in each management area would work together using information on their aquifer, supported by computer modelling and bore monitoring data, to determine appropriate arrangements for use. Aquifers would not be allowed to be drawn below a certain level. Seasonal flexibility at property level would be negotiated within each management area. It could include provision for a temporary, but not a permanent trading system, retaining long-term control of the resource within the Valley. LWUF agreed to independent oversight and compliance. Irrigators would work towards sustainability and efficiency.

When the Moreton draft WRP (DNRMW, 2006) was released, however, a key strategy was for conjunctive (or combined) volumetric allocation of surface and groundwater for existing licence holders within the Central Lockyer, and possibly extending to part of the Lower Lockyer. The remaining area was to be managed under a management framework to be developed in consultation with irrigators, referring to the co-management framework. The LWUF was concerned that this proposal would continue the inequitable regulation which has allowed unfettered access to groundwater for those in the Upper and Lower Lockyer, yet restrictions on take only in the Central. They sought co-management for the entire Valley. In addition, discussions indicated that government could not sit on the proposed Board because of its compliance role (LWUF, 2006). The negotiation process continues over the same issues, now at the stage of a draft Memorandum of Understanding, with the LWUF aiming for a consistent approach across the Valley that allows for greater user 'ownership' of resource management and equity in terms of regulation.

An issue of debate between LWUF and government was the ownership of meters. LWUF wanted to own, maintain and monitor meters on farm bores, whereas the state government metering policy requires that meters are owned and monitored by DNRW. This was important to irrigators who wished to monitor directly and more frequently than DNRW to better understand the relationship between water use and aquifer levels, and to be independent and show responsibility for land and water use. They also thought it would be less costly and meant meter installation could occur more quickly. In spite of this point of disagreement, both parties agree that there should be meters, and that compliance should be independent (LWUF, 2006).

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[6] This is one of a nation-wide set of collaborative, community-based multi-stakeholder bodies established to coordinate natural resource planning and management at a regional scale, under Australia's National Action Plan for Salinity and Water Quality, and Natural Heritage Trust 2 (see http://www.nrm.gov.au/about-nrm.html for details). These are similar in function to watershed bodies in the USA.

[7] Voluntary groups comprising rural landholders, private citizens and sometimes others, working at local scales within a national network to achieve a healthy environment and sustainable agriculture.

[8] Recognised Indigenous customary owners of land.

Participatory action research by one of this paper's authors (Baldwin) has identified underlying values and interests in relation to water allocation and use among both irrigators and non-irrigators (government staff, landcare group office bearers and local residents) in the Lockyer Valley. This research identified strong basic needs of irrigators as security, economic well-being, sense of belonging, recognition, and control over one's life (Baldwin, 2008). These are needs which, according to Fisher & Ury (1991), must be addressed to avoid or resolve conflict. In addition, irrigators value fairness, a 'triple bottom line' perspective (i.e. taking into account environmental, social and economic factors), and espouse both a private interest and broad view of public interest in terms of sustainable water use. They are particularly concerned about the effect of future regulation on their livelihood and the Lockyer economy. These values and interests are consistent with and supportive of the LWUF's proposed co-management framework. A strong sense of community was also identified, giving a good prognosis for co-management according to Van Vugt's (2002) 'alternative community model' (Baldwin & Ross, under review).

Typically, the term 'co-management' describes an arrangement in which management decision-making is shared (preferably equitably) between government and resource user parties (McCay & Jentoft, 1996). However, DNRW has indicated that its role of ensuring compliance prevents it from being a partner: it refers instead to a 'regulatory self-management model' (DNRM, 2005b, p. 35). LWUF continues to use the term 'co-management', now referring to a community-based management approach similar to Ostrom's self-governing concept. In this approach, the government is envisaged as participating only in a Technical Advisory Committee and in ensuring compliance, with no involvement on the Board. As a result, in this study, 'co-management' for the LWUF proposal reflects Ostrom's intent in its design and we use the terms 'self-governance' and 'self-regulation' interchangeably with 'co-management'.

## 6. Design principles for self-managing the groundwater CPR

Ostrom (1990, 1992, 2005) observes that design principles exist in most of the effective CPR systems reviewed, while the failed ones usually lack these principles. 'A design principle is an element or condition that helps to account for the success of institutions in sustaining the physical works and gaining the compliance of generations of users to the rules-in-use' (Ostrom, 1992, p. 68). While Agrawal (2003) suggests that there may be over 30 factors that affect successful management of commons, this paper focuses on Ostrom's eight principles as a foundation for refinement of the LWUF co-management approach. We describe each of the design principles in turn, describing how the LWUF co-management proposal relates to each.

### *6.1. Design principle 1: clearly defined boundaries*

The first design principle requires resource users to identify clearly the boundaries of the system they intend to administer, as well as individual access rights to the system (Ostrom, 1992, 2005). In the Lockyer, the boundaries and extent of the aquifers (quantity of water available) underlying the land are not clear, nor are users' rights of access. Groundwater users have bores to access water but in many cases these are not formally recorded. Definition of boundaries and rights will help prevent free-riding users who might try to withdraw groundwater without contributing to the collective management process; for example, by drilling bores without permission.

For LWUF, meeting this principle requires division of the region into aquifer management zones, identification of water use at each specific bore location and also the volume of water that can be appropriated sustainably. However, because the location of only a small proportion of bores has been formally recorded and only a portion of Lockyer irrigators have meters on bores, meters need to be installed, bores registered, and additional gathering of data on resource use and effect on the aquifer is required over the next couple of years to clearly define the resource boundaries and sustainable yield. As foreshadowed in the draft Moreton WRP, the final Plan continues with Central Lockyer regulation under which users have individual volumetric allocations. Unless traditional operation is modified, this provides the possibility of co-management only for the Upper Lockyer with negotiations still to take place on the extent of application to the Lower Lockyer.

Although this design principle clearly identifies users, there is a chance that those included may not withdraw water equitably. This requires the second design principle.

### *6.2. Design principle 2: proportional equivalence between benefits and costs*

The second design principle involves groups of users developing rules to allocate benefits (e.g. water extracted) proportional to inputs (e.g. time; payment for water): how much, when, and how the resources are to be harvested. Users are more likely to keep the resource well-maintained and sustainable when the rules associated with the distribution of benefits are generally consistent with the distribution of costs, so that they receive equitable benefits from their contribution (Weinstein, 2000; Ostrom, 2005).

According to the DNRW's metering policy, each participant in the Lockyer will pay DNRW an annual fee for the capital cost of each meter, its maintenance and monitoring. However, to be consistent with Ostrom's principle, it would be appropriate to pay for management costs and water extracted. This will be of concern to irrigators who have indicated in interviews their apprehension about the threat of increased costs and the consequent effect on livelihoods (Baldwin & Ross, under review; Baldwin & Pretty, 2005; Baldwin & Ross, 2006). On the other hand, there is some indication from interviews that Lockyer irrigators may accept water charges if they know the funds will be used to benefit their own management of the water resource directly. Ostrom (1992, p. 83) emphasises that long-term implementation of a reform proposal to apply this design principle in particular is achievable if governments 'anticipate and understand' possible opposition from the irrigators for higher water charges. Full cost recovery (i.e. recovery of operational, maintenance and administrative costs) for all rural surface- and groundwater-based systems or transparent identification of a Community Service Obligation (CSO) is a requirement of the Intergovernmental Agreement on the National Water Initiative (clause 66(v) (Commonwealth of Australia, 2004)).

### *6.3. Design principle 3: collective-choice arrangements*

According to the third design principle, users will have the ability to create and adjust their working rules over time to maintain resources at a level suitable to the local environment. This principle requires that all participants deem rules fair, otherwise they will be ignored (Ostrom, 1992; Weinstein, 2000; 2005).

As mentioned under principle 2, the users in each sub-management area in the Lockyer will form a group to develop rules with advice from DNRW, SEQ Catchments, and independent researchers. In surface water irrigation systems, the state of the resource and the effects from irrigation are

more easily seen and understood than in groundwater systems. Since there is currently limited understanding about the aquifer performance in some parts of the Lockyer, the management rules will need to be monitored and modified predominantly by users as more information becomes available over time.

A basic rule in the Lockyer co-management proposal is to identify the level of the aquifer beyond which no further extraction will be allowed in each sub-catchment or management area. Users will be advised when the level reaches trigger points where extraction is initially reduced and then ceased. Further, there will be group agreement on the proportion of 'sustainable take' that each user is allowed, based on a combination of factors still to be worked out but most likely related to historical use and location of the bore and impact of extraction on the aquifer. Ongoing communication between users will be needed to ensure rapid response to triggers and temporary trading.

One way irrigators can contribute to enduring systems is by making significant investments in monitoring and sanctioning actions themselves (Ostrom, 1992). This has led Ostrom to identify the fourth and fifth design principles.

### *6.4. Design principle 4: monitoring*

The fourth principle requires that monitors supervise rule-compliance and users' behaviour. Ostrom (2005) emphasises that rules must be enforced to achieve strong governance. User groups can select their own monitors in durable resource regimes who are then accountable to the groups. Monitors oversee resource conditions as well as harvesting activities. This helps to reassure participants that all stakeholders are conforming to the rules of the system (Ostrom, 2005).

Monitoring is an area of disagreement between DNRW and LWUF. DNRW proposes that government will own, install, maintain and monitor meters to ensure effective compliance, consistent with its 'Statewide metering strategy'. The LWUF however proposed that the Forum would use funds contributed by users to purchase and install meters, employ an independent monitor, and report to government. LWUF offered that government could do an audit of compliance at any time. A major incentive for monitoring by users is to better understand water use and the relationship with aquifer levels, to learn more about the groundwater system for more responsive management and therefore more efficient and cost-effective irrigation. LWUF believed that it will be more cost-effective for irrigators or LWUF to own meters rather than government. While government has rejected users owning their own meters, it is supportive of user involvement in monitoring and a shared real-time database.

### *6.5. Design principle 5: graduated sanctions*

Many enduring, self-regulating systems involve monitoring and sanctioning by participants rather than by external authorities (Ostrom, 1992). Given this, Ostrom (1992) finds the continued commitment to landholder-designed rules remarkable. GWA (2006, p. 11) offers the reason that 'self-management organisations based on shared business objectives also hold an effective hostage asset over recalcitrant members, in that the Board can deny them access to the business services'. According to Ostrom (2005), strong governance arrangements use graduated sanctions whereby an initial sanction may function as awareness-raising or as a warning to others in the community. Continued non-compliance then needs to impact on the benefit cost ratio of breaking local rules.

In cases of non-compliance in the Lockyer, it is important that the organisation representing the interests of the group as a whole, LWUF, must be able to enforce compliance on an individual. Although not yet resolved, sanctions might be enforced through contractual arrangements, on a sliding scale including initial discussion among group members and a warning, leading to a water or cost penalty, the latter being implemented by DNRW. The ultimate sanction is the Queensland government's promise to step in and regulate individually if areas do not comply with sustainable yield agreements. At the same time, an individual must be protected from unjust actions by the majority. To implement graduated sanctions, a conflict resolution mechanism is important.

### *6.6. Design principle 6: conflict resolution mechanisms*

The sixth principle strengthens the previous principles (Ostrom, 2005). Conflict resolution mechanisms that are fast, low-cost, and local are essential to ensure issues (among users or between users and officials) are resolved, particularly in cases where their jointly-made rules are interpreted differently (Ostrom, 1992, 2005). Being able to voice and resolve conflicts quickly and share resolutions within the management area reduces the potential for breakdown of trust and reinforces understandings of the rules (Ostrom, 2005). Ostrom (1992) notes that conflict resolution mechanisms are often informal, and that leaders frequently resolve conflicts. Further, Ostrom suggests that a conflict resolution mechanism at a level above that of a local resource might reduce the problem of 'elite capture of a local resource' (Ostrom, 2005, p. 268). Mackay (2005) also supports use of a neutral third party to sit on water supply business bodies, to diffuse tensions about water allocations and help reach an equitable solution.

The Lockyer lacks the history of formal collaboration about groundwater irrigation that one finds in surface water irrigation systems, but 'neighbourliness' is a practised norm. Baldwin & Pretty (2005), Baldwin & Ross (2006) and Baldwin (2008) revealed a strong sense of community in the Lockyer. The need to cooperate, forced by water scarcity and backed by an overall sense of community, could provide a basis for collaboration among irrigators. Although the details are not yet completely resolved, there is likely to be a graduated system of conflict resolution just as for sanctions. If the local management group cannot resolve an issue, a 'tribunal' comprised of two from the LWUF Executive and an external party could be brought in. If the conflict is more serious, independent and skilled third party mediation could be sought.

### *6.7. Design principle 7: recognition of rights to organise*

If a user organisation's authority to make rules is challenged by government, it will be destabilised. To hold user-group office bearers or members accountable for their actions, they need to be seen as legitimate groups (Ostrom, 1992). Ostrom (2005) argues that at least partial recognition by a national or local government affects the competence of users to organise and build a more capable regime over time.

There are three ways in which this principle applies to the Lockyer:

- the LWUF needs to be seen by the irrigators as their legitimate representative;
- the government needs to see the LWUF as the legitimate representative of the irrigators and as capable, responsible, and accountable; and;
- the NSW model of irrigators having shares in the licences which belong to the corporation provides a possible approach to 'co-management' in those areas of the Lockyer already regulated.

In relation to the first point, it is estimated that there are more than 600 irrigators in 18 sub-catchments in the Lockyer, with about 160 of those being active commercial operations. The LWUF has slowly been building up membership and all 18 areas are usually represented at its monthly meetings. Executive members of the LWUF have consulted with each area to confirm irrigator support of the co-management proposal and to demonstrate the support to government.

In relation to the second point, an allowable take and rules of use will be enshrined in the Resource Operation Plan and reflected in individual licences. Some aspects may need to be formalised in a contract between DNRW, LWUF and management zone to be enforceable by law. The third point regarding irrigators having shares in a corporation licence is subject to discussion between the Queensland and federal governments prior to implementation.

### *6.8. Design principle 8: nested enterprises*

This design principle applies to comparatively large CPR systems. In a complex, large-scale CPR, 'appropriation, provision, monitoring, enforcing, conflict resolution, and governance activities are organised in multiple layers of nested enterprises' (Ostrom, 1990, p. 101).

Table 1. Ostrom's design principles applied to the Lockyer Valley groundwater CPR.

| Design principles | Lockyer proposal |
|---|---|
| 1: Clearly defined boundaries | 18 sub-catchment management areas within entire Lockyer. Access rights to water to be determined over the next couple of years with improved data collection documenting bores, water use and aquifer characteristics. Equity across the Valley is an issue |
| 2: Proportional equivalence between benefits and costs | Rules of use will identify extraction limit for each management area. Group agreement on extraction rules within management area. Water extraction should be costed proportional to benefits i.e. use. Current proposal relates to costing according to number of meters |
| 3: Collective-choice arrangements | Rules will need to be monitored and adapted over time, as more information is available within each management area. Rule changes will need to be negotiated within management area groups |
| 4: Monitoring | Irrigators are committed to investing in meters and an independent monitor to monitor resource conditions, irrigator behaviours and compliance, to assure all participants of conformance with rules. Disagreement with government on ownership and control of meters and monitoring |
| 5: Graduated sanctions | Local management area groups would meet to discuss non-compliance with range of penalties: warning, water limit, or financial penalty. Continued non-compliance would be managed via DNRW and would need to impact on the benefit cost ratio of breaking local rules |
| 6: Conflict resolution mechanisms | Graduated system commencing with local management area group, followed by tribunal of LWUF Board and external person or neutral third party mediator |
| 7: Recognition of rights to organise | LWUF recognised as legitimate by government through increased membership of management area representatives and clear support of co-management approach. LWUF to become corporate identity with formal agreements and contracts with DNRW, implementing resource extraction limits specified in ROP |
| 8: Nested enterprises | Small sub-catchment based management areas, nested within an overarching governance framework established under the auspices of an LWUF Board, legitimised by formal agreements, support and auditing by DNRW. Government (not on Board) would provide appropriate nesting |

Reeve (2003) refers to nested hierarchies of governance as a means to manage natural resources sustainably. Such institutions would involve government, irrigator groups (similar to LWUF), district committees (similar to Lockyer sub-catchment groups), and the Regional Resource Management Group (similar to SEQC). Success could be achieved through application of a number of principles, including well-developed social capital and institutional capacity in all groups with an interest in the resource, so that all groups can represent their interests and run effective decision-making processes.

The LWUF proposal is for a system of small management zones, nested within an overarching governance framework under the auspices of a LWUF Board which would be responsible for managing an allocation or arrangements as specified under the Water Resource Plan and Resource Operation Plan, and possibly through contractual arrangements between all parties, yet to be worked out. While LWUF's initial proposed Board structure included government, not having government on the Board would be consistent with the concept of nested governance.

Ostrom (2005) succinctly summarises the design principles as follows. Collective action and monitoring issues are more likely resolved when monitors themselves modify resource management rules (design principle 3) in a manner that holds them accountable to rule-enforcing local users (design principle 4) where access to a resource is well-defined (design principle 1), costs are proportionate to benefits (design principle 2) and sanctions are graduated (design principle 5). Thus, cooperation intensifies in the long term and, consequently, little monitoring and few sanctions are required for compliance with shared norms. Support for the regime can be implemented through formal external acknowledgment of the ability to organise (design principle 7) under nested regimes (design principle 8) that support conflict resolution mechanisms both within and between organisation levels (Ostrom, 2005).

Table 1 illustrates key components of the LWUF framework in relation to each of Ostrom's principles and where further consideration by the negotiating parties is needed.

## 7. Discussion

Ostrom's eight design principles were formulated on the basis of hundreds of successful and unsuccessful case studies involving surface and groundwater, fisheries, and forestry. These case studies were collected from all over the world within diverse socioeconomic and political states of affairs. The principles are generic and thus should be treated as excellent guidelines rather than pre-specified, rigid blueprints in formulating the institutional framework of a new CPR. We have applied the design principles to explain the self-governing characteristics of the LWUF's proposed groundwater management for the Lockyer and to suggest enhancements to the arrangements currently planned.

The Lockyer Valley groundwater system has both defining attributes of a CPR. It is difficult to exclude a landholder from withdrawing water from the groundwater system (low excludability), and once water is withdrawn, it is no longer available to other landholders (high subtractability). The lack of control entailed in open access has led to unsustainable rates of usage, reducing the quantity of water available. It also reduces water quality owing to salinisation resulting from overdrawing of the aquifer in some places. A management approach that recognises these CPR properties is needed.

The way the LWUF, in conjunction with the Queensland government, is trying to solve the over-extraction problem through co-management is a CPR solution, but better understanding of CPR management theory and application could improve the approach. For example, while DNRW has declared the entire Valley as a subartesian area, it has not agreed that co-management would be applied

across the Valley, instead focusing on the Upper Lockyer. This does not recognize the connection between the aquifers serving these areas, and places landholders under different management regimes. A system that is not seen as equitable and fair will not be enduring (design principle 1).

An iterative process will be needed to establish effective rules of use, as insufficient information is currently available on water use and aquifer levels throughout the Lockyer. The system needs to be designed to allow a few years for data gathering, negotiations, trial and adaptation of extraction levels within and between management zone groups, LWUF and DNRW (principle 3). Associated with this is the identified need for effective conflict resolution mechanisms (principle 6). This will be especially important during the first few years of establishment while members gain understanding of the 'rules' and the system.

DNRW's metering policy requires government to own the meters to reduce potential conflict of interest in terms of compliance, and irrigators to pay for the capital cost of meters, monitoring and maintenance over time. However, an issue of great concern to many irrigators has been the potential costs associated with regulation and the consequent effect on livelihood. This would be exacerbated if a charge for the amount of water used is introduced, as recommended in principle 2. While the current government proposal does not include a charge for amount of water used, such a policy has been publicly discussed, raising irrigators' concerns that metering might be the 'thin end of the wedge' for water charging. It may be that they would be more supportive of paying directly for the amount of water used if the funds were returned to their Board (principle 2).

Both LWUF and DNRW have agreed on the need for meters on bores, independent monitoring for compliance, and an effective range of compliance measures (principle 5). However, they disagree on who should own the meters and be responsible for monitoring. Applying Ostrom's principles suggests that responsibility should be with the irrigators as there is greater compliance with co-governed systems (principle 4).

Over the last four years, the LWUF has increasingly been establishing its identity and credibility in the region and with government. It is seen as the major spokesman for irrigators in the district. To achieve its goal, LWUF needs to continue to pursue a consensus approach to management whereby any concerns can be addressed to the point where members can 'live with' the solution. Once this occurs, formal recognition of the LWUF role and relationship with DNRW and irrigator management groups can be clarified in agreements and contracts. The role of government as advisor, auditor and in compliance will be important in strategically strengthening the self-governing approach (principle 7). The entire proposal is consistent with principle 8, providing nested enterprises.

The LWUF has succeeded in having co-management reflected in the Moreton Water Resource Plan, although not to the extent it had hoped. Detailed arrangements for co-management will be specified in the Resource Operation Plan and closely monitored for compliance.

## 8. Conclusion

This study indicates that the past lack of recognition of CPR characteristics of the groundwater resource has contributed to its over-appropriation in the Lockyer Valley, where LWUF—a newly formed organisation of irrigators—is currently self-organising within a regulatory framework. We have applied well-established design principles to analyse overappropriation problems associated with the groundwater CPR in the Valley. The design principles offer LWUF and the Queensland government excellent guidance to enhance their current proposals and co-manage their water resource. Above all, the

design principles support the direction the LWUF is taking, including the concept of managing the resource in a nested way with local self-management within the government.

Managing shared natural resources as CPRs is a relatively new idea to both government and irrigators in the Lockyer. While conceptualising the groundwater system as a CPR is important, developing institutions (rules-in-use) to deal with the subtractability and excludability of the CPR system is crucial. By applying and customizing the generic self-governance model of Ostrom (1990, 1992, 2005), this study has provided support for the LWUF approach so far, and guidance for LWUF and DNRW to enhance the co-management approach.

There are, however, some challenges facing the DNRW and irrigators alike, triggering conflicts that might undermine co-management attempts. Baldwin & Ross (2006) have proposed a 'shared space' in which both parties could negotiate, with the good offices of a neutral third party to facilitate discussion and manage potential conflicts. Once strong sharing institutions for the LWUF to co-manage irrigation waters within a nested arrangement provided by DNRW in the WRP and ROP and national framework are achieved, the prospects for sustainable management of the groundwater CPR appear promising.

## Acknowledgements

The authors thank the Lockyer Water Users Forum, SEQ Catchments and the Department of Natural Resources and Water for Baldwin's opportunity to work with them. The first author gratefully acknowledges institutional assistance from Global Center of Excellence (COE) program at Yokohama National University to finalise the article. We thank the Co-operative Research Centre for Irrigation Futures (CRC IF) for its sponsorship of Baldwin's research on water sharing, and The University of Queensland for sponsorship of Sarker's research on common property and institutional arrangements. Shabaz Khan of the CRC IF, Bill Carter of the University of the Sunshine Coast, and anonymous reviewers have provided helpful comments on a draft of this paper.

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Received 3 October 2007; accepted in revised form 2 December 2007