OPTIMISING SUSTAINABLE USE OF GROUNDWATER: A CHALLENGE FOR SCIENCE AND WATER MARKETS

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Abstract: Prior to the 1980s, sustainability principles for groundwater use in Australia were poorly understood and rarely practiced. Disquiet over cases of severe degradation of some aquifer systems raised the level of awareness in the 1980s and aquifer over-development was eventually recognised as a threat to long-term supplies, water quality and dependent ecosystems. By the time Australia committed to Ecologically Sustainable Development in 1992, it was clear that many groundwater practices were unsustainable.

Today, groundwater typifies the difficulties facing sustainable management of natural resources. Aquifers are poorly understood, yet the prompt implementation of appropriate controls and practices could ensure the preservation of those systems that are, as yet, not impacted. This is especially important given that aquifers are more vulnerable to irreversible impacts than are surface water systems.

So a window of opportunity now exists for the successful protection of Australia's precious groundwater resources. One water management practice which has the potential to enhance the sustainable management of groundwater is trade in groundwater allocations. This has been made possible within Australia through the Commonwealth of Australian Governments national water reform framework.

Since the reform process commenced, groundwater trading has taken a back seat to surface water trading. This must change or else the gains made from surface water reform will be negated via poor groundwater policy. The characteristically interconnected nature of groundwater and surface water demands integrated management of these resources.

Over 30 per cent of Australia's groundwater systems are approaching or beyond sustainable extraction limits. Trading stands to facilitate the allocation of these finite groundwater resources to their highest value use. It can also, if managed correctly, protect against impacts to both the aquifer and all groundwater users (including the environment). Furthermore, trading promises to provide dynamic responses to Australia's highly variable water demand and supply needs.

Groundwater trading must, however, be administered effectively and with due consideration to the physical, social and environmental constraints shaping sustainable groundwater supply. Implementing these ideals is proving difficult. The fact that each Australian State and Territory has been granted the flexibility to adopt its own approach compounds the drama. The current evolution of different groundwater trading policies will also hinder future trade within aquifers crossing political boundaries.

Drivers of Australia's Water Policy Reform

Water is not only a vital resource to Australia's residential and industrial water users, it is integral to Australia's agricultural production[1]. Water is also the essence of

[1] Agricultural production alone contributes over $7 billion to Australia's annual revenue (Department of Agriculture, Fisheries and Forestry Australia, 2002) and accounts for approximately 70% of total water consumed (Tisdell *et. al*, 2002).

Australia's natural wealth. Yet water scarcity is increasing within Australia, even though Australia has the highest per capita water storage capacity in the world (Schofield *et al.*, 2003). The variable nature of Australia's climate means the volume of water harvested one year cannot be relied upon the next[2]. More and more, water supply cannot meet the growing demand[3] and conditions of water deficit ensue, as reflected in water restrictions and progressing environmental degradation of our water resources.

Development of extensive new water catchments to increase Australia's security of supply is both physically and economically unfeasible. Therefore, Australians must commit to greater recycling and reuse of water, improved water distribution systems[4], decreased water usage[5] and enhanced allocation of their limited water resources so that they are applied to the highest value uses. It is with respect to this last approach that water trading comes to the fore, especially as it promises dynamic responses to Australia's highly variable water demand and supply needs. If implemented and managed correctly, trade can act as a publicly driven redistribution mechanism.

Pigram (1999) states that Australia's water industry is being called upon to rationalise conflicting claims on the water resource and to achieve consensus on the redistribution of demand in time and space between existing and emerging uses and values of water for the environment. Such changes have been partly brought about by diminishing opportunities to locate sites at which to harvest additional water resources, along with the difficulty of funding and winning support for new works[6]. Symptoms of resource degradation such as salinity, poor water quality, toxic algal blooms and loss of bio-diversity have also driven water resource management onto the national agenda. This is appropriate since aquifers and rivers don't end at state boundaries. Water reform is of national significance and therefore requires federal direction.

Wide ranging reforms in the management of Australia's water resources began in the 1980s, leading to broad restructuring of water authorities and greater public sector involvement in the water industry. Economic instruments and market-based approaches, such as the rationalization of water pricing and establishment of water markets, have assumed greater priority due to this deregulation of the water industry. The frequently cited reason for reducing government involvement is that this will achieve efficiency gains in the delivery of water services.

Prior to the 1980s, water authorities were focused on developing and delivering water services. With respect to groundwater this saw the emphasis on locating and developing aquifers. By the end of the 1970s, however, Australia entered a mature water phase, characterised by rising marginal supply costs[7], intensified competition between disparate users, increasing relative scarcity and increased interdependencies amongst water users (Randall, 1981). At the same time, growing environmental awareness saw the focus shift from resource development to management of the resource as an

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[2] According to Smith (1998) Australian dam storage capacities need to be six times those of Europe to achieve a similar security of supply.

[3] The Australian Bureau of Statistics (2000) reports a 19% national increase in water consumption between 1993-94 and 1996-97, with 95% of this apportionable to the irrigation sector. Urban centres have generally shown either low increases or net decreases in water consumption per person over the same period (Thomas & Bennett, 1999).

[4] e.g. pipelining of open and unlined irrigation channels

[5] e.g. water efficient appliances, pricing, education etc.

[6] This is because development of water capture, diversion and storage infrastructure has been associated with environmental degradation (Smith, 1998). Fullerton (2001) notes that a level of scrutiny exists now in Australia which means that building new dams is "much harder to pull off".

[7] the incremental cost of water diversion and transmission costs was sharply increasing and an aging and deteriorating reticulation system was contributing to increased operation and maintenance costs and pressure for replacement expenditure (Randall, 1981).

ecological, economic and social system due to growing concern regarding degradation and the sustainability of water use. Watson (1990) identifies economic efficiency and ecological sustainability as the twin focal points of contemporary water policy, reflecting emerging international trends in resource management.

The first official international platform for sustainable development was *The Brundtland Report* (World Commission on Environment and Development, 1987). This report defined sustainable development as: *development that meets the needs of the present without compromising the ability of future generations to meet their own needs.* Later, *Agenda 21* was developed as a working plan for action (United Nations Conference on the Environment, 1992). Australia, as a signatory, agreed to comply with the principles of ecologically sustainable development set out in this Rio declaration, including those principles applying to planning and policy for water management in Australia. This understanding of ecologically sustainable development was endorsed by CoAG[8] in the *National Strategy for Ecologically Sustainable Development* (1992) which states: *Ecologically Sustainable Development is using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.*

Commitment to the principles of ecologically sustainable development has had, and continues to have, many implications for the management of Australia's water - both fresh and marine. For example, in 1994 it helped drive CoAG to endorse a wide-ranging program of water reforms known as the CoAG Water Reform Framework. The need for economic restructuring of the Australian water industry, together with growing environmental concerns also contributed to the push for these reforms (Schofield *et al.*, 2003). According to Bernard Wonder, Acting Secretary, Agriculture, Fisheries and Forestry – Australia (2001), there is now widespread recognition across all sectors of society that sustainable management of our water resources is fundamental to our national well-being and one of the country's highest priorities.

This agrees with the international vision for groundwater management that was developed during the Third World Water Forum held in Japan in 2003 and subsequently submitted to the Interministerial Conference in Kyoto. The thematic statement on groundwater advocated a pragmatic, incremental approach to improved groundwater management, especially in developing countries, where small steps in the right direction will ultimately lead to long-term benefits (Kemper, 2004). It further emphasized the importance of stakeholder involvement at all levels.

The CoAG Water Reform

In 1994 all Australian State and Territory governments, along with the Commonwealth, recognised the need for coordinated action to halt the widespread degradation of Australia's natural resources. Through the Council of Australian Governments (CoAG), national policy was developed for the efficient and sustainable reform of Australia's rural and urban water industries. By explicitly linking fiscal and environmental objectives, CoAG sought to generate an economically viable and ecologically sustainable water industry. The final CoAG Water Reform Framework stressed the need to improve both the efficiency of water use and the environmental management of the nation's water supply. In developing this framework, CoAG recognised the need to develop a consistent approach to water reform throughout Australia, while allowing each State and Territory the flexibility to adopt its own approach to implementation depending on its own unique institutional and natural characteristics.

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[8] The Council of Australian Governments - comprising the heads of the Commonwealth, State and Territory governments

The key elements of the reform framework are:

- all water pricing is to be based on the principles of full cost recovery and transparency of cross-subsidies;
- any future new investment in irrigation schemes, or extensions to existing schemes, are to be undertaken only after appraisal indicates it is economically viable and ecologically sustainable;
- States and Territory Governments, through relevant agencies, are to implement comprehensive systems of water allocations or entitlements, which are to be backed by the separation of water property rights from land and include clear specification of entitlements in terms of ownership, volume, reliability, transferability and, if appropriate, quality;
- the formal determination of water allocations or entitlements, including allocations for the environment as a legitimate user of water;
- trading, including cross border sales, of water allocations and entitlements within the social or physical and ecological constraints of catchments;
- adoption of an integrated catchment management approach to water resource management;
- the separation, as far as possible, of resource management and regulatory roles of government from water service provision;
- greater responsibility at the local level for the management of water resources;
- greater public education about water use and consultation in the implementation of water reforms; and
- appropriate research into water use efficiency technologies and related areas (AFFA, 2002).

The principles behind the development of water markets (i.e. the definition of property rights to water and the separation of land and water assets) are particularly critical if Australia is to manage its water resources on a sustainable basis and improve the efficiency of water use (AFFA, 2002).

<u>Ensuing Groundwater Program</u>

The CoAG Water Reform Framework of 1994 did not specify which aspects applied to surface water and which to groundwater, however, the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) was engaged to further investigate and report on the management arrangements relating specifically to groundwater. ARMCANZ subsequently prepared a policy discussion paper for advice to States and Territories on groundwater regarding issues such as trading, pricing, drilling, well construction and institutional arrangements. In total, 12 recommendations were accepted by CoAG, including:

<u>Recommendation 1:</u>

Groundwater management policies should employ the principles of ecologically sustainable development and should be directed at achieving sustainable use of the *resource. ARMCANZ should develop an agreed, nationally consistent definition and approach to sustainable groundwater yield.*

Recommendation 3:

Groundwater and surface water resource management should be better integrated, including approaches to pricing (especially adjacent to public surface water regulated schemes), water allocations and trading to ensure consistency.

Recommendation 5:

States should develop groundwater management plans based on a sound understanding of the resource. These plans should be the primary support for the development of groundwater allocation and property right systems to support intra-aquifer trading both within the States, and across State borders (ARMCANZ, 1996).

As affirmed by Recommendation 5, groundwater management plans are fundamental to the assessment of trading scenarios. These plans should not only detail an aquifer's sustainable yield, allocation and use, they must also address community consultation processes and, where necessary, strategies to reduce use to sustainable levels.

While CoAG incorporated all twelve ARMCANZ recommendations into the Water Reform Framework, it agreed that groundwater management arrangements would not be considered an assessable component of the reform package. As such, periodic payments made by Federal Government to the States and Territories for adherence to reform targets were only applicable to surface water reforms. Given the lack of financial incentive, the impetus to instigate groundwater trading reform has understandably been less than it has for surface water trading reform. However, as highlighted by ARMCANZ (1998), growing focus on the interdependence between groundwater and the broader natural resource base will increase pressure to reform Australia's groundwater management, especially as surface water reforms result in escalating use of groundwater as an alternative[9].

Schofield *et al.* (2003) claim that while it is difficult for groundwater priorities to compete with surface water priorities given the great differences in resource response time, in the long term, the cost of ignoring the linkages could be high. It is also imperative that gains made from surface water initiatives are not negated via poor groundwater policy. Hence surface and groundwater must be managed in a consistent, coordinated manner.

Sustainable Yield:

To manage groundwater according to the principles of sustainable development and also ensure security of access for priority users, including the environment, total allocation within the groundwater system should not exceed that system's sustainable yield[10]. In May 2000 the National Groundwater Committee agreed on the following definition of sustainable yield (Evans, 2001): *the groundwater extraction regime, measured over a specified planning time frame, that allows acceptable levels of impact and protects the higher value uses that have a dependency on the water.*

[9] e.g. differential pricing between surface and groundwater will not only shift further demand to groundwater, it will give users of groundwater less incentive to conserve the resource.
[10] i.e. potential withdrawal from the system should not be permitted beyond that volume which can be yielded sustainably

While development of a consistent approach was relatively easy, the definition has shown that it can be an elusive concept (Russell, 2002), as evidenced in Russell's discussion of the following key points:

- The *extraction regime* should be specified within time and space. Specification simply as a volume per year is unlikely to be adequate, even though this been the case for the majority of past practice. Extraction triggers such as water level and water quality impacts may also need to be specified, along with accounting rules. The planning period considered may extend for several years or even decades, possibly influenced by the frequency of recharge events[11].

- As all groundwater withdrawals impact the system to some extent, placing stress on existing users and groundwater dependent ecosystems, sustainable extraction should cause only *acceptable levels of stress.* Optimal use of groundwater resources will frequently require tradeoffs within and between sectors and therefore acceptable levels of stress will invariably be influenced via social acceptability in preference to hydraulic sustainability[12].

- *Higher value uses* include environmental, economic and social values.

Methodology for sustainable yield calculation actually varies greatly between and within countries. This is to be expected, given the diversity of legislation, groundwater uses, environmental values and cultural expectations. In the United States, for example, sustainable yield is defined as 'safe yield' and the focus is on providing security of access to groundwater users. In Britain and South Africa, meanwhile, the primary criterion of sustainability is maintenance of baseflow in streams fed by groundwater (Russell, 2002). Russell contends that given these differences, Australia should not draw too heavily on experiences elsewhere in developing its own approach to sustainable groundwater management.

In Australia there is no nationally agreed methodology for calculating sustainable yield. A variety of different approaches have therefore evolved. Most generally take into account the specific aquifer characteristics, however some are set at 'default' values. For example in NSW sustainable yield is given a default value equal to 70% of annual recharge while in the Northern Territory this default is set at 50% of recharge (NLWRA, 2001). The National Land and Water Resources Audit (2001) in fact found that sustainable yield was principally calculated as being all or the majority[13] of recharge (which was taken as a percentage of the assessed rainfall - commonly between 1% and 5%).

Limiting the extraction of groundwater to the mean annual recharge across the aquifer does not, however, recognise the externalities resulting from well interferences at any given point in time or location, i.e. it does not account for third party interference or environmental degradation caused by dense bore arrangements or concentrated extraction regimes. Determining an aquifer system's sustainable yield then, requires balancing the potential impacts of groundwater withdrawal with the various environmental, social and economic issues. Rarely does this equate to a technically derived 'magic' number (Evans, 2002). From a management perspective, however, a

[11] Foster (1999) suggests determining the period over which the resource balance should be evaluated can be a challenge in itself, especially in more arid climates such as Australia's, where major recharge episodes occur as infrequently as once a decade, or even once a century.
[12] Banyard (1998) states the allocation of the right to use groundwater is indeed a social process based on hydrogeological estimates.
[13] i.e. equal to recharge minus that volume of water assigned for environmental and indigenous cultural requirements, for instance, the maintenance of mound springs.

volume must ultimately be set and it is this volume which limits the quantity of groundwater available for allocation.

It should be noted that there are some exceptional situations where management policies seek to 'overdraw'[14] groundwater, including mine dewatering and the use of hypersaline water. This practice occurred, for example, within the Las Vegas Valley during construction of the Southern Nevada Water Project, with temporary revocable groundwater rights issued prior to Colorado River water becoming available (Morros & Duerr, 1995). The South Australia and Victoria *Groundwater (Border Agreement) Act 1985* also permits planned depletion of groundwater in this region.

Such approved or condoned cases of excessive groundwater extraction usually occur where groundwater is intentionally or unintentionally given a lower socio-economic value than the competing activity. For instance, the Latrobe Valley open cut coal mines supply some 80% of Victoria's power, however the mining technology requires the extraction of large quantities of groundwater – well beyond sustainable yield. Confined water pressures have been lowered over an area of some $1000 km^2$, with a maximum reduction in pressure head of approximately 130m at the Hazelwood mine. As well as impacting on the groundwater resources, this reduction in groundwater pressures has caused extensive regional subsidence (Brumley, 1998).

This example of unsustainable practices currently exists as energy is assigned a higher community value than the groundwater. However, as concerns over greenhouse gas emissions from fossil fuels develop and the demand for potable groundwater increases, the balance will gradually shift towards better management of the groundwater resources. Until that time, ARMCANZ (1996) argue that intentional over-allocation can be considered acceptable provided there is a publicly accepted strategic benefit, the resource is used efficiently, not wasted, and is tightly managed. The possible consequences of excessive groundwater withdrawal include:

<u>Reversible Interference:</u>

- Pumping lifts/costs increase
- Well yields decrease
- Springflow/baseflow reduction
- Effect on phreatophytic vegetation

<u>Irreversible Deterioration:</u>

- Saline water intrusion/upconing
- Ingress of polluted waters
- Aquifer compaction/yield reduction
- Land subsidence effects (Foster, 1999)

It is also important to note that groundwater systems may in some circumstances be over-allocated but underused[15]. However periodic activation of unused allocations does pose significant threat to the long-term sustainability of these aquifers. Therefore water

[14] i.e. groundwater is depleted quicker than it is replenished. This practice is also known as groundwater mining.

[15] i.e. only a portion of the allocations are activated and the system is not stressed

managers are now intent on allocating only up to or less than the level of sustainable yield, or 'clawing back' entitlements such that they do not exceed the sustainable yield. In this way, should sleeper or dozer licences be activated, extractions from the overall system ought to remain at a sustainable level.

Australia's Groundwater Markets

According to the Natural Resource Management Standing Committee (2002), the concept of groundwater trading has been developed for some time[16], but has not been applied to anywhere near the same extent as with surface water trading within Australia. This can be put down to the various scientific, social, economic and political impediments to trade – some of which are in common with surface water, while others are unique to groundwater. Of particular concern is the deficiency in reliable data on Australia's groundwater resources, the fact that groundwater supplies are relatively less portable than surface reserves, and the potential for groundwater transfers to have greater impacts on third parties.

As there are currently few areas within Australia where embargoes on groundwater allocations exist, development of water markets in groundwater is in its infancy here. Where allocation limits are not imposed, applicants can relatively easily and inexpensively apply for a new groundwater licence to obtain additional supply (subject to appropriate hydrogeological conditions), averting the need to attain such groundwater via transfer. Australian groundwater markets are therefore termed 'thin', i.e. immature. There is significant potential, however, for groundwater trading to expand across Australia as pressure on our water resources continues to grow.

As noted by ARMCANZ in *Allocation and Use of Groundwater - National Framework for Improved Groundwater Management in Australia* (1996), significantly different hydrogeological and management environments exist between the States [and territories]. For this reason, it is appropriate that CoAG have granted each jurisdiction the flexibility to adopt its own approach to the implementation of groundwater trading. Subsequently various local and regional policies have evolved, and continue to evolve, across the nation, reflecting different geological and ecological conditions, past policies, water management practices and commitments to water users, as well as scientific and methodological development (Schofield *et al.*, 2003).

This can however lead to problems where groundwater reserves do not coincide with State borders and conflicting management practices exist between jurisdictions administering the one resource. For example, it is expected that the moratorium on surface water allocations which exists within the Murray Darling Basin will increase demand for groundwater within these regions, possibly via inter-state groundwater trading.

In *Australia's State of the Environment Report* (2001), Ball states that since 1996 several jurisdictions have developed new groundwater management policies. In general, these are focussed on licencing requirements, with almost all states having introduced new water resource legislation to underpin policy. There is also growing recognition of the need to manage groundwater in a sustainable manner, however Ball (2001) points out that when it comes to groundwater management, as distinct from surface water management, the application of national water reforms are not being seriously applied by the States and Territories.

[16] In October 1987, delegates at the Australian Water Resource Council workshop on groundwater allocation in Sydney recommended transferability should apply in totally allocated groundwater systems. Furthermore it was decided that such transfers should be subject to determination of hydrogeological feasibility, with conditions to be reviewed where supply problems arose (AWRC, 1987).

The activation of dormant licences as a result of trading is a well-recognised phenomenon in surface water markets. This effect has also been experienced with groundwater markets. For example, in the North Adelaide Plains area of South Australia, groundwater trading had been active for just four years when it became apparent that the trade of sleeper licences to high production areas had lead to reduced localised aquifer pressure and groundwater levels (Holland, 1998). To manage this, rules for groundwater transfer were applied, dividing the aquifer into zones, with transfers not permitted into zones where increased use would lead to further decline in pressure levels. Transfers out of such zones were allowed, as were transfers within any zone provided they did not create interference (Pigram *et al.* 1992).

Conclusion:

Groundwater trading stands to benefit sustainable management of groundwater by optimising the economic benefits of groundwater use. Within the context of sustainability philosophy, this should only occur in consideration of the hydrogeological constraints and the environmental requirements. This poses a considerable challenge, however there is no sensible option but to move forward with groundwater trading in harmony with surface water trading. To be constrained by the attitude that it is 'all too difficult' is reminiscent of some views expressed when enforceable yield limits were first introduced in Victoria in 1995, with a trigger of 70% allocation as the prompt for a higher level of management.

The difficulty of obtaining reasonable estimates of sustainable yield has caused concern, but it has effectively focused attention on the issue of how to manage sustainable use of groundwater and has led to new approaches such as linking yield with aquifer response measures. Similarly groundwater trading needs to be fostered and better methods developed to optimise the application in an integrated social, economic, technical and environmental context. There remains considerable work to be done in all these areas. For instance, the community generally finds groundwater very difficult to understand and hence balancing social expectations is hard; hydrogeological data is acquired incrementally and 'full' information is never economically feasible or practicable to obtain; and the need for environmental allocation is under-appreciated by most groundwater users.

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