

## Robust Design of Managed Aquifer Recharge Policy in Australia

Facilitating Recycling of Stormwater and Reclaimed Water via Aquifers in Australia - Milestone Report 3.1

John Ward and Peter Dillon

National Water Commission – Raising National Water Standards Project

April 2009

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills.

CSIRO initiated the National Research Flagships to address Australia's major research challenges and opportunities. They apply large scale, long term, multidisciplinary science and aim for widespread adoption of solutions. The Flagship Collaboration Fund supports the best and brightest researchers to address these complex challenges through partnerships between CSIRO, universities, research agencies and industry.

The Water for a Healthy Country Flagship aims to achieve a tenfold increase in the economic, social and environmental benefits from water by 2025. The research contained in this report is partially supported by National Water Commission and components involved collaboration with researchers from Duke University, Durham, United States and CEMAGREF, Montpellier, France.

For more information about Water for a Healthy Country Flagship or the National Research Flagship Initiative visit [www.csiro.au/org/HealthyCountry.html](http://www.csiro.au/org/HealthyCountry.html)

**Citation:**

Ward, J. <sup>1</sup> and Dillon, P. <sup>2</sup>(2009) Robust design of Managed Aquifer Recharge policy in Australia. CSIRO Water for a Healthy Country Flagship Report to National Water Commission for Raising National Water Standards Project: Facilitating Recycling of Stormwater and Reclaimed Water via Aquifers in Australia - Milestone Report 3.1, April 2009.

<sup>1</sup>Water for a Healthy Country Flagship Urban Water Theme/ CSIRO Sustainable Ecosystems

<sup>2</sup>Water for a Healthy Country Flagship Urban Water Theme/CSIRO Land and Water

**Copyright and Disclaimer**

© 2008 CSIRO To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

**Important Disclaimer:**

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

**Cover Photograph:**

Well head of one of the ASR wells at City of Salisbury's Parafield stormwater harvesting facility. This well is used to inject reedbed-treated stormwater into a brackish aquifer and subsequent recovery water for irrigation, industrial use and to blend with reclaimed water in non-potable reticulated water supplies at the nearby subdivision of Mawson Lakes. (Photo by P. Dillon, CSIRO)

## **ACKNOWLEDGEMENTS**

The presented research was partially funded by the Australian National Water Commission as part of the Raising National Water Standards Programme. The report represents Part One of a project entitled 'Facilitating Recycling of Stormwater and Reclaimed Water via Aquifers in Australia'. The research was commissioned to inform decision makers determining policy related to Managed Aquifer Recharge in Australia and does not form part of any approved Government policy.

Randall Cox of the Queensland Department of Natural Resource Management, Peter Baker of the Bureau of Regional Science, Chris O'Boy of the Western Australian Department of Water and Neil Power of South Australian Department for Water, Land and Biodiversity Conservation, provided insights as part of the project advisory committee.

Kalita Marsh and Professor Jim Saltzman of Duke University provided the policy analysis of MAR regulations and legislation in the United States.

Agnes Grandgirard provided analysis of French MAR policy and legislation.

The authors gratefully acknowledge the collegial support, comments and insights provided by John Radcliffe, Andrea Cast, David Kaczan, Paul Pavelic, Simon Toze and Jim McColl of CSIRO; Mike Young (University of Adelaide) and Leif Wolf, (University of Karlsruhe). Yvonne Thompson and Bill Till (Western Australia Department of Water) provided valuable commentary.

Any mistakes or omissions remain the sole responsibility of the authors.

# EXECUTIVE SUMMARY

## Motivation for this report

Managed aquifer recharge (MAR) is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit. Source waters for recharge include stormwater, reclaimed water, natural waters and water treated to drinking standards. Policies are required to address the risk management of water quantity and water quality. Water quantity and quality in MAR systems are interdependent and their joint, coordinated management is likely to determine the overall success of policy intervention. MAR systems involve the management of water quantity in three distinct phases or operational elements: i) source water harvesting, ii) recharge and storage in aquifers and iii) recovery for use. These water quantity phases are the subject of this report. Water quality and human health and environmental aspects related to MAR operations are addressed under the National Water Quality Management Strategy in Phase Two of the Draft Australian Guidelines for Water Recycling: Managed Aquifer Recharge (EPHC, 2008c).

To promote efficient and effective water allocation, Australian water reform has emphasised institutional and governance approaches promoting science based water planning and subsequent voluntary transfers of consumptive water through market exchange. These in turn are reliant on enforceable, exclusive, excludable and transferable property rights. To conform to the National Water Initiative (NWI), management approaches for MAR in urban water systems are required to introduce markets and market incentives when appropriate.

What remained unclear in the Australian urban water context is the degree of alignment of State policies providing for new water management technologies, such as MAR operations, with explicit NWI water reform directives of market development. Concerns have been expressed by NWI signatories about the extent to which the current institutional and regulatory environment facilitates water reform in metropolitan and regional urban centres. Comprehensive Australian water quality guidelines for MAR are available; however exploration of the market potential for water quantity entitlements has received minimal attention.

This report explores the policy requirements necessary to clearly define secure entitlements to facilitate a market based approach to manage the water quantity elements of MAR. The approach introduces price based incentives associated with low transaction costs without creating unintentional externalities.

## Robust design: aligning MAR policies with the National Water Initiative

To assist MAR policy design, the report describes a unified framework of policy instruments across all the operational elements of MAR, drawing on the principles of the robust separation of water interests. To achieve the separation of water interests, The National Water Initiative (CoAG 2004) recommends the independent management of water access entitlements, specified as unit shares, periodic water allocations and the impacts of use. The framework defines water access entitlements as perpetual unit shares of a defined consumptive volume of a water resource, periodic allocations are made in accord with annual inflows, storage volumes and in proportion to the number of shares held. Final water use accounts for variability in biophysical attributes and activity. The risk of variable water availability is prescribed and assigned between users and the Government.

The rule based decision framework considers how to align regional biophysical, economic and hydrologic variables enabling a systematic governance arrangement of MAR. The

management regime allows for the independent and flexible management of MAR elements characterised by separate and potentially exclusive policy objectives.

Robust separation is a concept developed by Young and McColl (2003) in the context of rural surface water systems; a concept that contributed to the National Water Initiative reform process. The separation of rights requires a three tiered system of instruments to distribute and allocate volumes of water efficiently over time. A Water Plan establishes the community values and science-based guidelines to appraise the state of a water system and prescribe the rules to determine the environmental and consumptive “pools”. This allows managers to resolve the tension between consumptive use and the environment.

When more than one person has an interest in the consumptive “pool” the first policy instrument defines the characteristics and number of unit shares of the pool and the distribution of shares to individual interests. This allows water managers to distribute access entitlements to available consumptive water.

The second instrument defines an independently managed process to periodically allocate the amount of water to each share. This allows water authorities to independently manage the consumptive pool that varies when faced with changing ambient conditions and to assign the risk of a variable water supply. The instrument specifies the rules of enforcement by an independent agency and the circumstances of compensation.

The third instrument prescribes or proscribes the obligations of water use and takes into account existing water users and third party effects. Since the impact of water use varies according to geography and activity, this allows the environmental and health impact of water use to be managed independently.

According to the decision framework, each phase of an MAR operation requires the specification of an entitlement to a unit share of a defined consumptive pool in combination with independently managed rules to establish periodic allocation, enforcement and the conditions of use. Robust design is proposed in this report to entitle source water, aquifer storage space and the recovery of stored water. Final water use of extracted MAR water is subject to end use licence conditions, cognisant of third parties including the environment. These are likely to be managed by water quality regulatory instruments and a system of minimum standards.

The policy framework described in this report sets a reference bench mark for MAR management that is consistent with the NWI water reform principles.

### **Does current policy constrain MAR development?**

To improve understanding, the report evaluates the legislation, policies and guidelines providing for MAR in each Australian State. Water legislation and property right regimes for MAR operations in France, Arizona, Colorado, and California are also summarised. Details of State policies for each MAR operational element are provided in the Report Appendix. Policy instruments were classified according to their role in the management of source water harvesting, aquifer recharge and the recovery of stored water. The primary objectives of the evaluation were to identify the degree of NWI policy alignment, instrument consistency and potential impediments to market approaches to efficiently allocate urban water.

In contrast to the rural sector, water reform initiatives have had limited influence on urban water management. All States are characterised by partial integration between jurisdictions, institutions and managing agencies providing for MAR. MAR operational elements are subject to the provisions of an array of policies, at times attempting to comply with competing

and incompatible policy requirements. As a result the potential for alternative market based approaches has received minimal attention.

As a general principle, effective market exchange of water is partially contingent on fully specified property rights, sufficient market participants and hydrologic connections and water supply considerations that permit the trading of water entitlements or allocations.

Generally, State policy providing for access to source water remains disaggregated and poorly defined. Arrangements for recycled and waste water are likely to proceed via negotiated contracts between interested parties. Stormwater ownership and access entitlements are likely to prove more contentious. There are no examples of fully specified and enforceable rights entitling operators to a secure, non-contentious share of a defined pool of stormwater.

South Australia, Western Australia and Victoria are supportive of MAR, expressed as either the adaptation of existing Acts or the introduction of new legislation tailored to an MAR element. For example the South Australian *Local Government Stormwater Management Amendments Act 2007* includes stormwater infrastructure within defined surface waters, making explicit the provisions and capacity to regulate the capture of stormwater. South Australia is the only state to specify provisions for stormwater in this manner. However surface water is not a prescribed resource in Central Adelaide water management plans, allowing for free stormwater access. That is there is no security or an excludable right for those operators that invest in stormwater as an MAR source.

The South East Queensland and Sydney urban water plans have considered and not adopted MAR as a primary supply option in favour of purified recycled water stored in surface dams and desalination schemes respectively. MAR has not featured in Tasmanian efforts towards urban water reform.

There are no State examples of fully specified and enforceable rights entitling operators to a secure, non-contentious share of a defined aquifer storage space. To further compound uncertainty, the status of MAR source water is potentially redefined as native groundwater when introduced into an aquifer. It is therefore subject to the licensing and allocation provisions of prescribed or regulated groundwater systems. The right to extract MAR recharged water in a fully allocated and potentially overdrawn groundwater system remains poorly or informally defined. Tensions will be especially acute during periods of aquifer stress, when groundwater extraction allocations are likely to be severely restricted or prohibited. Tensions are likely to escalate in aquifers where multiple interests can easily access a common pool, groundwater resource. Periods of water stress are precisely when stored MAR water can best augment restricted urban water supplies.

To improve the security of water rights for commercial operators, MAR source water recharged into an aquifer requires institutional differentiation from native groundwater. This report describes how this can be achieved through entitlements to a share of available aquifer storage space and a system of defined recharge credits for recovery.

The absence of well defined entitlements to access stormwater, recycled water, and aquifer storage is consistent with the observations of several commentators, who argue this is likely to result in equivocal aquifer extraction, future legal wrangle and potential detrimental impacts on receiving environments. There are strong possibilities that existing legislation, policies and institutions may require effort in adaption to market innovations in urban water management.

### **Robust solutions to MAR policy constraints**

As the level of water recycling increases, the choice and implementation of alternative policy instruments also assume increasing importance. The accelerated implementation of recycling projects, made more acute with the ongoing drought, warrants the systematic adoption of further developed or alternative policy options and frameworks that are consistent with the NWI.

In addressing the policy constraints to MAR development, the final section of the report describes two hypothetical case studies managed according to the principles of robust separation. The case studies model management regimes for a localised and an expanded market for water recovered from MAR projects. Modelling the characteristics of South Australian ASR projects and aquifers provides biophysical context to policy.

The first example describes the role of robust separation principles in the supply of non-potable water characterised by limited localised trading of recovered water. There are likely to be circumstances in urban water systems where entitlements are assigned to either multiple interests or a single entity, most likely a statutory body or water agency. The example describes the circumstances where a system of contractual arrangements with a single storm water entitlement holder is likely to prove a superior and more administratively feasible solution than market exchange.

The second example describes a MAR scheme supplying potable water. Bulk water supply is managed independently of mains distribution. Infrastructure is operated by a General Grid Manager and its contractors with access arrangements by a Bulk Water Supply Manager who coordinates competitive supply options, including MAR. Expanded supply, trading and security opportunities are enabled through a combination of robust entitlements, development of a Water Security Fund and rules for yearly carry over of stored water.

Robust separation describes a rigorous and systematic approach to define a property right regime that accounts for the environment as a primary, legitimate water entitlement holder and facilitates secure, economically efficient and low cost trading and administration. The report also describes French MAR policies which illustrate the role of robust separation principles in reallocating resources reliant on negotiation as an alternate coordination mechanism to market exchange. The discipline of robust separation requires that water access entitlements be specified as unit shares of a defined consumptive pool, periodic allocations account for changing conditions and a water use license addresses externalities. These are to be managed independently.

Adherence to the principles of robust separation contributes to policy design that seeks the resolution of tensions associated with achieving efficient and equitable water allocation for MAR operational processes. Those tensions occur between consumptive use and the environment and amongst diverse users with competing demands.

This report contends that specifying property rights in this manner is a necessary precursor to MAR policy that endeavours to coordinate individual actions into socially beneficial outcomes. Robust separation principles apply regardless of whether MAR policy relies on an ensemble of market based, negotiated, or administrative instruments.

Finally, adoption of a unified robust framework among management jurisdictions will be the most expedient approach to securing and maximising the public benefits of MAR. The framework allows for the development of policy that promotes MAR for water supply augmentation where it is the most cost effective option in Australian cities, towns and rural areas. Just as construction of exploratory wells in an aquifer need not wait for a jurisdiction to form policies on over-allocation within that aquifer, implementation of MAR demonstration projects has not, nor should be forced to await MAR-accommodating policies. However, until policies provide secure access to the benefits of investment in MAR, the rate of uptake will lag behind its potential and investments in inferior water supply options are likely to continue.

# CONTENTS

<b>1. Introduction</b>	<b>1</b>
1.1. Policy instruments to share scarce water resources	2
1.2. Accounting for entitlements of MAR operational elements	3
1.3. The National Water Initiative and the Robust Separation of rights	5
1.4. Report Objectives and Structure	6
<b>2. Australian Urban Water Policy</b>	<b>9</b>
<b>3. Managed aquifer recharge</b>	<b>16</b>
<b>4. Institutions and property rights in a mature water economy</b>	<b>23</b>
4.1. The multiple economic benefits of water	23
4.2. Institutions and water property rights	24
4.3. Water as a common pool resource	27
4.4. Robust design and the separation of rights	30
4.5. Applying robust design to a countercyclical MAR groundwater system	33
<b>5. State Water plans, legislation and the projected role of MAR</b>	<b>39</b>
5.1. South Australia	39
5.2. Victoria	43
5.3. Western Australia	46
5.4. Queensland	48
5.5. NSW	51
5.6. Tasmania	54
<b>6. International regulatory frameworks for MAR</b>	<b>56</b>
6.1. Regulatory Frameworks for MAR in the USA	56
6.1.1. Types of Groundwater Rights	56
6.1.2. Some State Groundwater Policy and Law	58
6.1.3. State policy and law specific to managed aquifer recharge	58
6.1.4. Arizona water banking	59
6.2. Regulatory framework for MAR in France	60
<b>7. Applying the principles of robust design to MAR</b>	<b>64</b>
7.1. Example one; Stormwater MAR for localised water supply	64
Harvesting stormwater	66
Aquifer recharge, storage and recovery	68
7.2. Example two: MAR and a water security fund for drinking water supplies	73
<b>References</b>	<b>77</b>
<b>Appendix 1</b>	<b>86</b>
South Australia	86
Source water harvesting and capture	88
Source water retention: ponds and wetlands	91
Aquifer recharge	91
Recovery of recharged water	93
Final use of recovered water: environmental and public health compliance	95
Victoria	96
Source water harvesting and capture	98
Aquifer recharge and recovery	101
Final use of recovered water: environmental and public health compliance	103
Western Australia	105

Source water harvesting and capture .....	106
Aquifer recharge and recovery .....	109
Final use of recovered water: environmental and Public Health compliance.....	109
Queensland .....	111
Source water harvesting and capture .....	114
Aquifer recharge and recovery .....	115
Final use of recovered water: environmental and public health compliance.....	115
NSW .....	117
Source water harvesting and capture .....	119
Aquifer recharge and recovery .....	122
Final use of recovered water: environmental and public health compliance.....	123
Tasmania .....	125
Source water harvesting and capture .....	127
Aquifer recharge and recovery .....	129
Final use of recovered water: environmental and public health compliance.....	129

## LIST OF FIGURES

Figure 1 Two examples of managed aquifer recharge, (a) ASR and (b) SAT, showing the seven elements common to each system.....	20
Figure 2 Schematic of recharge and recovery entitlements and allocations for MAR in (a) an average year, (b) a wet year, and (c) a dry year.....	34
Figure 3 Countercyclical allocations of MAR recharge and native groundwater extraction...	37
Figure 4 ASR operations in the Adelaide Mount Lofty Ranges management region .....	65
Figure 5 Example of the depreciation of stored MAR water .....	70
Figure 6 Urban water management including a Water Security Fund and robust designed MAR.....	76

## LIST OF TABLES

Table 1 Resource management and environmental protection policies invoked by managed aquifer recharge operations.....	18
Table 2: Examples of unintentional, unmanaged and managed aquifer recharge .....	19
Table 3 Example of evaluation criteria and hazard critical control points for source waters, aquifer characteristics and end use obligations.....	22
Table 4 Classification of property regimes.....	27
Table 5 Governance instruments for MAR based on the robust separation of rights .....	33
Table 6 Policy framework of French MAR schemes.....	62
Table 7 Managed aquifer recharge operating according to robust design principles .....	72

# 1. INTRODUCTION

Most Australian cities are subject to increasingly variable rainfall patterns, acute water stress and increasing populations. As a corollary they are experiencing mature urban water economies, characterised by limited opportunities for future water impoundments, rising incremental supply and impoundment costs, intensified competition between diverse users and increased interdependencies amongst water uses (Randall 1981). In response water utilities and governments have sought new water supplies that are more reliable than, and independent of traditional storages.

Recycled water has assumed a recognised role in mature water economies by augmenting existing urban supplies and deferring the development of new water resources. The resource characteristics of recycled water are thus changing from a waste stream requiring disposal to one of commercial value.

The Strategic Urban Water Plans developed recently in Australian cities point to an increase in the provision and consumption of recycled water, which will assume a crucial role in diversifying the portfolio of urban water resources. The volume of recycled water from 2002-2006 has increased for Australian states except NSW (Radcliffe 2007a, p.388). Marsden Jacobs (2008) estimates 23% of effluent and 25% of stormwater will be recycled by 2015.

Radcliffe (2007) notes a number of factors that have acted as substantial motivators in the increased recycling of urban water. The drier period of the latter years of the 20th<sup>C</sup> and first few years of the 21st<sup>C</sup> compared to earlier years, and increasingly stringent effluent disposal standards and regulations have led to increased recycling efforts. Water supply shortages leading to prolonged and more severe water restrictions, as well as opportunities to access Commonwealth water funds have also contributed to recycling increases.

In concert with mature urban water economies these influences have increased the interest and levels of innovation in water recycling and reuse undertaken and investigated by urban water agencies.

As the level of water recycling increases, the choice and implementation of alternative policy instruments also assume increasing importance. Instrument frameworks will need to provide for the management, rights of ownership, rights of access in a changing world and the obligations of final use of recycling operations. The acceleration of implemented and intended recycling projects, made more acute with the ongoing drought, has warranted a systematic analysis of alternative policy options and frameworks.

Substantial advances have been made in the scientific understanding and technologies associated with Managed Aquifer Recharge (MAR). MAR is currently promoted as one recycling strategy to augment existing supplies and in many jurisdictions is assuming increasing importance in the portfolio of urban water management strategies (Pavelic *et al.* 2006a,b; Dillon 2005, SA EPA 2004). The harvesting, storage and recovery of urban stormwater and reclaimed water in sub-surface aquifers buffers seasonal shortages and more recently, partially remedies inter-drought water stresses in Australian cities.

MAR has the capacity to augment domestic and industrial supply by converting urban water waste streams and high flow flood events into groundwater base flow. Future

extractions of stored water are able to cost effectively satisfy diverse water demands through water quality differentiation; *viz.* supplying users requiring non-potable water, often characterised by lower treatment costs. Historically potable water supplies have been accessed to meet those demands. Satisfying the demand for water differentiated by quality with fit-for-use waste water streams effectively extends the potable mains water supply for water stressed urban systems.

## **1.1. Policy instruments to share scarce water resources**

When consumers can abstract water from a common source without impinging or diminishing the perceived needs of other consumers, there is no need or incentive for the voluntary exchange in water or defined rights to water. In the absence of water scarcity (both actual or perceived), there is little pressure for the clear distribution of entitlements to water resources as all demands can be adequately met with current supplies, precluding the need for a coordinated social solution (Demsetz 1967).

A simple MAR system approximates such a non-contentious system and might be typified by:

- Perennial, non-diffuse source waters and retention ponds associated with minimal or science based environmental flows that resolves the tension in consumptive and non-consumptive use;
- Source waters managed by an independent agency both willing and able to comply with statutory obligations;
- Non-controversial and cost effective treatment of aquifer injectant;
- Comparable water quality characteristics of injectant and receiving waters;
- An aquifer environment that is not subject to localised increases in hydrologic pressures and capacity constraints;
- MAR externalities that are of low marginal value or are managed;
- An adaptive and mutually agreed governance regime, where risk is clearly and unequivocally defined.

These conditions are rarely if ever present in practice. As the level of relative scarcity increases, as in mature water economies, an escalation in tension arises between competing uses, necessitating some form of adjudication to establish an equitable, judicious balance between users. Institutional arrangements and water policy approaches are implemented to resolve those tensions.

Relaxing the assumptions of a simple MAR scheme is likely to introduce conflict and contestability. In real world operations, a systematic approach is required to align the more complex characteristics of source waters, the aquifer and final use with economic and policy interpretations central to the development and management of MAR.

If MAR is commercially viable for one operator, then it is also likely to be viable for a number of operators in the same aquifer or with the same water source. In the absence of coordination or cooperation, each operator potentially impinges on the access to water for recharge of others, on the total available aquifer storage volume, and in confined aquifers, on the groundwater pressures at the sites of other proximal operators. In brackish confined aquifers the operations of one MAR site are also likely to influence the shape of the plume of fresh injectant in the aquifer at neighbouring sites, and hence influence the recovery efficiency (proportion of

injected fresh water that can be recovered at a salinity that meets requirements of uses) of other operations (Dillon *et al.* 2007).

MAR schemes are likely to operate in environments of high relative scarcity of water resources. Multiple source waters, variable aquifer characteristics subject to competing demands and the potential for third party effects are likely to introduce contestable dimensions to MAR operations. Contestability is likely to be further confounded by the need to comply with water quality regulations to ensure environmental and public health standards. Effective management of MAR in all jurisdictions will require the careful coordination of policies specific to water quality and water quantity.

The relative scarcity, limited availability of water and the variability of the Australian climate were recognised early in European settlement, resulting in the recognition of a need to resolve contestability and introduce policies to proportionately share water.

Alfred Deakin's Victorian *Irrigation Act* of 1886 defined ownership of water and rights to water use, acting as the precursor to current legislative arrangements in Australian states. The seminal legislation:

- exclusively vested the right to the use, flow and the control of water in any watercourse in the state;
- subordinated the rights of the individual in that private riparian rights could not compromise the cardinal rights of the state; and
- highlighted the need for the rights of the individual and the state be fully defined.

Deakin's notion of sovereign rights to water vested with the state remains the cornerstone of contemporary water legislation and as a consequence influences urban water reform.

Importantly the *Irrigation Act* 1886 did not prohibit private irrigation or water supply schemes (Smith 1998). The *Act* was (and remains) premised on the assignment of water allocations to private, co-operative and municipal water supply corporations. However, Deakin's perception of the value of water was primarily as a source of national economic development. This contrasts to the recognised multiplicity of economic benefits attributed to water that condition contemporary Australian Water Reform (CoAG 2004).

MAR policies will need to manage an array of multiple benefits and services conferred by most elements of the urban water cycle. Designing a portfolio of instruments, locally targeted to manage specific water related values is a systematic policy approach promoted by the NWI (CoAG 2004).

To promote efficient and effective water allocation, Australian water reform has emphasised institutional and governance approaches promoting voluntary transfers of water through market exchange. These in turn are reliant on enforceable, exclusive, excludable and transferable property rights vested in the individual.

## **1.2. Accounting for entitlements of MAR operational elements**

The Australian water reform process has made substantial progress in addressing the constraints and tensions associated with mature rural water economies, however

the reforms have had limited influence in urban water systems (NWC 2007, Productivity Commission 2008). The advances of both MAR and Australian water reform are relatively recent, limiting opportunities for urban water policy makers to gain experience and expertise in market design, testing and field implementation. Until recently, appraisals of the relative importance of market based approaches in urban policy portfolios have also been informal and often arbitrary (Hatton MacDonald and Dyack 2003, Brown 2005, Jiminez 2007, NRPPC 2007, Productivity Commission 2008).

As a corollary, simple rules and evaluation protocols to identify *a priori* the comparative advantages of market based policy instruments to resolve specific urban and MAR water re-allocation and coordination dilemmas have not yet emerged.

The Productivity Commission (2008), AATSE (2004), Brown (2005), Hatton McDonald and Dyack (2003) and ACIL Tasman (2005) have noted the absence of well defined entitlements to access stormwater, recycled water and aquifer storage. They contend there are consequent impediments to the development of MAR, leading to equivocal aquifer extraction, future legal wrangle and potential detrimental impacts on receiving environments or adjoining groundwater systems. Focussing on water quality, Jiminez (2007) describes an *ad hoc* development of stormwater governance and legislation in Victoria, pointing to limited integration between jurisdictions, institutions and managing agencies. The Australian Natural Resource Policies and Programs Committee (2007) contend there are strong possibilities that existing legislation, policy and institutions may not be readily adapted to market innovations in natural resource management (including water) or subject to instrument failure, with an attendant social cost. The rapid development of regional MAR is likely to exacerbate this disjunction.

Urban water management has generally remained immune from the NWI water reform initiatives and structural reform (NWC 2007). Despite aspects of water utility commercialisation and some examples of water franchising (e.g. South Australian Government) nearly all major metropolitan water utilities and Authorities remain Government owned monopolies (Productivity Commission 2008).

The Productivity Commission (2008 p. 106) notes that the natural monopoly typifying urban water utilities is partially explained by the public good aspect of ensuring community health, the legitimate and competing claim for environmental water, risk sharing of lumpy and long term investments, and the high transportation costs relative to resource value.

Prior to the Australian water reform process and the ensuing reliance on water markets, the ideology and ensuing pressures of national economic development were a potent impetus to bypass private market structures (Tisdell *et al.* 2002). Water Authority reluctance to deploy market institutions for water management was seen as a corollary of prevailing technical and fiscal impediments. Early commentators such as Hartman and Seastone (1970) suggested that impediments included a perceived ubiquity of external effects of water diversion, the difficulty in estimating the extensive suite of non-market values associated with water use and the magnitude of investment needed to facilitate efficient water transfers. Possibly as a result of the dominance of government urban water monopolies, the potential for alternative market based approaches has received minimal attention.

Literature based insights indicate that until recently, research endeavours and inquiries have prioritised the environmental and public health aspects of recycled water, including MAR, as supply options to augment existing supplies (*inter alia*

EPHC 2008 a, b; SA EPA Code of Practice 2004; Qld EPA 2005; NSW DEC 2006; WA EPA 2005 and WA Department of Water 2008, Jiminez 2007, Dickey and Reznikov 2008).

Water distribution and waste removal, environmental and public health are the components of the non-contestable aspects of urban water management (Productivity Commission 2008). Generally, regulatory instruments and minimum standards are best suited to manage non-contestable dimensions compared to market based approaches. Opportunities for market approaches in the contestable areas of alternative water supply remain relatively unexplored.

Until recently there has been limited discussion in the literature focussing on the analysis of urban water access rights, volumetric entitlements and allocations that account for seasonal variability. These are institutional characteristics that have been central to water reform in rural water catchments. Fully articulated entitlements corresponding to a proportional share of a defined water resource are pivotal to the effectiveness of MAR schemes that rely on the voluntary exchange of individual transferable rights.

Radcliffe (2007 p.322) exemplifies these considered opinions in arguing that:

“If greater remediation and use of recycled water is to occur, investors will require adequate provisions of security and freedom to operate. The same principles of entitlement allocation and use licensing should be adopted as already apply to suppliers and users of water from surface catchments and groundwater basins. The issue of title in the management of sewage and recycled water has received little attention”.

### **1.3. The National Water Initiative and the Robust Separation of rights**

As signatories of the National Water Initiative (NWI), States and Territories have agreed to NWI (s.37, s.28) which recommends that water access entitlements be specified as unit shares of a defined consumptive pool, and periodic water supply (allocations) and the impacts of use be managed independently (CoAG 2004). The framework defines water access entitlements as perpetual unit shares of a defined consumptive volume of a water resource, periodic allocations are made in accord with annual inflows, storage volumes and in proportion to the number of shares held. Risk is assigned between users and the Government.

By ratifying the NWI, the States have agreed to facilitate the operation of efficient water markets and make efforts to minimise the transaction costs on water trades. Efforts to promote an appropriate mix of water products and markets will need to recognise and protect the needs of the environment; and provide appropriate protection of third-party interests. The National Water Commission (2007) has proposed that NWI also articulate similar water management priorities specific to urban water cycle management.

The robust separation of water rights, articulated by Young and McColl (2003), provides a theoretical design framework that has informed recent Australian water reform initiatives, particularly in rural water management.

The endorsement of robust separation principles by the NWI warrants a rigorous investigation of the capacity of the framework to guide the design of effective MAR

market based policy. Evidence from rural water reform suggests the approach is a judicious first step to improve the compliance of urban water management with the NWI.

Young and McColl (2003) argue that the separation of rights provides for the independent management of the twin water policy objectives of distributional equity (including the environment as a legitimate user of water) and economic efficiency in a changing world.

Robust separation proposes a three tiered system of instruments to distribute and allocate volumes of water efficiently over time. A Water Plan establishes the community values and science-based guidelines to appraise the state of a water system and prescribe the rules to determine the environmental and consumptive “pools”. This allows managers to resolve the tension between consumptive use and the environment.

When more than one person has an interest in the consumptive “pool” the first policy instrument defines the unit shares of the pool and the distribution of shares to individual interests. This allows water managers to distribute access entitlements to available consumptive water.

The second instrument defines an independently managed process to periodically allocate the amount of water to each share. This allows water authorities to independently manage the consumptive pool when faced with changing ambient conditions and to assign the risk of a variable water supply.

The third instrument prescribes or proscribes the obligations of water use. Since the impact of water use varies according to geography and activity, this allows the environmental and health impact of water use to be managed independently.

In an extension of Tinbergen (1950), robust systems are characterised by the use of separate instruments for each policy objective. In the case of MAR, robust separation will need to be considered for each distinguishable or discrete component of the urban water cycle utilised by MAR operations. Assigning entitlements and allocations is appropriate for the three MAR elements characterised by volumetric metrics; viz. source waters, aquifer recharge and storage and the recovery of stored water.

Young (2005) has recently applied the notions of robust design to resolve enduring tensions of over allocated water and excess irrigation drawdown from a ground water system in the south east of South Australia. We have adapted this line of reasoning as a guiding reference for the robust design for urban MAR market based policies.

The main difference between the system proposed by Young (2005) and that needed for MAR is that MAR schemes provide an additional source of water and storage capacity.

## **1.4. Report Objectives and Structure**

What remains unclear in the Australian urban water context is the degree of alignment of policy providing for new water management technologies, such as MAR operations, with explicit NWI water reform directives of market development. The capacity of existing urban water legislation to provide consistent and coordinated guidelines to promote MAR operations also remains unresolved.

Reform procedures and directives emphasising the exchange of tradeable independent water rights, have been extensively implemented in rural water systems compared to urban counterparts (CoAG 2004). The National Water Commission (NWC 2007) highlighted underlying concerns by NWI signatories that the current State legislative and regulatory environments may not facilitate water reform in metropolitan and regional urban centres.

This report has two key objectives:

Firstly, to address NWC concerns, evaluate the degree of alignment of State policies related to MAR with the urban water reform objectives set out in the National Water Initiative.

Secondly, to develop a rule based decision framework to guide regional MAR policy design and improve the alignment of instruments with NWI policy objectives. Accounting for the biophysical and hydrologic variables of an urban water system provides the basis for volumetric entitlements responsive to system capacities. Volumetric considerations are necessary but not sufficient for comprehensive MAR policy. Ideally the framework would incorporate water quality monitoring regimes antecedent to compliance with public and environmental health regulations and where appropriate, the necessary property right conditions to facilitate coordination mechanisms to resolve the tension and conflicts of competing individual interests. The report explores the conditions for market exchange, negotiated bargaining, social compacts and statutory regulation. A primary focus of the research is the development of a systematic approach to jointly align policy instruments, resource characteristics and water reform objectives.

To address potential water reform impediments and sources of tension, the report describes a systematic approach to align the more complex characteristics of source waters, aquifer storage, recovery and final use with economic and policy interpretations central to the development and management of MAR.

Combining the operational elements of MAR with the principles of the robust separation of rights into a unified framework suggests a systematic governance arrangement. The report describes a framework that allows for the independent and flexible management of MAR elements often characterised by separate policy objectives. A governance framework based on robust separation principles, with the potential to distribute entitlements, allocations and use obligations is summarised is developed in chapter 3.

**Section 2** of the report sets out the **National Water Initiative guidelines and obligations** specific to MAR operations. The discussion focuses on water reform objectives of developing efficient urban water markets characterised by low transaction costs relative to the benefits of trade. Market instruments to reallocate urban water may not always be the most appropriate policy strategy. Voluntary exchange is reliant on institutional capacity to clearly articulate enforceable entitlements and allocations. The discussion reflects underlying concerns by NWI signatories about the extent to which the current institutional and regulatory environment facilitates water reform in metropolitan and regional urban centres. The general consensus indicates that the same principles of entitlement allocation and use licensing that already apply to suppliers and users of water from rural surface catchments and groundwater basins should be adopted for urban water systems.

**Section 3** describes **the operational elements of MAR**, highlighting policy instruments and arrangements that distinguish water quality from managed water volumes. Water quality is managed using principles of hazard analysis and critical control points (HACCP) and has been extensively documented in the recent Australian Guidelines for the risk management of stormwater and MAR. The section describes volumetric entitling as key to the management of the three MAR operational elements of harvesting source water, aquifer storage and the recovery of stored water.

**The economic characteristics of water, institutions and property rights** associated with the multiple benefits of water are introduced in **Section 4**. Water is something of an economic curiosity, simultaneously providing both consumptive and non-consumptive benefits, and characterised as either a private, public or common pool resource. The degree of water policy success is generally contingent on the correspondence of instruments with resource characteristics and alignment with prevailing individual and community attitudes and motivations. Adapting Young and McColl's (2003a) analytical framework enables a systematic approach to jointly align policy instruments, resource characteristics and water reform objectives. The section concludes with a schematic and details of a systematic policy framework characterised by entitlements as unit shares, periodic allocations and use obligations for each MAR operational element. .

**Section 5 summarises the relevant State Acts, Policies and Guidelines** that provide for MAR. Instruments are differentiated according to their role in the operational elements of source water capture and harvesting, retention, aquifer storage and recovery. Aspects of water quality such as treatment levels prior to recharge and suitability for final use are assumed to be managed using the regulatory instruments of environmental, food and public health policy and legislation. **Section 6** summarises the water legislation and property right regime for MAR operations in France and the United States (Arizona, Colorado, and California). A more comprehensive review of MAR related policy for each Australian State is provided in Appendix 1. The intention of the evaluation is to indicate the degree of policy alignment with the NWI objectives and the potential impediments to market approaches to efficiently allocate urban water.

**Section 7 details examples of MAR** operations as though they were managed according to the developed systematic governance framework. Example one describes a counterfactual MAR scheme operating with stormwater, a brackish low transmissive aquifer, existing groundwater users and a non-potable final use. These characteristics typify MAR schemes in Adelaide, South Australia. Example two describes a similar source water and aquifer environment with potable final use coupled to an existing potable water supply infrastructure. Both MAR schemes are fashioned according to robust separation principles.

## 2. AUSTRALIAN URBAN WATER POLICY

The National Water Initiative (NWI) represents a 108 clause agreement ratified in 2004 by the Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia and the Australian Capital Territory; the Northern Territory and Tasmania became signatories in June 2005. Western Australia signed in 2006. The NWI sets out objectives, outcomes and actions for the ongoing process of Australian water reform, and timelines to achieve this reform. The objective of the NWI is the development of:

*“A nationally-compatible, market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes” (NWI clause 23).*

The NWI (Clause 24) describes the agreed outcomes and commitments to specific actions set out on the basis of the following key elements:

- 1) Water access entitlements and planning framework;
- 2) Water markets and trading;
- 3) Best practice water pricing;
- 4) Integrated management of water for environmental and other public benefit outcomes;
- 5) Water resource accounting;
- 6) Urban water reform;
- 7) Knowledge and capacity building; and
- 8) Community partnerships and adjustment.

Urban water reform is one of the eight key elements of the National Water Initiative. The urban reform outcomes sought are set out in Clause 90 of the National Water Initiative, including initiatives to:

- 1) provide healthy, safe and reliable water supplies;
- 2) increase water use efficiency in domestic and commercial settings;
- 3) encourage the re-use and recycling of wastewater where cost effective;
- 4) facilitate water trading between and within the urban and rural sectors;
- 5) encourage innovation in water supply sourcing, treatment, storage and discharge; and
- 6) achieve improved pricing for metropolitan water (consistent with National Water Initiative Clause 66).

By ratifying the NWI, the States and Territories have agreed to establish water market and trading arrangements that will (NWI clause 58):

- i) facilitate the operation of efficient water markets,

- ii) minimise transaction costs on water trades,
- iii) enable the appropriate mix of water products to develop, based on tradeable access rights, entitlements or allocations,
- iv) recognise and protect the needs of the environment; and
- v) provide appropriate protection of third-party interests.

In accord with the National Water Initiative paragraph 92 (iv), The Australian, State and Territory Governments committed to a review of institutional and regulatory models for achieving integrated urban water cycle management. The review process aims to identify and develop policies and instruments to achieve more efficient water use in Australian cities.

The NWC (2007) review of the progress of integrated urban water reform in Australian states recommends an institutional analysis of water quantity management. The institutional analysis is also intended to complement the development of a set of Australian Guidelines for the risk management of water quality associated with recycling. Focussing on public health and the environment, draft guidelines for stormwater harvesting and use and managed aquifer recharge have been released for comment (EPHC 2008 a,b,c).

In principle there are three fundamental objectives of Integrated Water Cycle Management and Water Sensitive Urban Design. Firstly, to minimise the impact of urban development on regional water balances inclusive of the claims of dependent ecosystems and the natural environment. Secondly, to address water scarcity in cities by diversifying supply options to include all components of the urban water cycle (NWC 2007). Lastly to maximise urban water “metabolism” by retaining, reusing and recycling water entering the urban water management cycle for as long as possible.

The NWC (2007 p.6) notes that

“The Council of Australian Governments’ agreement to this action in the National Water Initiative reflects underlying concerns about the extent to which the current institutional and regulatory environment facilitate Integrated Water Cycle Management. This has become more pressing as water scarcity is increasingly becoming a driver for interest in and uptake of Integrated Water Cycle Management in some metropolitan and regional urban centres”.

The Council of Australian Governments (CoAG) has recently received the Council for the Australian Federation draft urban water planning principles. The agreed urban water planning principles were submitted to COAG in October 2008 for adoption. The (Draft) Urban Water Planning Principles are as follows (see Marsden Jacob (2008 p.2):

- 1) Deliver urban water supplies in accordance with agreed levels of service including specified levels of reliability and safety.
- 2) Base urban water planning on the best information available at the time and invest in acquiring information on an ongoing basis to continually improve the knowledge base.

- 3) Adopt a partnership approach so that the community is able to make an informed contribution to urban water planning, including consideration of the appropriate supply/demand balance.
- 4) Manage water in the urban context on a whole-of-water-cycle basis.
- 5) Consider the full portfolio of water supply and demand options, from both natural and manufactured water sources.
- 6) Develop and manage urban water supplies within sustainable limits.
- 7) Use pricing and, where efficient and feasible, market mechanisms to help achieve planned urban water supply/demand balance.
- 8) Periodically review the assumptions upon which urban water plans are based and make adjustments if the assumptions change.

Guided by these operational definitions of urban water management, water Authorities responsible for urban water management have initiated a raft of Metropolitan and State Based Strategic water plans (for Water Plans see CoAG 2004, Schedule E).

1. "Water-Proofing Adelaide"<sup>1</sup> establishes a 20-year blueprint for the strategic management of the water resources available to metropolitan Adelaide and adjacent semi-rural areas. Strategies include opportunities to encourage the use of alternative water resources, including MAR with stormwater.
2. The "NSW Metropolitan Water Plan"<sup>2</sup>, has developed an integrated approach to metropolitan water in Sydney and includes a portfolio of increased water supplies, demand management strategies, water reuse initiatives and urban development guidelines.
3. The Victorian, "Our Water Our Future"<sup>3</sup> sets out 110 initiatives to achieve more sustainable water resource management and planning. Relevant to the urban water cycle are targets to reduce potable water use by 15% and achieve reuse levels of 20% of water by 2010.
4. The Queensland Water Plan 2008-2012<sup>4</sup> outlines the principles, strategies and actions to ensure sustainable water resource management, underpinned by various Queensland Regional Water Supply Strategies, to occur in tandem with Queensland's economic growth.
5. The Western Australian State Water Strategy<sup>5</sup> seeks a more sustainable water future through improved water use efficiency, significant advances in water reuse,

<sup>1</sup> [http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa\\_Strategy.pdf](http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa_Strategy.pdf)

<sup>2</sup> <http://www.waterforlife.nsw.gov.au/about/plan>

<sup>3</sup> <http://www.ourwater.vic.gov.au/programs/owof>

<sup>4</sup>

[http://www.qwc.qld.gov.au/myfiles/uploads/Strategic%20plan/D%2008%20006968%20%20strategic%20plan%20-%20long%20version%20updated%20values%20\(QWC0000451\)\(3\).pdf](http://www.qwc.qld.gov.au/myfiles/uploads/Strategic%20plan/D%2008%20006968%20%20strategic%20plan%20-%20long%20version%20updated%20values%20(QWC0000451)(3).pdf)

<sup>5</sup>

[http://portal.water.wa.gov.au/portal/page/portal/PlanningWaterFuture/StateWaterStrategy/Content/State\\_Water\\_Strategy\\_complete\\_001.pdf](http://portal.water.wa.gov.au/portal/page/portal/PlanningWaterFuture/StateWaterStrategy/Content/State_Water_Strategy_complete_001.pdf)

diversified supply and fostering innovation and research solutions. Water reuse is proposed to increase by 20% by 2012.

6. The *Tasmanian Water Management Act* (1999) provides for the development of integrated water management planning. The Water Governance Arrangements<sup>6</sup> and an implementation plan to address Tasmanian water planning and NWI initiatives focus on water entitlements and allocations. Water trading is addressed as nested within a regime of cost reflective water pricing. Tasmanian urban water reform focuses primarily on demand management.
7. The ACT: "Think Water, Act Water"<sup>7</sup> is a long-term water resource management strategy focusing on improved water use efficiency, reduced water quality impacts, enhanced ecological values in waterways and protection of recreational and amenity value. The ACT strategy includes a recycling target of 20% by 2013.

Generally the State strategic plans have emphasised the setting of objectives and management of the environment and public health risks. The plans:

- i) set out aspirational targets for water recycling and re-use,
- ii) established the role of recycling in mitigating environmental degradation,
- iii) sought to establish environmental objectives and the referring guidelines,
- iv) reviewed instruments and strategies to ensure public health and methods to reduce community uncertainty and unfamiliarity.

Clause 60 of the Australian Labour Party's 2007 National Platform and Constitution has been adopted as Labour Party policy and states:

60) Labour supports recycling wastewater and sets a goal of 30 percent of Australia's waste water being recycled by 2015<sup>8</sup>.

The strategic plans offer limited operational guidance and strategies to entitle elements of the urban water cycle and promote efficient and effective water allocation through the voluntary market exchange of transferrable rights to water.

The principles of entitlement to access and manage urban water, providing investors with adequate provisions of security and freedom to operate are only recently being considered in policy discourse. As Radcliffe (2008, p.324) notes, "...for recycled water... the same principles of entitlement allocation and use licensing should be adopted as already apply to suppliers and users of water from surface catchments and groundwater basins".

With an increasing reliance on recycled water in general and in some cases MAR, some State agencies are reviewing the notion of urban water entitlements, assigning risk, options for proportional shares in consumptive pools and equitable allocations in a changing world.

---

<sup>6</sup> [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUY-6KY3CM/\\$FILE/Water%20Governance%20Tasmania.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUY-6KY3CM/$FILE/Water%20Governance%20Tasmania.pdf)

<sup>7</sup> [http://www.thinkwater.act.gov.au/documents/TWAW04-05progress\\_report\\_web.pdf](http://www.thinkwater.act.gov.au/documents/TWAW04-05progress_report_web.pdf)

<sup>8</sup> [http://www.alp.org.au/download/now/2007\\_national\\_platform.pdf](http://www.alp.org.au/download/now/2007_national_platform.pdf)

Regulatory and instrumental reviews of MAR in Victoria (Lumb 2006) and South Australia (Dickey and Reznikov 2008, Dyson 2008) are recent examples that explore aspects of the current status of MAR related entitlements and allocations, identifying dimensions of policy overlay, competing policy objectives and potential conflict.

The development of 'integrated' strategies for the management of urban water is a priority under both the National Water Initiative Framework and the State based strategic water plans. Brown (2005) argues that integration is constrained by 'institutional inertia', that despite the technical potential for novel management solutions since the 1980s, organisations are slow to develop the management structure required for implementation. The integration called for occurs at two levels. Firstly, the technical cooperation of different parts of the urban water system, for example, the stormwater system, sewerage system, treatment plants, with associated modelling tools to predict and control their interactions under different environmental scenarios. Secondly, change by the administrative agencies to cohesively manage the more diverse set of policy tools, and allow stakeholder input where possible (Rauch *et al.* 2005). In most cases, the most significant obstacle is the administrative inertia (Brown 2008).

The Western Australian Economic Regulation Authority (ERA) recently reviewed the proposed Water Corporation's procurement model (ERA 2007 p. v). The ERA identified a lack of opportunity and incentive for the private sector to develop alternative innovative supply and demand management options. Centralised coordination without sufficient checks and balances and an unclear delineation of roles and responsibilities were recognised as additional impediments. A proposed procurement alternative relies on the establishment of an Independent Procurement Entity, whose primary focus is to separate the role of the State owned water authority and the supply of bulk water entitlements.

The Independent Procurement Entity (IPE) thus identifies real and perceived conflicts of interest of a state water authority acting as sole supplier, seller and conservator of bulk water (Productivity Commission 2008). The proposed procurement formalises a process to reduce the risk of political interference, clarifies the role of government and reduces institutional uncertainty for private water operators. The ERA suggests the procurement model has parallels with the independent Reserve Bank of Australia, but instead of achieving a target inflation rate, the IPE would achieve the Government's target level of water security.

Based on government indications of supply and security needs, the entity would identify future supply shortfalls and seek ways to meet these shortfalls via supply augmentations and demand management options developed by both the private sector and the Corporation. According to the ERA the alternative model allows for greater competition in the identification of alternative options, ensuring that all possible alternatives are considered and subsequently the least cost combination of options is developed. Ideally, least cost options are expressed as reduced water charges for consumers.

Effective water markets facilitated by a regime of transferable entitlements vested in individuals and issued via neutral auctions assume priority in the ERA recommendations. The Productivity Commission (2008) suggests that in concert with third party access to the State water reticulation infrastructure<sup>9</sup> the proposed reforms

---

<sup>9</sup> See Hilmer *et al.* 1993. For comprehensive Australian reviews, see Acil Taman (2005) and Marsden Jacob (2005).

provide a basis for competitive supply options in addition to current formal water procurements. Water distribution and reticulation infrastructure in Australian States is typically a natural monopoly.

The Queensland, (QWC 2007), Victorian (VCEC 2007), Tasmanian (MWST 2006) and South Australian (Natural Resources management Act 2004) Governments are considering urban reform and structural change along similar lines.

In response, the NWC (2008a) update on water reform recommends (p. 21) improved institutional and market arrangements for urban water. The report notes that “there is a range of barriers to the full and timely implementation of water reforms...’policy bans’ by some governments on certain urban water supply options add in some cases a lack of clarity on the specific reforms required and the accountability for delivering them” (p. 20).

Consistent with opinions noted above, The NWC (2007) reviewed research priorities to promote urban water reform, recommending:

- i) Documenting current institutional and regulatory arrangements for water supply, wastewater and stormwater management impacting significantly on Integrated Water Cycle Management in all jurisdictions;
- ii) Analysing the extent to which current arrangements in priority areas are likely to achieve better integration of urban water cycle planning and management in line with National Water Initiative outcomes;
- iii) Identifying strengths/deficiencies in current arrangements to achieve relevant National Water Initiative outcomes;
- iv) Identifying options for reform in priority areas; and
- v) Recommendations on how to develop best practice guidelines or other appropriate policy instruments or guidance.

The NWI has also identified cost reflective or scarcity-based urban water pricing as a priority area of review. Generally, state owned urban water utilities operate administrative pricing systems that aim to equate revenue with cost (NWC 2007a). Generally, urban water prices do not reflect water scarcity during periods of water stress or drought. To compensate for poorly matched supply and demand, Authorities generally rely on escalating water restrictions rather than cost reflective or scarcity water pricing.

In the Section on Urban Water Pricing, The NWC Annual Report (2008 Ch 2, p. 16) states:

1. Continuing metropolitan water restrictions underline the need to ensure reliable urban water supplies and restore public confidence in the security of their supply. The Commission regards long-term temporary water restrictions as an inequitable and inefficient way of balancing supply and demand. While demand management certainly has an important part to play, the Commission considers improved supply to be critical to delivering secure, sustainable urban water into the future.
2. Two-part inclining block tariffs are commonly used in the urban water sector across Australia. A two-part tariff is made up of a fixed (service availability) charge and a variable (usage-based) charge. In most jurisdictions, two or

more blocks or tiers (up to eleven) are incorporated into the variable charge levied on residential users so that the variable component of the charge increases as water consumption exceeds these pre-determined blocks or thresholds. This tariff structure is commonly referred to as an inclining block tariff.

3. Inclining block tariffs are inequitable as they disadvantage households with larger numbers. They are also not very effective in influencing consumption as the cost impact of reaching higher tiers is often not evident until well after the event, particularly where billing is infrequent. Inclining block tariffs often result in a departure from marginal cost pricing. The Commission therefore considers a two-part tariff with a single variable charge to be a more efficient and equitable tariff structure, and one which is simpler for customers to understand and respond to.

Despite providing a supplementary water supply, suitable for periods of water stress or low rainfall periods, MAR operates in a competitive environment with other water supply options. MAR characterised by specified access entitlements and complete contracts enabling mercantile exchange is likely to offer an efficient economic solution. However, operating in an environment of subsidised or below cost urban water pricing clearly disadvantages recycling endeavours including commercial MAR operations.

Urban water pricing is not the intended focus of this report. However, consistent and equitable pricing arrangements are crucial for promoting commercial MAR schemes and mitigating a perceived lack of confidence in the opportunities for MAR in specific areas where there are water shortages. Cost reflective urban water pricing is dealt with in more detail by for example the Productivity Commission (2008), Hatton McDonald and Dyack (2003), Grafton and Kompas (2006) and Young and McColl (2007).

The NWC Annual Report refers to both institutional reform and the need for transparent pricing policies for recycled water and stormwater (NWC 2008, p.18). The report states:

1. Urgent progress is required to improve pricing policies for recycled water and stormwater. Consistent with NWI commitments, pricing policies for recycled water and stormwater should be congruent with pricing policies for drinking water so as to stimulate efficient water use regardless of the source. Recycled water and stormwater schemes need to be considered in a system-wide context and prices should reflect externalities and avoided or deferred costs. Prices for recycled water and stormwater should reflect underlying cost differences associated with providing products of different quality and fit for a range of different uses.
2. Institutional reform in the water sector has not kept pace with other sectors such as telecommunications, electricity, gas and ports. Institutional arrangements in the water sector should be reviewed to provide greater opportunity for private sector investment and innovation. Regulatory reforms, including price-setting, allocation and tradability of bulk water resource access rights, and third-party access to natural monopoly infrastructure, have the potential to promote more efficient resource use and greater choice in water services and water products.

3. Structural reform of the urban water sector would provide opportunities to ensure competitive pressure is brought to bear where it makes sense to do so (for example in sourcing water at the wholesale level and at the retail supply level).

Consistent with the NWI objective of facilitating market approaches for water reform where appropriate and NWC recommendations for continuing structural reform of the urban water sector, this report focuses on identifying appropriate policy instruments including market approaches, to promote MAR within existing State based policy frameworks.

### 3. MANAGED AQUIFER RECHARGE

Managed Aquifer Recharge (MAR) is an umbrella term for a range of methods (Dillon 2005). These methods involve the deliberate recharge of water to aquifers when water is plentiful and recovering it during times of peak demand or water stress (Pyne 2005).

MAR has the capacity to augment domestic and industrial supply by converting urban water waste streams and high flow flood events into groundwater base flow. Future extractions of stored water are able to cost effectively satisfy diverse water demands through water quality differentiation; *viz.* supplying users requiring non-potable water, characterised by lower treatment costs.

Multiple source waters including peak stormwater flows and waste water streams can be harvested, treated passively (e.g. constructed wetlands) or actively (e.g. dissolved air flotation/filtration) and injected into confined aquifers for subsequent recovery for non-potable purposes (Pyne 2005, Pavelic *et al.* 2006a, Swierc *et al.* 2005,. Pathogen and contaminant attenuation during aquifer residency may also provide opportunities for potable applications (Pavelic *et al.* 2005, Dillon and Toze 2005, Dillon *et al.* 2005, 2008a, Page *et al.* 2008, EPHC 2008, 2008a).

Pavelic *et al.* (2006) and the South Australian EPA (2006) highlight additional benefits of ASR, including:

- A reliable storage preventing evaporation, algal growth and mosquito breeding;
- A continuity to water supplies during periods of prolonged drought and substantial reductions in water supply;
- Potential for contaminant and pathogen attenuation and natural disinfection during storage; enhanced by long dwell times;
- Freshening zones in brackish aquifers that otherwise would have limited beneficial use (contingent on aquifer characteristics);
- Potential for reduced pumping costs, amelioration of salt intrusion, restoration of groundwater levels, and surface subsidence (through increased hydraulic pressures)
- The detention element associated with ASR has capacity to mitigate peak flows in flood events.

Dillon *et al.* (2007 p.1) has developed a policy management matrix, and proposes that:

“MAR potentially creates conflict between water conservation and water quality protection and this will require regulators to have a sound basis for policies. Sectoral responsibilities for environmental and health regulation and water resource management roles will require coordination for efficient approval of new MAR projects and to avoid perverse outcomes.”  
The policy matrix described in EPHC (2008c) is shown in Table 1.

The process is managed to ensure adequate protection of both human health and the environment. In May 2008 the Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and the National Health and Medical Research Council (EPHC) released Phase 2 of the Australian Guidelines for Water Recycling: The AGWR Augmentation of Drinking Water Supplies (EPHC 2008a) was released as guidelines and AGWR Stormwater harvesting and reuse (EPHC 2008b) and AGWR Managed aquifer recharge (EPHC 2008c) were released as public consultation drafts.

The Australian guidelines for MAR are explicit in covering only the water quality, protection of human health and environmental impact of aspects of MAR operations. That is the right hand side of Table 1.

**Table 1 Resource management and environmental protection policies invoked by managed aquifer recharge operations**

<b>Resource</b>	<b>Management issue:</b> <i>Water storage allocation and entitlements</i> <b>Attribute:</b> Quantity (not addressed in the Australian Guidelines)	<b>Management issue:</b> <i>Protection of human health and environment</i> <b>Attribute:</b> Quality (addressed in the Australian Guidelines)
<b>Source of water for recharge</b>	<ul style="list-style-type: none"> <li>• Environmental flow requirements</li> <li>• Water allocation plans and surface water entitlements</li> <li>• Inter-jurisdictional agreements</li> <li>• see below If source is groundwater</li> </ul>	<ul style="list-style-type: none"> <li>• Catchment pollution control plan — see Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse (EPHC–NHMRC–NRMMC 2008)</li> <li>• Water quality requirements for intended uses of recovered water (see <i>Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies</i>)</li> <li>• Risk management plan for water quality assurance (see Phase 1 of the guidelines)</li> <li>• If source water is groundwater, requires a quality protection plan for source aquifer in accordance with Groundwater Protection Guidelines (NWQMS 1995)</li> </ul>
<b>Groundwater</b>	<ul style="list-style-type: none"> <li>• Groundwater allocation plan and groundwater entitlements</li> <li>• Resource assessment accounting for groundwater-dependent ecosystems</li> <li>• Demand management</li> <li>• Allocatable capacity and entitlement for additional storage in the aquifer</li> <li>• Inter-jurisdictional agreements</li> </ul>	<ul style="list-style-type: none"> <li>• Groundwater quality protection plan for recharged aquifer in accordance with groundwater protection guidelines (ANZECC–ARMCANZ 1995)</li> <li>• Water quality requirements for intended uses of groundwater — see Water Quality Guidelines for Fresh and Marine Waters, 2000; Phase 1 of the guidelines or Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies (EPHC–NHMRC–NRMMC)</li> <li>• Risk management plan for water quality assurance beyond attenuation zone, accounting for aquifer biogeochemical processes</li> </ul>

(Source: EPHC 2008c, ch1)

This report addresses the management issues identified as water access entitlements and allocation for harvesting, storage, recovery and the final use of MAR: viz. the left hand side of the Table. For discussion regarding MAR water quality, we rely on the recommendations of the Australian Guidelines to ensure the protection of human health and the environment.

The Australian Guidelines for Managed Aquifer Recharge (EPHC 2008a) classifies aquifer recharge enhancement as:

1. unintentional aquifer recharge;

2. unmanaged aquifer recharge — that is, an intentional water-related activity known to increase aquifer recharge, but one that is usually undertaken to dispose of water rather than recovery;
3. managed aquifer recharge — that is, an intentional activity to recharge aquifers to recover water for economic or environmental purposes, which must assure adequate protection of human health and the environment.

For reporting purposes we rely on the definition of MAR detailed in the Australian Guidelines. Therefore policy analysis and management for unintentional and unmanaged aquifer recharge are not considered in the report discussions. Table 2 details examples of unintentional, unmanaged and managed aquifer recharge.

**Table 2: Examples of unintentional, unmanaged and managed aquifer recharge**

Unintentional	Unmanaged	Managed
<ul style="list-style-type: none"> <li>• Clearing deep rooted vegetation or soil tillage</li> <li>• Leakage from water pipes and sewers</li> <li>• Irrigation deep seepage</li> <li>• Infiltration of runoff from impervious areas</li> <li>• Spraying herbicides</li> </ul>	<ul style="list-style-type: none"> <li>• Stormwater drainage wells and sumps</li> <li>• Septic tank leach fields</li> <li>• Mining and industrial water disposal to sumps</li> <li>• Floodplain water harvesting</li> </ul>	<ul style="list-style-type: none"> <li>• Injection and systems with recovery wells</li> <li>• Infiltration systems with recovery wells</li> </ul>

(Source: EPHC 2008c ch2)

The EPHC (2008a p. 21) notes that recharge may progress from unmanaged to managed activities. Recharge changes can be managed by appropriately accounting for human health and environmental risks and by approval of the activity's effects in regional groundwater management and surface water allocation plans. The EPHC Guidelines continue:

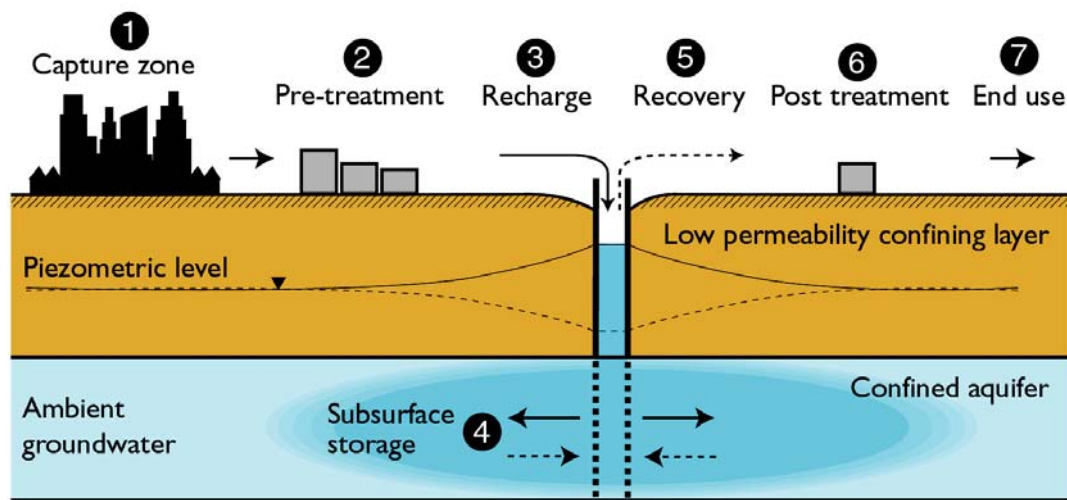
“For example, stormwater disposal to aquifers in Mount Gambier (South Australia) ...has occurred since the 19th century. This water makes a valuable contribution to the groundwater balance and to securing future supplies. In Mount Gambier, the risks to groundwater quality and drinking water supplies from stormwater drainage were recently evaluated and found to be acceptable. The transition from unmanaged to managed aquifer recharge will be complete when current plans for water quality protection and security are adopted and implemented by the relevant authorities...In catchment areas of drinking water supply wells drawing from the same unconfined aquifer, protection of groundwater quality could be assisted by applying these guidelines. The guidelines could be used to provide blanket advice on appropriate practices for rainwater and stormwater infiltration, to ensure that the drinking water supply remains safe”.

Just as the EPHC Guidelines can be applied to managing water quality in the transition from unmanaged to managed aquifer recharge, similar vigilance will be required when considering policy instruments and guidelines specific to volumetric entitlements.

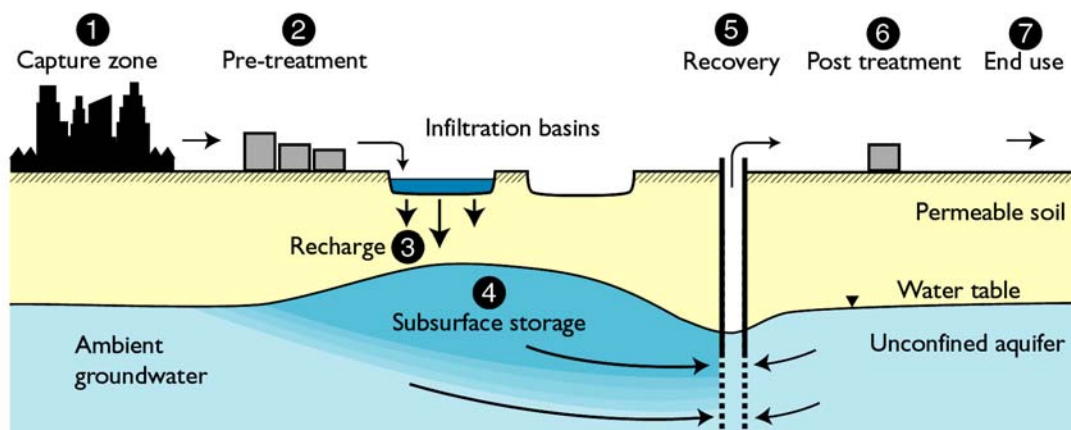
Two examples of managed aquifer recharge are illustrated in

Figure 1: they are aquifer storage and recovery (ASR) in a confined aquifer and a soil aquifer treatment system (SAT) in an unconfined aquifer. The SA EPA (2004), EPHC (2008c) and Dillon *et al.* (2009) illustrate other examples of MAR schemes.

Managed aquifer recharge takes many different forms adapted to the local situation. Recharge can be via wells, infiltration basins, galleries, and induced by pumping groundwater from sand deposits next to a water body to induce infiltration. Dillon *et al.* (2009) note there are two main types of aquifers – those that beneath a layer of clay, which requires injecting water via a well (a confined aquifer in Figure 1a) and those that are unconfined and allow water to seep through permeable soils, which can be enhanced by infiltration basins and galleries (Figure 1b).



(a) Confined Aquifer



(b) Unconfined aquifer

**Figure 1 Two examples of managed aquifer recharge, (a) ASR and (b) SAT, showing the seven elements common to each system. Piezometric level is the level of water in a well if a well were constructed. For an unconfined aquifer this is the water table. During recharge levels rise and near recovery wells levels fall. (source: Dillon *et al.* 2009)**

Figure 1 schematically illustrates the operational processes or elements of the urban water management cycle utilised by MAR. Sources of water, following appropriate treatment, can be recharged, stored within an aquifer and then recovered suitable for a specified end use. The circled element numbers in the following discussion correspond with those shown in

There are multiple combinations of sources, water treatments and end uses. Human health and environmental aspects of operational elements ②, ④ and ⑥ are addressed in the Australian guidelines (EPHC 2008c) and State regulations. Elements ③ ④ and ⑤ represent aquifer recharge, storage and recovery, and are currently regulated using licensing arrangements likely to be associated with entitlements to access the aquifer to recharge and store harvested source water, and recover water from the aquifer respectively.

The final use of recovered MAR water (⑦) is currently regulated through environmental protection and public health regulation in Australian jurisdictions.

The governance of water volumes associated with MAR might be typified by clearly defined separate entitlements to three MAR operational elements. From the above figures, these elements are:

- ① The harvesting of source water
- ③ The recharge of source water that is ④ stored in an aquifer, and
- ⑤ The recovery of water from the aquifer.

The Australian Guidelines identified potential source waters for MAR to include; stormwater, reclaimed water (derived from treated sewage), desalinated seawater, surface waters from streams and lakes, groundwater extracted from other aquifers, and water stored from drinking water distribution systems.

Depending on State-specific legislation, separate acts provide and prescribe actions for individual source waters, administered by independent authorities, utilities or agencies. MAR source waters are managed by a raft of policies that simultaneously provide for development and flooding, natural resource management, environmental impact, urban planning, roads and construction and public health. Individual policies are guided by specific objectives specified in the relevant Act. Objectives set out standards and targets that can at times be inconsistent and act in opposition, introducing policy tension and conflict. Subject to ambient or *status quo* conditions, policy inconsistencies may remain nascent, only revealed with the introduction of novel solutions to augment urban water supplies such as MAR. Section 5 identifies policies for each MAR operational element at a state level. Policy inconsistencies are also highlighted.

Table 3 describes an example of evaluation criteria and risk based management through regulated compliance with either volume or water quality specifications (Swierc *et al.* 2005, EPHC 2008c). For the purposes of illustration, we assume that non-compliance with any critical control point invokes a regulatory veto and until rectified, precludes further participation in MAR. The Table suggests a vector of aquifer characteristics, compromising in broad terms; potential aquifer storage capacity, infiltration rates, dwell times, injectant mobility and transmission, and ambient aquifer water quality which may predict the suitability of an aquifer for MAR. Monitoring is a necessary precursor for the enforcement of property rights and Table 3 illustrates a rule based decision framework to enable the alignment of regional

biophysical and hydrologic variables with policy initiatives. For specific water quality and environmental conditions to be met by MAR projects see EPHC (2008c)

**Table 3 Example of evaluation criteria and hazard critical control points for source waters, aquifer characteristics and end use obligations**

①	③	⑤	⑦
Capture Zone	Recharge	Recovery	End use
Source waters	Aquifer characteristics <sup>1</sup>	Extraction	
Surface waters Other Groundwater Stormwater Recycled water Reclaimed waters Desalinated	Sensitivity of aquifer dependent ecosystems (volume and water quality) Vulnerability of confining layers to pressure changes Mineral dissolution Aquifer thickness Porosity Potential Injection rates Vertical and horizontal hydraulic gradient Landform/ topography Groundwater salinity Vulnerability of other groundwater users to pressure changes Pathogen/contaminant fate and attenuation	Declining or rising aquifer Independence of injection and extraction well or consortium of well heads managed collectively	Demand for potable non-potable water Industrial commercial or agricultural use Consumptive non-consumptive use Change in water quality through use Potential for salt or metal mobilisation in receiving zone Depth of receiving water table Hydraulic conductivity
↑	↑	↑	↑
② Treatment <sup>2</sup>	④ Aquifer storage	⑥ Post treatment and end use licence	
Monitor source water quality in relation to water quality requirements for recharge  Right to recharge is contingent on compliance with water quality requirements	Monitor groundwater pressures / levels to assess against criteria  Monitor groundwater water quality to assess against criteria  Monitor injected volume to assess against allowable volume	Monitor volume and quality of extracted water to assess against criteria for use  Comply with demand requirements and associated water quality standards  Comply with water use licence conditions	

<sup>1</sup> Modified from LWA (2001.p104), Pavelic *et al* (2006b), Brodie *et al.* (2007) South Australian EPA (2004) <sup>2</sup> Sieves/screens, settling ponds, retention ponds/ wetlands (subject to residence and dwell times), secondary treatment, DAFF.

Later, Table 5 will describe a representation of governance arrangements that seeks to align the hydrological, economic and policy interpretations of MAR. Section 4.5 details the proposed governance scheme, which:

- i) identifies the elements of the terrestrial water cycle specific to MAR,

- ii) points to hazard and critical control points,
- iii) describes aquifer characterisation to help identify the potential of MAR, and
- iv) determines the nature of property rights for each system element consistent with the principles of robust separation of water rights expressed in the NWI.

Uses of recovered water can include drinking water supplies, irrigation, industrial supplies, and toilet flushing. In addition ecosystems can be sustained or existing groundwater uses protected by raising piezometric heads to support base flows, maintain lakes or groundwater dependent vegetation and by protecting against saline intrusion.<sup>10</sup>

## 4. INSTITUTIONS AND PROPERTY RIGHTS IN A MATURE WATER ECONOMY

### 4.1. The multiple economic benefits of water

Colby (1995) argues that defining property rights to water in a modern context is complicated by the provision of multiple benefits and services, rendering the characterisation of water as an economic good as both enigmatic and something of a technical curiosity.

Water transgresses agency, state and national jurisdictions; it seeps, drains, evaporates and flows according to the forces of gravity, regardless of prescribed statutes. Water exists as solid, liquid and gaseous phases within different facets of the hydrological cycle and is characterised by a dynamic, stochastic supply according to meteorological and biophysical parameters.

Water resources have both consumptive and non-consumptive uses, constitute market and non-market values, include private good and public good values and are characterised by a high likelihood of external effects. Water can be defined as a stock resource, such as groundwater and surface water subject to chemical changes and permanent depletion when abstractions exceed recharge rates. Water is also classified as a replenishable flow resource, such as unimpeded natural flows used for recreation, maintaining riparian environments and the re-entry of consumed water into the hydrological cycle.

Water rights have quality attributes that significantly affect their economic value, which have been often been disregarded in the formal determination and specification of property rights. Water quality is a function of, *inter alia*, sediment and turbidity, pathogen content, salinity, biologically available oxygen and contaminate levels. Different users can tolerate different water qualities. The same consumer can tolerate different qualities when applied to different uses, for example safe pathogen and chemical free drinking water compared to non-potable water suitable for sewerage and drainage (Rix 1993).

Water as a public good is characterised by non-exclusive and non-rival consumption. Recreational uses, for example, are non-exclusive, in that one user cannot prevent

---

<sup>10</sup> (compiled from Dillon *et al.* 2009, EPHC 2008c ch1, SA EPA Guidelines, Lumb 2006 and NDSW DEC 2006)

the use of water by another, and non-rival in that in the gaining of the benefit of recreational use, it does not diminish the recreational experience of another user. The use of the waste assimilative capacity of water to carry pollutant and contaminate loads is non-exclusive. In contrast, the pollution and contamination are non-rival dis-utilities to affected parties. The benefits accruing by provision of instream flows for riparian ecosystems are non-rival (Randall 1981).

Markets, regulatory instruments and community crafted social compacts are water policy approaches implemented to resolve those tensions and achieve socially acceptable collective outcomes.

Multiple water sources, retention schemes, water treatments, heterogeneous aquifers and the array of potential uses confer high levels of operational flexibility and adaptation for MAR schemes. Conversely, multiple operational elements introduce a complex, challenging and interdependent policy environment. Each element utilises water of different economic characteristics requiring a specific policy response and instrument design. For example MAR source water may be harvested from either a common pool watercourse or from stormwater that potentially has the attendant properties of a private good. Policy instruments designed to account for and manage the attributes of a public good are not suited to efficiently and effectively manage, for example, a private good.

Specific policy instruments are more likely to achieve policy objectives when they correspond with specific resource characteristics. To achieve urban water reform objectives, MAR policy frameworks are most likely to consist of a portfolio of sequenced and targeted instruments, designed and implemented to account for both resource heterogeneity and diverse community attitudes and values.

## 4.2. Institutions and water property rights

The NWC (2007, p.12) states:

“The term “institutional models” is generally taken to refer to the roles, powers, functions, incentives and accountabilities of the various entities or institutions involved in a particular sector or activity. A well-designed institutional framework can be defined as one that provides the right incentives and sanctions for entities to facilitate the optimal social outcomes (in this case the outcomes sought by Integrated Water Cycle Management). This requires clear objectives, well-aligned incentives, and absence of conflicts of interest.”

Although the intent of policy outcome is similar, economics relies on a different array of definitions regarding institutions<sup>11</sup>.

This is an important distinction in a discussion of MAR entitlements, for the theory of cost effective or efficient resource allocation arising from assigned individual property rights is grounded in how institutions are defined.

Vatn (2005, p.10) lists some definitions of Institutions as:

- “settled habits of thought to the generality of man (Veblen 1919, p.239);

---

<sup>11</sup> For institutions involving natural resources, see (*inter alia* Bromley 1991, Ostrom 1994, 1998, 2005, Veblen 1919, Commons 1934, Vatn 2005, Hodgson 2006)

- “rules and conventions of society that facilitate coordination among people regarding their behaviour” (Bromley 1991, p.22);
- “rules of the game in a society or, more formally are the humanly devised constraints that shape human interaction” (North 190, p.3);

In a general review of the semantics and definitional variants of institutions, Hodgson (2006, p.2) consolidates several disciplinary pedigrees and defines institutions as “systems of established and prevalent social rules that structure social interactions”.

Institutions are the self-perpetuating ‘*going concerns*’ that order the relationships between individuals in society, providing the laws, constitutions, contractual regimes and moral and ethical precepts (Randall 1987). The market, implemented in the context of non-attenuated property rights, is itself an institution, subject to the same social conventions influencing the entire institutional framework.

Institutions shape, direct, influence and constrain; they define the incentives, disincentives, obligations and freedoms facing individuals. Institutions exist in a dynamic state of tension between stability and modification. They need to be malleable enough to accommodate change, brought about by extensive and pressing social consensus, balanced within a predictable and stable framework (Randall 1987). They must be in accord with the value system of society, without substantial variance, or they run the risk of social divergence resulting in excessive monitoring and compliance costs and at the extreme, civil disobedience and anarchy (Bromley 1991, Randall 1978).

Property rights are one of the elements of the institutional framework, which subsequently places thresholds and restrictions on the specification and manipulation of property rights for social and economic purposes (Randall 1987).

Property, according to Bromley (1991),

*“...is a benefit (or income) stream, and a property right is a claim to a benefit stream that the state will agree to protect through the assignment of duty to others who may covert, or somehow interfere with the benefit stream...  
(p)roperty is not an object but rather a social relation that defined the property holder with respect to something of value (the benefit stream) against all others”*  
(Bromley 1991 p. 2).

Bromley (1991) states that negotiable water entitlements must therefore be specified in terms of secure, enforceable rights, articulating the duties of the right holder, the obligations of those excluded from the right and the duties and obligations of the managing authority.

The construct of property relies on the recognition by society of the legitimacy of the individual claim to a benefit (that is gained by using a resource). Society is then prepared to forgo that claim and enter into a contract of compliance to enforce the rights to that claim (Bromley 1991). Property rights afforded to individuals are subordinate to the social recognition of those rights. Rights can only exist where there is a social mechanism that specifies duties and binds individuals to those duties. If the state, according to prevailing social norms, will not recognise and enforce the property right claim, then the right fails to gain legitimacy as an instrument (Bromley 1991).

Fully articulated, non-attenuated property rights are:

1. completely specified, so that it can serve as a perfect system of information about the rights that accompany ownership, the restriction on those rights and the penalties for their violation;
2. exclusive, so that all rewards and penalties resulting from an action accrue directly to the individual empowered to take action;
3. transferable, so that rights may gravitate to their highest-value use;
4. enforceable and completely enforced (an un-enforced right is no right at all).

Schlager and Ostrom (1992) propose that articulated private property rights are comprised of a complete bundle of property rights, which consist of rights of access, withdrawal, management, exclusion and transfer. Private property rights are vested in the individual, and in the granting of that bundle of rights, the individual can anticipate state sanctioned enforcement against those that choose to lay claim without consent.

The rights of access and withdrawal grant the individual the authority to access and make use of property. The right of management grants the individual the authority to decide the manner in which the property is used. The right of exclusion allows control of access to the property with expectation of state enforcement when required. The right of transfer allows the individual to sell, lease, rent, bequeath or otherwise dispose of the property.

Commenting specifically on rural surface water rights, Randall (1981) argues that negotiable water entitlements must be specified in terms of the secure, enforceable rights and duties of the right holder and the duties and obligations of the managing authority. Water rights need to be resolved and articulated in terms of (Randall 1981 p. 202):

1. the time-span of the entitlement and provisions for rental rights to deliveries in the event that long term entitlements are specified;
2. the method of accommodating the stochastic nature of water availability. Possibilities include individual rights to some specified small fraction of deliverable water available, and the specification of different entitlement classes in terms of reliability that is, the probability of water delivery;
3. the time and place of delivery;
4. the ownership of tail waters and return flows and the attendant obligations upon the owner.
5. the conditions under which entitlements could be transferred, with special reference to transfers which would change the time and /or location of water demand.

Water is characterised by multiple economic benefits and constructed social values, hence it has been defined by different notions of property. As a consequence, water as a shared resource has been managed according to various property regimes. Private property and centralised State management regimes are not the only choices available to water policy makers (Quiggin 1986, Randall 1987, Ostrom 1998, Ward *et al.* 2008). They represent the extremes of a continuum of possible property management regimes. Four of the intervals on that continuum are shown in Table 4:

**Table 4 Classification of property regimes**

Type of regime	Implications
<b>State Property</b>	Individuals have a duty to observe the use and access rules determined by the controlling (or management) agency of the state. The agency has the right to determine the access and use rules.
<b>Private Property</b>	Individuals have a right to undertake socially acceptable uses and a duty to refrain from socially unacceptable uses. Non-owners have a duty to allow socially acceptable uses to occur unimpeded, and a right to expect that only socially acceptable uses will occur.
<b>Common Property</b>	The management group (owners) has a right to exclude non-members (a right sanctioned and enforced by the same authority structure pertinent to private property). Non-members have a duty to abide by the exclusion. Individual members of the management group (the co-owners) have both rights and duties with respect to use rates and maintenance of the resource owned.
<b>Non-Property (open access)</b>	There is no defined group of users or owners and the benefit stream is available to anyone. Individuals have both privilege (the ability to act without regard to the interest of others) and the right (the incapacity to affect the actions of others) with respect to use rates and maintenance of the asset. The asset assumes the status of an open access resource.

(Source Bromley 1991)

In discussing policy innovations for recycling (Radcliffe 2007) refers to these property regimes as the state approach, the market approach, the consensus based approach and the empowerment approach respectively. Depending on the economic characteristics of the water resource and the parameters of scarcity, there are examples of all regimes having been applied to manage water. Different regimes may confer comparative advantages in achieving specific policy objectives, for example, equity, distributional justice and the scale of water diversions.

MAR is characterised by several operational elements, where water from each element is likely to be described by discrete economic characteristics. Stormwater, aquifers and receiving environments of recovered water are likely to be common pool resources and warrant exploration as to the challenges and opportunities of appropriate policy prescription and instrument design.

### **4.3. Water as a common pool resource**

In some urban settings, water can be classified as a common pool resource, partially characterised by enforceable, exclusive, excludable and transferable rights to utilise a defined amount from the total available water. The substantial residual component of available water confers a mutually shared, environmental benefit to the owners of those extractive rights, which is both costly to exclude beneficiaries (a characteristic shared with public goods) and subject to rival or subtractable consumption (a characteristic shared with private goods).

When joint outcomes depend on multiple actors contributing inputs or actions that are costly and difficult to quantify, and policy instruments are deficient in restricting

usage, incentives exist for individuals to act opportunistically. Opportunistic actions lead to resource over appropriation, often at a level where aggregate overuse and reduced benefits occur. A social dilemma arises when individuals are tempted by short term gains to over appropriate the common pool resource, thereby imposing group shared costs on the common pool community (Ostrom 1998). Individual over-appropriation will eventually lead to reduced benefits for all.

Markets (private and common property), regulatory instruments (state property) and social compacts (common property and common pool resources) are water policy approaches implemented to either resolve or reduce contestability.

Markets are attractive because of their ability to coordinate and truthfully reveal private information. They are effective economisers of information, expressed as precise price signals (Smith 2002) and coordinators of price signal responses into collective action. Bowles and Gintis (2002 p. 423) posit that when comprehensive and coherent contracts can be drawn and enforced at low cost, markets are superior to other governance structures; particularly *"[w]here residual claimancy and control rights can be closely aligned, market competition provides a decentralised and difficult to corrupt mechanism that punishes the inept and rewards high performers"*.

In contrast, the state is relatively well suited for handling particular classes of problems where it alone has the power to make and enforce the rules that govern the interaction of private agents: e.g. if participating is mandatory (public health, education and defence)(*ibid*). Bromley (1991), Ostrom *et al.* (1992), Ostrom (1998) and Bowles and Gintis (2002) articulate an alternative arrangement, proposing that common pool resources can be effectively managed if information, communication and sanctioning options are available to those using the resource.

Bowles and Gintis (2002 p. 424) argue that *"...communities can resolve common pool dilemmas that states and markets are not well equipped to manage, especially where the nature of social interactions or of the goods being transacted makes contracting highly incomplete or costly"*. Adjudication on distribution, exclusion or enforcement initially relies on the revelation of dispersed private information, unavailable to the state. Socially crafted institutions coordinate revealed information into collective governance by applying rewards and punishment to members according to their conformity with or deviation from social norms [*ibid*].

Community crafted arrangements tend to rely on social norms that utilise incentives that reinforce collective action such as trust, reciprocity, reputation and prestige, personal and community pride and the avoidance of group sanctions [*ibid*, Ward *et al.* 2008]. Communication and the high probability of future interaction promotes strong (or conditional) reciprocity and the avoidance of retaliation; sanctions reinforce the benefits of the social compact through reputation. Successful socially crafted compacts that utilise communication are reinforced by self monitoring, strong reciprocity or conditional cooperation and a series of escalating, credible sanctions.

In a general sense policy instruments are the tools available to policy makers to influence societal processes and behaviour such that they align with and remain compatible to defined economic, environmental and social targets. These are made operational as policy objectives and their level of success expressed as measures of effectiveness, efficiency and equity. To avoid the social costs of poor policy performance, instruments are required to be aligned with individual values and motivations and account for specific resource characteristics. In many circumstances it may be prohibitively costly to address the non-exclusivity parameter of a common pool resource: *viz.* to assign individual defined property rights. In those

circumstances either non-market based instruments or novel, carefully sequenced hybrid instruments are candidates likely to be superior in achieving policy objectives.

To promote efficient and effective water allocation, Australian water reform has emphasised institutional and governance approaches promoting voluntary transfers of water through market exchange where appropriate. These in turn are reliant on enforceable, exclusive, excludable and transferable property rights vested in the individual and independent of land. In addition, a competent and willing regulatory framework is antecedent to effective markets, to ensure the specification and enforcement of fully articulated property regimes (Quiggin 1998, Young and McColl 2003a, b).

Tradeable MAR entitlements and allocations involve establishing an enforceable threshold for management, either as maximum effluent levels, prescribed resource usage or minimum environmental provision; distributing entitlements among participants as a quantum or unit share(s) and allowing trade of those units among those in the scheme. The environmental objective is to ensure the total number of units does not exceed the prescribed threshold for a given accounting period (usually one year). To satisfy compliance obligations, each participant in the scheme must be able to surrender units equal to their entitlement at the end of the accounting period. Therefore, participants can choose actions in response to individual management capacity, aquifer and resource attributes and production costs. Non-compliance incurs individual penalties which are typically greater than the costs of complying.

While the cap imposes a cost on individuals, the opportunity to trade has the potential to compensate that loss or reduce the cost burden. Some individuals will choose to use more than their quantum (and incur a debit), and others will choose to use less (being rewarded with credits). This results in a tension in the contracting process. There is a need to negotiate contracts so there is sufficient differential in the system to encourage trade but not so much that the negotiated output prevents a feasible solution. A challenge for market based MAR policy is to create the opportunity for a frictionless market setting where participants could quickly learn to understand the advantages of trade with low learning and exchange costs relative to trade benefits. Information from market exchange, expressed as coherent prices signals, would reveal any differences in returns to management options and these would be immediately discovered and exploited.

An important advantage of quantity based instruments over other policy options is a greater level of environmental certainty as a result of the prescribed and enforceable threshold or cap. There are a number of preconditions for a functioning and effective cap and trade scheme for MAR elements. They are:

- There is credible and reliable science to establish a threshold level that is clearly understood and matches the resource condition target;
- There are cost effective monitoring schemes in place that are transparent, consistent and credible to all participants. There must also be a clear link between management actions and the subsequent environmental outcome. In cases where the environmental outcome is not readily visible (for example recharge into aquifers) an agreed proxy indicator may be necessary;
- The nature (toxicity) of contaminates is such that market exchange will not result in localised concentrations, which may cause excessive either aquifer degradation or hoarding of entitlements;

- There is sufficient differentiation in individual production costs across the MAR region. If there are no differences there is no incentive to trade;
- There are regulatory agencies with effective regional jurisdiction to monitor and audit compliance levels and effectively enforce individual breaches;
- There are sufficient numbers of participants to ensure cost effective exchange opportunities and satisfaction of trading requirements;
- The transaction costs of monitoring, gathering information, enacting the exchange and enforcement are low in relation to the potential benefits gained;
- There are adequate and effective administrative institutions to ensure a functional market and;
- It is politically feasible to develop transferable, enforceable and tradeable private property rights, to minimise government intervention and allow flexibility of decision making.

Similarly, the analysis of competitive markets is premised by a set of predicates, articulating that exchange outcomes are highly excludable, divisible, transferable and fully internalised by those engaged in the exchange process. In an idealised market, agents acting as profit maximisers responding optimally to coherent, accurate and reliable price signals can reach collective decisions resulting in an ordered, predictable outcome which is superior to other possibilities and dispositions. The reality is that the full set of conditions necessary to ensure frictionless and efficient markets and to comply with cap and trade prerequisites are rarely if ever present. In many market settings there are numerous impediments to the satisfaction of these conditions. An overview of the practical consequences to water related market outcomes is specified in Ward *et al.* (2008) and are considered in the examples in Section 7.

#### **4.4. Robust design and the separation of rights**

The robust separation of water rights, articulated by Young and McColl (2003), provides a theoretical design framework that has informed recent Australian water reform. As signatories of the National Water Initiative (CoAG 2004), States and Territories have agreed to NWI (s.37, s.28-32) which recommends that water access entitlements be specified as unit shares of a consumptive pool defined by a water plan (s.36), subject to periodic water supply (allocations) and an accounting of the 3<sup>rd</sup> party impacts of water use. Entitlements, allocations and obligations of final use are to be managed independently, ideally using separate policy instruments.

The NWI framework defines water access entitlements as perpetual unit shares of a defined consumptive volume of a water resource. Periodic allocations are made in accord with annual inflows, storage volumes and in proportion to the number of shares held. Risk is assigned between users and the Government.

According to Young and McColl (2003) the separation of rights provides the opportunity for the twin water policy objectives of distributional equity (including the environment as a legitimate user of water) and economic efficiency in a changing world to be managed independently. As a result, both entitlements can be traded (permanent trades) as can annual allocations (temporary trades) at relatively low transaction costs.

A system is defined as robust when it has demonstrated an ability to *recover gracefully* from the whole range of exceptional inputs and situations in a given environment. Young and McColl (2003) note that robust systems are also one step below *bulletproof*, and carry the additional connotation of *elegance* in addition to careful attention to detail. Robust systems persist without the need to change their foundations. They have a structure that inspires confidence and can be expected to produce efficient and politically acceptable outcomes in a changing world. Relevant examples of robust institutions are:

- i) The limited liability share company structure— where interests expressed in proportional terms (shares) and dividends are managed separately.
- ii) The Torrens Title system – with guaranteed recording of all interests on a register, formal settlement procedures, and irreversibility of market transactions.
- iii) The banking and finance system – with internet debit and credit accounting systems, exchange rates and associated formal transaction mechanisms.

Principles set out by Tinbergen (1952), Mundell (1960) and Coase (1960) provide the formal, theoretical basis for robust design. Tinbergen argued successfully that there is a need for as many control instruments as there are policy objectives: i.e. there is a need for one instrument for the policy targets of entitlement distribution, one for allocations which reflect climatic variability and one for resource use that accounts for third party interests. Mundell argued that to ensure stable outcomes, instruments need to be paired with objectives over which they have most influence. Finally Coase stipulated that, contingent on low transaction costs relative to benefits, efficient outcomes are achievable regardless of the initial distribution of tradable rights.

According to Young and McColl (2003) to achieve a robust framework for water access entitlements there must be at least one set of instruments for each significant water resource problem, especially in heterogeneous landscapes. That set is comprised of separate entitlement, allocation and externality instruments. Discrete sets of instruments are required when both individual and collective water decisions are feasible.

Young and McColl (2003), the NWI (CoAG 2004) and Young (2007) propose a three tiered “unbundled” or separated system of instruments to distribute and allocate volumes of water (or other natural resources) efficiently over time. A Water Plan establishes the community values, rules and science based guidelines to appraise the state of a water system and subsequent to that appraisal, prescribe the rules to determine the environmental and consumptive “pools”.

When more than one person has an interest in the consumptive “pool” the first policy instrument defines the unit shares of the pool and the distribution of shares to individual interests. This allows water managers to distribute access entitlements to available consumptive water.

The second instrument defines an independently managed process to periodically allocate the amount of water to each share. This allows water authorities to independently manage the consumptive pool when faced with changing ambient conditions and to assign the risk of a variable water supply.

The third instrument prescribes or proscribes the obligations of water use. Since the impact of water use varies according to geography and activity, this allows the environmental and health impact of water use to be managed independently.

A robust system of water management will:

- 1) resolve the resource allocation tension between consumptive use and the environment: and amongst consumptive users, issues related to equitable distribution and use;
- 2) provide secure, economically efficient trading associated with low costs and administrative feasibility;
- 3) clarify the assignment of risk making it clear where responsibility lies, under what circumstances compensation is due, and specify the processes for obtaining redress, and
- 4) address the management of externalities accounting for the interests of third parties, future generations and the environment – with minimum controversy.
- 5) A robust system also must pass the conventional tests of efficiency and fairness in a changing world.

Young and McColl (2003a), in accord with NWI (CoAG 2004) contend that these objectives are best achieved through the robust separation of water interests and recommend:

- 1) **water entitlements** specified as secured long term unit shares of a variable pool of consumptive water, subject to periodic allocation;
- 2) an agreed process for **the allocation** of water when it becomes available, typically on an event, season or annual basis contingent on science and the state of the resource, managed independently of entitlements;
- 3) a process to assign risk defining unequivocally where responsibility lies, under what circumstances compensation is due, and the processes for obtaining redress with non-controversial settlement;
- 4) conditions and **obligations specified in a separate water use licence**, cognisant of third parties and mitigating negative external effects;
- 5) the introduction of debit and credit accounting systems, water exchange rates and associated formal transaction mechanisms;
- 6) the guaranteed recording of financial and other formal interests on a register, formal settlement procedures, and irreversibility of market transactions;

In an extension of Tinbergen (1950), robust systems are characterised by the use of separate instruments for each distinguishable or discrete component of the water cycle and water use system. Young and McColl (2003) contend that the separation of water interests into component parts facilitates more efficient accounting and management systems, providing for the adjustment of one system component without disrupting or readjusting another.

Combining the operational elements of MAR with the principles of robust separation rights into a unified framework suggests a systematic governance arrangement. The framework allows for the independent and flexible management of elements characterised by separate and potentially exclusive policy objectives. A governance framework based on the robust separation principles with the potential to distribute entitlements, allocations and use obligations is summarised in Table 5.

**Table 5 Governance instruments for MAR based on the robust separation of rights**

MAR governance instrument:	1	3	5	7
	Capture Zone	Recharge	Recovery	End use
<b>Entitlement</b>	Unit share in stormwater or effluent consumptive pool, (i.e. excess to environmental flows)	Unit share of aquifer's finite additional storage capacity	(Tradeable) extraction share which is a function of managed recharge.	
<b>Periodic allocation</b>	Periodic (usually annual) allocation rules. Potential for additional stormwater or effluent offsets	Annual right to raise the water table subject to ambient rainfall and total abstraction	Extraction volume contingent on ambient conditions, natural recharge and spatial constraints	
<b>Obligations and condition</b>	3rd party rights of access to infrastructure for stormwater and sewage	Requirement not to interfere with entitlements of other water users and water bankers	Existing licence may need to be converted to compatible entitlement to extract (unit share)	Water use licence subject to regional obligations and conditions, for use and disposal

#### 4.5. Applying robust design to a countercyclical MAR groundwater system

Figure 2 illustrates a simplified MAR scheme superimposed over an existing fully appropriated native groundwater system. The management of the MAR system represents a capacity sharing approach combined with the robust separation of rights, approaches that correspond with the objectives of the NWI. Dudley and Musgrave (1988) proposed a system of capacity sharing of surface water resources, based in part on a common property regime. Capacity sharing is explained thus:

“Capacity sharing is a water allocation system by which users are allocated a share of the capacity of the storage as well as inflows and seepage and evaporation loss. In effect the storage is partitioned into sub-storages which are credited with a volume of water according to the hydrological behaviour of the storage and its catchment. Users have non-attenuated [*fully specified*] rights in this water and can direct the manager of the storage concerning its retention or release” (Dudley and Musgrave 1991 p. 7, own italics).

Brennan and Scocimarro (1999) and Musgrave and Kaine (1991) discuss capacity sharing as a means of conferring tradeable property rights in surface water dams and to environmental flows in Australian river systems. The primary difference between the simplified MAR operation proposed below and those of Dudley and Musgrave (1988) and Young (2005) is that MAR schemes provide both an additional source of water and storage capacity.

**Figure 2 Schematic of recharge and recovery entitlements and allocations for MAR in (a) an average year, (b) a wet year, and (c) a dry year**

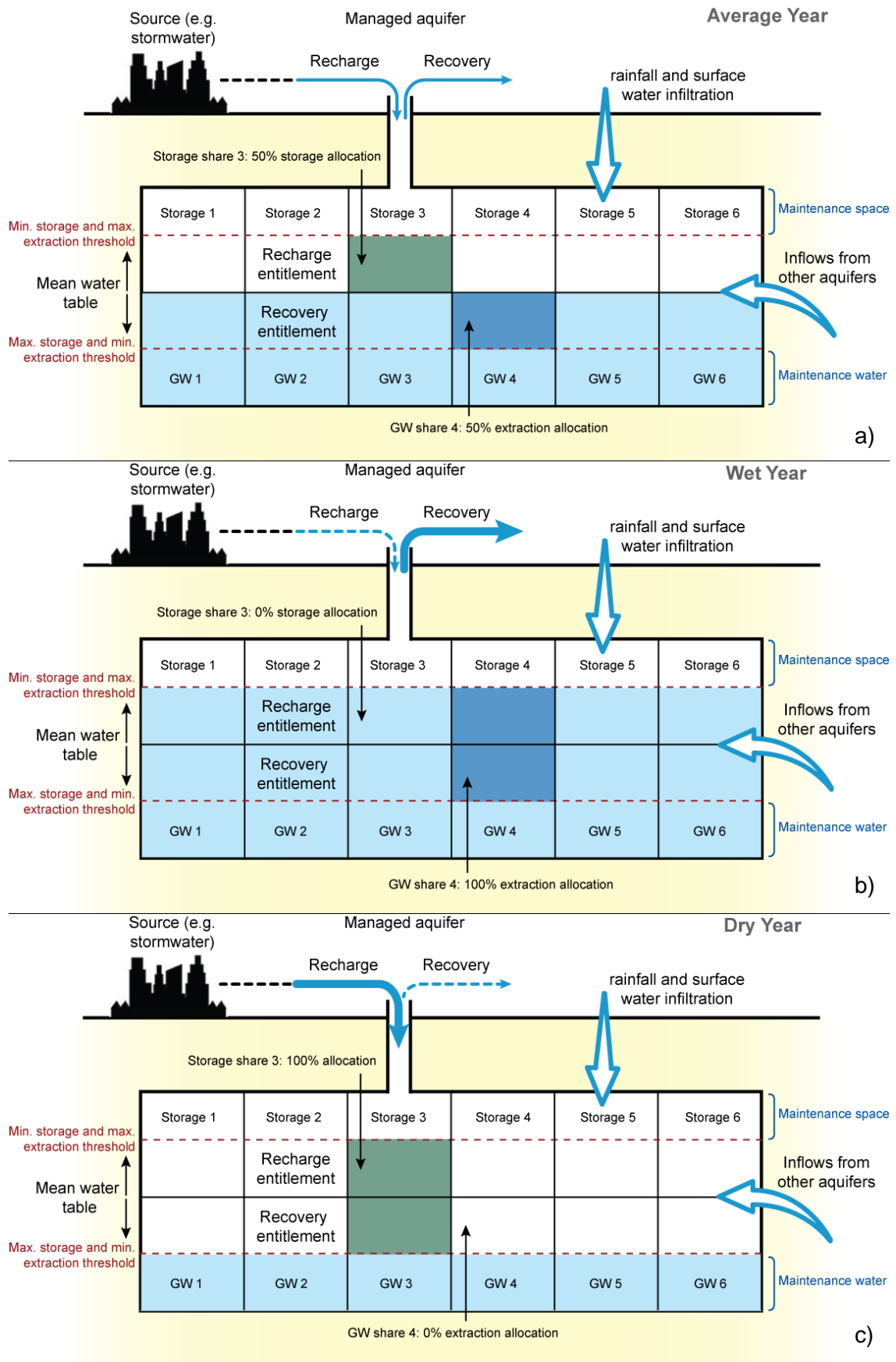


Figure 2 represents a conceptual groundwater system consisting of six existing shareholders with entitlements to extract groundwater and six MAR operators entitled to equal shares of the aquifer storage capacity. For illustrative purposes shareholder 3 is the sole MAR operator. The diagram is in three parts describing allocations of recharge and recovery for three scenarios representing average, wet and dry years respectively. For simplicity of conceptualisation, the diagram is drawn as though the aquifer is unconfined and the mean water table ranges between aquifer full and aquifer empty. The diagram can also be applied to confined aquifer systems by substituting piezometric head for water table. The maximum storage corresponds to the level above which environmental or economic harm is considered to occur, and the minimum storage level is the minimum acceptable level of well operation (e.g. all wells are capable of yielding adequate water to meet their allocations). In all cases, aquifer management is subject to protecting groundwater dependent ecosystems.

The figure assumes the MAR scheme recharges the aquifer counter-cyclically with existing users of abstracted native groundwater. That is, managed recharge occurs when rainfall and source water is abundant, and recovery occurs in times of water stress when demand from other groundwater water users is also highest. Conversely native groundwater is abstracted when the natural infiltration has been high and is limited during times of water stress.

The figure suggests that recharge water is differentiated from native groundwater in storage and that the MAR operator (shareholder 3) recovers recharged water before drawing on their native groundwater allocation. In many situations it will in fact be quite difficult to discriminate the mix of source water and native groundwater on recovery and the proportion will change during recovery. This does not alter the proposed water allocation policy proposed below. The figure may suggest that aquifer storage is non-leaky and aquifer storage volume is a definable single value. This also is incorrect, because each aquifer will generally have characteristic water residence times that may vary from months to many millennia, but a simple adjustment will be shown later to accommodate this effect in water allocations.

It is assumed here that pre- and post- treatment and all aspects of MAR operation and monitoring comply with MAR Guidelines (EPHC 2008c) and their jurisdictional equivalent legislation. For illustrative purposes it is assumed that stormwater is the primary source of water for MAR, and stormwater has been similarly managed with an entitlement of the consumptive pool available for harvesting. Stormwater entitlements and allocations are discussed in Section 7.

It is assumed that at the outset there exists an aquifer water management plan that defines the ambient environmental “pool” expressed as the range of allowable water table heights, or aquifer storage capacity and prescribes the management of native groundwater in the aquifer. According to the decision framework, each MAR process requires the discrete specification of a unit share entitlement of a defined pool and independently managed rules to establish periodic allocation and the conditions of use.

The first of these is an entitlement to access aquifer storage space to warehouse reclaimed or recharged water. Net aquifer storage capacity accounts for a finite storage space by prescribing a cap on water table height (piezometric head for confined aquifers).<sup>12</sup> The cap establishes the consumptive “storage pool”. A recharge

---

<sup>12</sup> The NRC (2008, p.187) notes that aquifer storage poses a substantial legal challenge, unique to MAR projects. Groundwater rights are relatively well developed in the United States, however there is no readily available reference for entitling access and management rights of aquifer storage rights. Thus in

entitlement represents a unit share in available aquifer warehousing space, defined as a quantum of the net storage capacity. The entitlement therefore defines the right to actively store additional water or the right to raise the water table.

The water plan also prescribes the consumptive pool for native groundwater. The native groundwater unit share represents the abstraction entitlement, defined as a quantum of the net extractive capacity.

In the first instance, the MAR scheme and native groundwater are assumed to be managed independently. This is achieved by way of separate native groundwater abstraction entitlements (GW 1–6) and MAR recharge entitlements (storage 1–6).

GW 1–6 represent six existing, independent, equal and tradeable native groundwater entitlements. Individual extractors can of course manage more than one entitlement. Groundwater is institutionally differentiated from ASR recharged water for illustrative purposes. Hydrological mixing of ASR recharge and native groundwater is inevitable. Monitoring to physically differentiate the two water sources is likely to be technically demanding and prohibitively costly.

Options for entitlement conditions that account for mixing by way of separate groundwater and MAR accounts are suggested in the case studies of Section 7. The minimum and maximum extraction thresholds represent the bounds of the extractive consumptive pool of native groundwater.

Storage 1–6 represents six individual and independent tradeable recharge entitlements. Individual MAR rechargers can of course manage more than one entitlement. We assume they are unit shares in the consumptive storage capacity of the aquifer that remains unoccupied by natural recharge. The minimum and maximum storage thresholds in the diagram define the bounds of the storage consumptive pool.

The illustration represents an aquifer with fully appropriated groundwater. There are no new entitlements available: that is all entitlements, by way of unit shares, have been assigned. The entitlements are subject to a yearly allocation defining the proportion of the entitlement (*viz.* the volume of groundwater) that can be abstracted.

Holding a recharge entitlement does not automatically confer the right to recharge water to the aquifer.

Variable yearly allocations to recharge, announced at the beginning of a water year, are equally apportioned to all recharge entitlements. Allocations, contingent on the height of the native groundwater table, are calculated as the deficit between natural recharge and total existing extractions. The periodic allocations for native groundwater abstraction in Figure 2 are prescribed along similar principles.

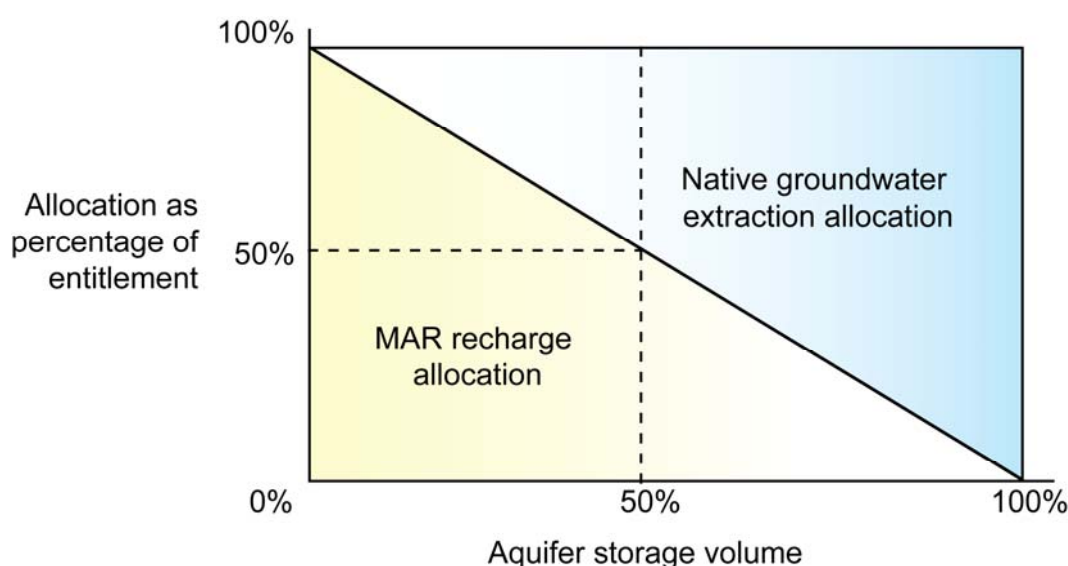
The minimum recharge threshold in Figure 2b (the uppermost water table) represents a 0% yearly allocation of MAR recharge entitlement. The threshold provides an instrument for managing agencies to maintain the minimum functional integrity of sub-surface aquifer storage, called here the 'maintenance space'. Recharge in excess of the minimum threshold is likely to cause third party effects, such as increased hydraulic pressures, effect building structures or foundations, geological structures or water logging. This represents an effective cap on managed recharge.

---

the absence of a statutory provision it is unclear whether the rights to aquifer space are controlled by the owner of land above, the owners of water use rights in the aquifer or by no one at all.

Conversely, a water table at the maximum recharge threshold of Figure 2c (the lowest water table) confers 100% of an ASR operator's recharge entitlement.

A water table at the maximum abstraction threshold allows a native groundwater user a 100% allocation of their abstraction entitlement (Figure 2b). The minimum threshold confers a 0% native groundwater abstraction allocation (Figure 2c). Abstractions of native groundwater in excess of the 0% allocation threshold corresponds to an over drawn aquifer. The minimum extraction threshold allows agencies to manage the minimum functional integrity of native groundwater, called here 'maintenance water' for example required to prevent saline intrusion or support groundwater-dependent ecosystems. The countercyclical allocations of recharge and native groundwater extraction as a percentage of entitlement is illustrated in Figure 3.



**Figure 3 Countercyclical allocations of MAR recharge and native groundwater extraction**

Clearly the definition of the threshold limits for entitlements for MAR and native groundwater abstraction operate counter-cyclically. Both MAR operations and native groundwater abstractors must operate according to allocations that account for ambient groundwater conditions set out in the water plan.

The principle reason for aquifer storage is to enable reliable access to a defined and independently managed volume of water in times of increased water demand or to meet contractual obligations. Secure entitlements to recover stored water are therefore critical in all MAR operations.

Options for defining entitlements to recover stored water are considered in the case studies (Section 7). One option is mindful of simplicity and parsimony in institutional design and suitable for schemes with low operator numbers. To maintain consistency with current administration processes the right to recover stored water would be annexed to an existing MAR recharge entitlement, expressed as a proportional volume of recharged water and that accumulated through previous aquifer storage. When combined with the careful temporal sequencing of policy instruments this strategy is likely to minimise transaction costs and encourage MAR scheme participation.

A second option allows for entitlements and periodic allocations to recover stored water to be independently defined. As the number of MAR operations increases, expertise in MAR and trading improves and the relative cost of transactions decreases, the potential of further efficiency gains and innovation may warrant the

unbundling of storage and recovery entitlements. The examples describe a possible configuration of recovery entitlements and allocations.

The robust separation of rights requires the independent management of entitlements and allocations. Consistent with the constitutional notion of the separation of powers, enforcement is also managed independently. Thus:

1. Entitlements in the aquifer storage and recovery “consumptive pools” are determined by the Water Resource Authority managing the overall condition of the resource with reference to a groundwater Resource Plan. Ideally an overarching Water Plan conjunctively manages groundwater and connected surface waters. ;
2. An expertise based agency, informed by current science, announces the periodic allocations;
3. An account register is kept of MAR entitlements that receive allocations, the actual allocations, volumes of recharge and recovery for each individual entitlement holder; and
4. Arrangements allow for the exchange of either transferable entitlements or periodic allocations to recharge the aquifer and recover water: enabling the entry of new aquifer users and the expansion of existing users.
5. The rules that prescribe infringements for using unallocated aquifer space and taking unallocated water are defined in the entitlement specification. An independent agency is responsible for the monitoring, investigation and enforcement of prescribed sanctions.

Figure 2 (a, b and c) represent the groundwater system subject to average, wet and dry years respectively. Figure 3a graphically illustrates an average year, characterised by a mean water table height and mean aquifer storage capacity, corresponding to a 50% recharge storage allocation for Storage unit share holder 3. The mean water table corresponds to a 50% native groundwater extraction allocation for GW extraction share holder 4.

An option for determining recharge allocations is to use for example a moving 5 year average of the storage capacity, accounting for both changing natural recharge levels and to provide additional predictability and more reliable planning. A moving average contingent on the magnitude of the public benefit provided by the private operations apportions risk more equitably between the government and commercial operators. The through flow and dispersal rates of the aquifer will determine the duration of the moving average.

Recovery of recharged water is tied to the recharge entitlement. In an average year the operator can recover 100% of stored water if water is taken in a prescribed period following recharge. A one year period for example would ensure there is sufficient stored water at the injection site for recovery. Stored water is subject to injectant migration and dispersal. Recovery of long term water deposits are subject to a depreciation rate that reflects characteristics specific to the aquifer (outlined in section 6). The recovery function is defined as part of the recharge entitlement.

We assume that the recovery of stored MAR water is secured through recovery credits determined by the volume of recharge and is institutionally differentiated from native groundwater. Alternative recovery entitlements are discussed in Section 6.

## 5. STATE WATER PLANS, LEGISLATION AND THE PROJECTED ROLE OF MAR

Section 5 is intended as a summary guide only and should not be interpreted in any way as representing approved State Government policy. In all States, several Government Departments have a role in the approval of MAR schemes. They should be consulted for clarification regarding specific approval and licensing arrangements for MAR operations.

The section documents and locates State policies according to the governance typology outlined in Section 4. Policies and instruments are listed in the following order:

- Those that prescribe or provide for the harvesting or capture of source waters.
- Those that provide for aquifer recharge and storage and
- Those that prescribe or refer to the recovery of recharged water.

Policies that prescribe obligations and regulations for final fit for use of recovered water generally relate to water quality. These are listed but not discussed.

A more comprehensive review of MAR related policy for each Australian State is provided in the Appendix. The review assumes that all State legislation prescribing actions to account for Native Title and Aboriginal Heritage will apply to all MAR operations.

Note: a summary of water quality regulatory frameworks and guidelines, applicable at the time, for Queensland, New South Wales and Victoria is provided in Radcliffe (2004, p.199-212). The National Water Commission water Governance website<sup>13</sup> provides an assessment of Australian water governance up to 2005. Fisher (2000) evaluates Australian water law developing a systematic and comprehensive classification of the structural elements and prescriptive rules. On a State by State basis, Fisher describes a legal structure for managing water resources within particular policy contexts. Some State legislation and Acts have been repealed or amended since 2000.

The National Research Council of America (2008. p.187) provides an important insight into the determination of access entitlements for aquifer storage in the United States that is relevant to Australian MAR policy. They argue that aquifer storage poses a substantial legal challenge, unique to MAR projects. Groundwater rights are relatively well developed in the United States although they generally do not recognise or account for connected surface waters. However there is no readily available reference for entitling access and management rights of aquifer storage rights. Thus in the absence of a statutory provision it is unclear whether the rights to aquifer space are controlled by the owner of land above, the owners of water use rights in the aquifer or by no one at all.

### 5.1. South Australia

#### Key Points

1. The *Local Government Stormwater Management Amendments Act 2007* set out the inclusion of stormwater infrastructure within defined surface waters, making explicit the provisions and capacity to regulate the capture of stormwater. South Australia is the only state to specify provisions for stormwater in this manner.
2. Surface water, including stormwater is not currently prescribed for Central Adelaide and the northern Adelaide plains. According to the current legislative framework,

---

<sup>13</sup> [http://svc044.wic032p.server-web.com/nwi/water\\_governance/index.cfm](http://svc044.wic032p.server-web.com/nwi/water_governance/index.cfm) currently being updated as part of the baseline evaluation for the 2010 NWI assessment [http://svc044.wic032p.server-web.com/nwi/water\\_governance/index.cfm](http://svc044.wic032p.server-web.com/nwi/water_governance/index.cfm)

stormwater can be harvested, diverted and stored in Adelaide and surrounding suburbs without the need for a water licence.

3. Aquifers intentionally recharged via percolation are likely to represent a prescribed activity of environmental significance (Schedule 1, 4(2) of the *Environment Protection Act 1993*). Direct injection via a well is subject to the provisions of the *Natural Resources Management Act 2004*. The EPA Code of Practice (p.2) states that “many ASR (*operations or wells*) will not need a licence”; however the conditions for exemption are not made explicit (own italics).
4. MAR granted approval under the either *Environment Protection Act* or the *Development Act*, both of which apply to large scale MAR schemes, may confer exemption from the provisions of the *Natural Resources Management Act*.
5. Source water assumes the status of groundwater when intentionally recharged into an aquifer. Extraction of stored water will require a licence and allocation for groundwater in a prescribed wells area, including the proposed Central Adelaide prescribed Wells area (*Natural Resources Management Act 2004* s.146 and s. 152). It is unclear that stored water can be extracted independently of the provisions of a prescribed groundwater area when that area is deemed as under threat (s.132).
6. Dickey and Reznikov (2008) argue that there remains a risk that other (groundwater) users will be granted licences to take stored water... as with ASR schemes outside prescribed wells areas, the operator of an ASR scheme has no proprietary right to the water stored under the scheme. The cumulative interference of domestic non-prescribed wells is an additional complicating factor.
7. The lack of clarity regarding instruments to protect stored water from third party influences is likely to act as a strong impediment to commencement of commercial MAR operations. The *Waterproofing Adelaide* (SA Gov 2005) seeks to review the legal issues surrounding ownership access rights to surface and groundwater resources to provide appropriate levels of security and certainty for potential stormwater users (Strategy 50).

	<b>Policy</b>	<b>Comment</b>
<b>1</b> Capture Zone	i) LGSMA Act 2007	Uncertain status of access to stormwater in metropolitan Adelaide despite stormwater prescribed as surface water.
	ii) NRM Act 2004	Provides for prescribed watercourses
	xi) CoP EPA 2004	Guidelines for source water quality
	vi) D Act 1993	Provides for retention ponds and wetlands
<b>2</b> Pre-treatment	iii) , iv), viii), xi), xii) and xiii)	
<b>3</b> Recharge	iii) E P Act	Provides for MAR as prescribed activity of environmental significance and stormwater discharge
	vii) D R 2008	Provides for construction of wells and bores
<b>4</b> Subsurface storage	ii) NRM Act 2004	Permit required to inject into aquifer
	ii) NRM Act 2004	Provides for aquifer storage: may be exempt with authorisation from EP Act or D Act
	iv) EPA 1993	Discharge of stormwater
<b>5</b> Recovery	xi) CoP EPA 2004	Notes many ASR will not require licensing but exemption conditions not explicit
	ii) NRM Act 2004	Rights to water vested with the state. MAR stored water not differentiated from native groundwater. Licence and allocation required in prescribed water areas
<b>7</b> End use	iii) , iv), viii), ix), xi), xii) and xiii)	

Numbers in the policy column refer to corresponding legislation listed below.

### **South Australian Acts and legislation applying to MAR**

- i) *Local Government (Stormwater Management) Amendment Act 2007*
- ii) *Natural Resource Management Act 2004*
- iii) *Environment Protection Act 1993*
- iv) *Environment Protection (Water Policy) Policy 2003*
- v) *Planning and Environment Act 1987*
- vi) *Development Act 1993*
- vii) *Development Regulations 2008*
- viii) *Public and Environmental Health Act 1987*
- ix) *Food Act 2001*
- x) *Local Government Act 1989*
- xi) *Code of Practice for Aquifer Storage and Recovery (EPA 2004)*
- xii) *The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)*
- xiii) *The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).*

## Key References

Dickey , S. and Reznikov, K. (2008) Aquifer Storage and recovery: Legal Issues. Paper presented at Saving the Last Drop: water scarcity and the law. Environmental Defenders Office, March 13th, Adelaide.

Dyson, M. (2008) Regulatory framework for stormwater re-use: Presentation to The Stormwater Re-user Workshop, 19<sup>th</sup> September, Adelaide

Waterproofing Adelaide: a thirst for change 2005-2025. Government of South Australia.

[http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa\\_Strategy.pdf](http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa_Strategy.pdf)

## 5.2. Victoria

### Key Points

1. Injected water (whether reclaimed or not) is not distinguished from native groundwater and is classed as groundwater post recharge. Therefore sovereign rights are transferred to the State and subject to licensing arrangements of prescribed groundwater allocations.
2. The *Water Act 1989* identifies who has rights to the use of water in waterways. Recycled water (defined as sewage intended for reuse) is excluded from the obligations of licensing, although the Act is not specific as to the “recycled” status of stormwater.
3. Stormwater management is not specified in the *Catchment and Land Protection Act (1994)*, although it may comprise inflows to either a special area water catchment, or contribute to downstream aquatic habitats.
4. Specifying volumes of harvested stormwater as a component of Melbourne Water’s flood management plan may be one area of MAR source waters that is consistent with regulatory requirements for sustainable management, albeit indirectly.
5. Melbourne Water accepts responsibility for management areas greater than 60 hectares and Local councils are responsible for areas less than 60 hectares. When stormwater assumes resource value, subject to uncertain interpretation of the 60 hectare bound, it is unclear jurisdiction and entitlement determination will lie.

	Policy	Comment
<b>1</b> Capture Zone	i) W Act 1989 xi) CLP Act 1994 xi) EPA 1970 ii) WI Act 1994; iii) WG Act 2006 and ix) LG Act 1989 viii) SEPP WA 2003 vi) P and D Act 1987	Provides for exemption of recycled water and sewage: stormwater not specified May provide for stormwater as inflow to special water catchment Provides for licensing of scheduled premises: compliant effluent and stormwater exempt May provide for stormwater: jurisdiction for stormwater catchment s<60 Ha unclear May provide for stormwater Stormwater may require approval via EP Act
<b>2</b> Pre-treatment	iii), v), viii), xi), xii) and xiii)	
<b>3</b> Recharge	i) W Act 1989 viii) SEPP GWV and WoV 2003	Does not provide for MAR recharge but likely to apply as prescribed activity Provides for maintaining water quality but likely to apply for construction of wells and bores and injection. Consideration of conjunctive use applies
<b>4</b> Subsurface storage	i) W Act 1989 viii) SEPP GWV	Provides for extraction of recharged water aquifer Provides for relaxed water quality attenuation zones that are likely to apply to MAR

	vi) P and E Act 1987	MAR may be considered as special area plan
5 Recovery	i) W Act 2004	Rights to water vested with the state. MAR stored water not differentiated from native groundwater. Licence and allocation required in prescribed water areas
7 End use	iv), v), viii), xii), xiii), xiv), xv), xvi) and xvii)	

Numbers in the policy column refer to corresponding legislation listed below.

In a State review and appraisal of MAR in Victoria, Lumb (2006) and the Victorian EPA (2006 p.26) recommend that the nature and extent of entitlements of water injectors and water used for MAR schemes and recoverable volume may require:

- amendments to the *Water Act* to give priority entitlements to injected water to operators of MAR schemes;
- provision that existing rights to water can coexist with entitlements to injected water;
- entitlements to be expressed as a percentage of the water injected;
- clarification of entitlements to recharge and entitlements to recover and use groundwater from MAR schemes; and
- provision to trade and transfer as appropriate.
- Establishing allocation may require consideration of the water injected into aquifers for reuse. Possible options for resolution are:
- amend the *Water Act* to allow allocation limits to take into account water injected into aquifers;
- express entitlements as a share; and
- amend groundwater management plans

### Key References

Lumb, K. (2006) Alternative urban water supplies; regulatory review of managed aquifer recharge (MAR) technical report. Hyder Consulting for the Victorian Government, Report No VC 02161-01-MAR. Melbourne.

Department of Sustainability and Environment (2006) A framework for alternative urban water supplies: managed aquifer recharge (MAR): A discussion paper. Government of Victoria

[http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/c5fa02c8a18b8174ca25723b000e4644/\\$FILE/Discussion%20paper%20-%20Managed%20aquifer%20recharge.pdf](http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/c5fa02c8a18b8174ca25723b000e4644/$FILE/Discussion%20paper%20-%20Managed%20aquifer%20recharge.pdf)

### Victorian Acts and legislation applying to MAR

- i) *Water Act 1989*
- ii) *Water industries Act 1994*
- iii) *Water Governance Act (2006)*
- iv) *Health Act 1958*
- v) *Environment Protection Act 1970*

- vi) *Planning and Environment Act 1987*
- vii) *Building Act 1993*
- viii) *State Environment Protection Policy (Waters of Victoria 2003 and Ground Waters of Victoria)*
- ix) *Local Government Act 1989*
- x) *Melbourne and Metropolitan Board of Works Act 1958 (repealed such that Melbourne Water now derives waterway, drainage flood mitigation direction from the Water Governance Act 2006).*
- xi) *Catchment and Land Protection Act 1994*
- xii) *The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)*
- xiii) *The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).*
- xiv) *Guidelines for the use of reclaimed water 2003*
- xv) *Health Act 1958*
- xvi) *Safe Drinking Water Act 2003*
- xvii) *Food Act 1984*

## 5.3. Western Australia

### Key points

1. The *Rights in Water and Irrigation Act 1914* (currently in review) does not differentiate MAR source waters from native groundwater. The rights to groundwater are vested with the State. The status of MAR source waters are therefore likely to be classed as groundwater and subject to the licensing obligations and allocations attendant with the aquifer.
2. There appears to be no provision in the *Rights in Water and Irrigation Act 1914* to regulate the infiltration or injection of MAR water in either prescribed or non-prescribed aquifers.
3. There is no specification or provision for the regulation of stormwater or stormwater use for MAR.
4. The *Environmental Protection Act 1986* is the primary Act to regulate water quality. Parts IV and V provide for the regulation of waste water from prescribed premises, including waste water treatment plants. This may be a *de facto* provision to manage MAR infiltration.

	Policy	Comment
<p><b>1</b></p> <p>Capture Zone</p>	<p>i) RiWI Act 1914</p> <p>v) SW manual 2007</p> <p>ii) EP Act 1986</p> <p>iii) P and D Act 2005</p>	<p>Rights to all water vested with the Crown</p> <p>Stormwater and recycled water not specified but may be considered under S.5c. s. 7(2) may apply to MAR source water in the public interest</p> <p>Primarily water quality: applies to retention ponds and wetlands. Parts iv and v apply to MAR: applies to works and avoiding environmental harm</p> <p>s.104 may apply to MAR</p>
<p><b>2</b></p> <p>Pre-treatment</p>	<p>ii), v), vii), viii), ix), x) and xi)</p>	
<p><b>3</b></p> <p>Recharge</p>	<p>ii) EP Act 2004</p> <p>i) RiWI Act 1914</p>	<p>As above and provides for well construction: MAR managed via hydro-geological assessment</p> <p>provides for licence to construct a well</p>
<p><b>4</b></p> <p>Subsurface storage</p>	<p>i) RiWI 1914</p>	<p>No provision for water quantity of aquifer infiltration</p>
<p><b>5</b></p> <p>Recovery</p>	<p>i) RiWI Act 1914</p>	<p>no differentiation of native and recharged waters: MAR required to obtain extraction licence and allocation</p> <p>Temporary extraction allocation application allowed for</p>
<p><b>7</b></p> <p>End use</p>	<p>ii), v), vii), viii), ix), x) and xi)</p>	

Numbers in the policy column refer to corresponding legislation listed below.

**Key References**

- i) *EPA Bulletin 1199 'MAR using treated wastewater on the Swan Coastal Plain' 2005*

**Western Australian Acts and legislation applying to MAR**

- ii) *Rights in Water and Irrigation Act 1914*
- iii) *Environmental Protection Act 1986 (Parts iv and v)*
- iv) *Planning and Development Act 2005*
- v) *Groundwater recharge guidelines (Appended to EPA Bulletin 1199)*
- vi) *Stormwater management manual 2007*
- vii) *Environmental Protection (Gnangara Mound Crown Land) Policy 1992*
- viii) *Recycled Water Supply Agreement Health Act 1911*
- ix) *Draft Guidelines for the Use of Recycled Water in Western Australia*
- x) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- xi) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

## 5.4. Queensland

### Key points

1. Institutional structures have been reformed in south east Queensland to address the problem of using multiple water sources collectively to secure water supply over a region. The reforms include the establishment of the Queensland Water Commission (applying to south east Queensland), and provision for the implementation of a whole of system Water Grid administered by an independent Water Grid Manager (QWC 2007, 2008). Bulk water supply is to be comprised of two statutory entities; one being South East Queensland dams and aquifers, the other relevant a manufactured water and treatment facilities. Recommendations include 3<sup>rd</sup> party access to connection rights to mains distribution and water treatment infrastructure by alternative bulk supply options. Three water retailers are proposed to distribute water to end users according to cost reflective pricing.
2. As stated in the Queensland Water Commission Draft water Strategy for South East Queensland (QWC 2008 p.119), aquifer storage and recovery is under investigation on the Gold Coast to store recycled water for irrigation purposes. Such opportunities in SEQ are considered to be limited and need to be assessed on a case-by-case basis<sup>14</sup>.
3. Purified recycled water stored in surface dams and desalination are the preferred options to augment urban water supplies in South East Queensland. QWC (2008) estimates these will supply 30% of the water demand by 2056.
4. The majority of institutional design and reform has focussed on policy related to purified recycled water stored in surface dams (*Water Availability and Entitlements Act 2008*).
5. Stormwater harvesting is currently (*considered*) a boutique solution and must be considered on a case by case merits. Stormwater may be stored in a small dam or reservoir or used to recharge a groundwater aquifer (there are a limited number of suitable aquifers in South East Queensland); (QWC 2008 p.91 inserted italics).
6. The scope for the economic use of stormwater harvesting in an established urban environment requires careful evaluation and would be unlikely to be precluded through ownership remaining with councils. On balance, it is the view of the Commission that stormwater drainage assets and responsibilities should remain with councils. (QWC 2007, p.32)
7. Water from groundwater aquifers will continue to make a small contribution in the delivery of urban supplies. The sustainable abstraction from these aquifers is expected to remain relatively static over time (QWC 2008, p.165).

---

<sup>14</sup> A MAR scheme has been in operation in the Burdekin Delta, Queensland since 1965. The scheme uses episodic and surplus surface water to recharge and replenish the Burdekin Delta aquifer, maintaining water tables and mitigating salt water intrusion. The aquifer is a primary source of water for a substantial irrigation industry. Although operating in a rural district the scheme provides guidance for urban MAR schemes able to utilise surplus or waste water sources, such as stormwater.

	Policy	Comment
1 Capture Zone	x) LG Act 1993 and iii) SER Act 2007 i) W Act 2000 and WA and E Act 2008	Management and hence entitlement of stormwater and infrastructure remains with Local councils. Recycled water managed for Purified Recycled Water for reservoir augmentation rather than MAR All rights to water remain vested with State.
2 Pre-treatment	vi), vii), viii), ix), xi) and xii)	
3 Recharge		
4 Subsurface storage	i) W Act 2000	Applies to storage: limited aquifer suitability
5 Recovery	i) W Act 2000	Recharge and native waters not differentiated: Generally aquifers fully allocated. MAR will require licence to recover
7 End use	vi), vii), viii), ix), xi) and xii)	

Numbers in the policy column refer to corresponding legislation listed below.

### Institutional impediments to water reform

The Queensland Water Commission (QWC 2007) Identified institutional impediments and barriers to water reform in Queensland. The QWC states (p.viii):

“The current institutional arrangements for urban water supply in South East Queensland suffer from serious systemic weaknesses. In summary these are:

- (1) confused accountabilities in terms of the roles and responsibilities of State and Local Governments for water security;
- (2) fragmented ownership arrangements with the bulk supply treatment and transport assets owned by 25 entities in the region;
- (3) a lack of regionally integrated approaches to supply, where Councils are focused on issues within their own local government boundaries;
- (4) no means by which the costs of new infrastructure and the water coming from that new infrastructure may be equitably shared across those who benefit;
- (5) limited regulation of asset maintenance that has resulted in differing service standards across the region, and in some cases insufficient funds being spent on maintaining assets;
- (6) water prices and the regulation of those prices are not managed in a consistent way; and
- (7) there is no opportunity for consumers to enjoy the benefits of a competitive market particularly at the retail level”.

## Key Documents

QWC (2008) Water for Today, water for tomorrow. South East Queensland water strategy-draft March 2008.

<http://www.qwc.qld.gov.au/myfiles/uploads/SEQWS/SEQWaterStrategy-Draft.pdf>

QWC (2007) Our Water urban water supply arrangements in South East Queensland

[http://www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban\\_Water\\_Supply\\_Arrangements\\_in\\_SEQ.pdf](http://www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban_Water_Supply_Arrangements_in_SEQ.pdf)

EHA (2006) Groundwater review of south east Queensland on-shore aquifer systems. Report prepared for the Queensland Department of Natural Resources Mines and Water: GW 05-25-REP-001.

DNRW (2007) Queensland Urban Drainage Manual Volume 1 2<sup>nd</sup> edition.

[http://www.nrw.qld.gov.au/compliance/wic/flood\\_risk\\_management.html](http://www.nrw.qld.gov.au/compliance/wic/flood_risk_management.html)

The manual sets out the objectives of stormwater management. It notes that the planning of stormwater systems needs to be integrated with land use planning as well as planning for other infrastructure (e.g. water supply). Guided by Water Sensitive Urban Design, stormwater planning should be integrated with water supply and wastewater planning as well as the management of ground waters. The Drainage manual sets out the provisions and legislative requirements for stormwater management in Queensland: see Summary Tables 2.03 and 3.08.

DNRW (2008) Recycled water management plan and validation guidelines.

[http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft\\_rwmp\\_validation\\_guidelines.pdf](http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft_rwmp_validation_guidelines.pdf)

DNRW (2008) Water quality guidelines for recycled water schemes

[http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft\\_water\\_quality\\_guidelines.pdf](http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft_water_quality_guidelines.pdf)

### **Queensland Acts and legislation applying to MAR**

- i) *Water Act 2000*
- ii) *Water Availability and Entitlements Act 2008*
- iii) *South East Water Restructuring Act 2007*
- iv) *Native Title Act 1993*
- v) *Integrated Planning Act 1997*
- vi) *Public Health Act 2005 (Section 57)*
- vii) *Environmental Protection Act 1994*
- viii) *Environmental Protection (Water ) Policy 2000*
- ix) *Model Urban Stormwater Quality Management Plans and Guidelines (EPA 2007).*
- x) *Local Government Act 1993*
- xi) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- xii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

## 5.5. NSW

### Key Points

1. MAR is not widely promoted as a viable option to augment Sydney water supplies. Referring to stormwater and MAR, the Water for Life: NSW Metropolitan water Plan p.46 states:
  - a. “As its supply is variable and dependent on rainfall, runoff must typically be stored and usually treated for future use. This can require an urban lake, constructed wetland, aquifer storage or storage tank. In Sydney, aquifers are generally not suitable for this purpose, and the space required for lakes and tanks is often unavailable in urban areas, unless a new development is under way”.
2. In contrast to the Metropolitan Water Plan position on MAR, Timms *et al.* (2007) argue that the Botany Sands aquifer is suitable for large scale MAR. The authors generally favour sewer mining for source waters compared to stormwater, based on improved volume reliability, avoiding the need for retention storages and ready access to advanced water treatment.
3. The Water Plan refers to the role of groundwater to augment Sydney’s urban water supply p.79 “On the basis of the independent expert analysis of the supply and demand balance, the Government has decided that groundwater and desalination will be used only in the event that dam levels fall to critical levels. Thus, groundwater will be used to help Sydney through severe droughts, as this maximises the yield benefit of the groundwater resources. It is intended to use groundwater only during drought periods, when dam levels fall below about 40%, and the groundwater aquifer will be allowed to recharge in non-drought periods”. MAR is not considered for additional groundwater recharge.
4. *The Water Management Act* 2000 s.56 defines a water access licence as an entitlement to a specified share in the available water management area from a specified water source (**the share component**). The **extraction component** entitles the licence holder to take water at a specified time, rate, location and circumstance. NSW policy corresponds to the NWI which defines water access entitlements as perpetual unit shares of a defined consumptive volume of a water resource. Periodic allocations are made in accord with annual inflows, storage volumes and in proportion to the number of shares held. Risk is assigned between users and the Government.
5. All rights to water are vested with the state. Recharged water is not differentiated from native groundwater and will require a water access licence, works approval and a water supply works approval. The legislation does not specify the status of stored MAR water when aquifers are overdrawn and allocations are 0% of the entitlement.
6. Stormwater reuse opportunities tend to be more cost effective on a small scale, where water is retained and reused as close to its source as possible. Rainwater harvested directly from roofs has a relatively high quality, requiring minimal or no treatment, compared to stormwater collected from drains in an urbanised catchment. For these reasons, priority has been given to rainwater tanks and local opportunities, as these options are the most cost effective, requiring less treatment and distribution.

	<b>Policy</b>	<b>Comment</b>
<b>1</b> Capture Zone	iv) EPA Act 1979 vi) PoEO Act 1997 i) WMAct 2000) v) LG Act 1993 vii) Dams Act 1978	Depending on nature and volume of source water, various Acts or combinations of Acts are invoked. Stormwater exempt from several Acts  All rights to water remain vested with State
<b>2</b> Pre-treatment	x), xiii) and xiv), xv), xvi)	
<b>3</b> Recharge	i) WM Act 2000	
<b>4</b> Subsurface storage	i) WM Act 2000 iv) EPA Act 1979	Applies to storage: limited aquifer suitability
<b>5</b> Recovery	i) WM Act 2000	Recharge and native waters not differentiated: Generally aquifers are fully allocated. MAR will require licence to recover
<b>7</b> End use	x), xiii) and xiv), xv), xvi)	

Numbers in the policy column refer to corresponding legislation listed below.

### **Key documents and Guidelines**

NSW Department of Water and Energy (2007) Interim NDSW guidelines for management of private recycled water schemes. New South Wales Government, Sydney. ISBN 978 0 7347 5940 5

[http://www.waterforlife.nsw.gov.au/\\_data/assets/pdf\\_file/0018/11772/Private\\_Recycled\\_Water\\_guideMay2008.pdf](http://www.waterforlife.nsw.gov.au/_data/assets/pdf_file/0018/11772/Private_Recycled_Water_guideMay2008.pdf)

Department of Environment and Conservation (2006) Managing urban stormwater: harvesting and reuse. New South Wales Government, Sydney. ISBN 1 74137 875 3

<http://www.environment.nsw.gov.au/resources/stormwater/managestormwatera06137.pdf>

Metropolitan Water Plan (2006) New South Wales Government, Sydney ISBN 0 7313 32687

[http://www.waterforlife.nsw.gov.au/about/plan/download\\_the\\_metropolitan\\_water\\_plan](http://www.waterforlife.nsw.gov.au/about/plan/download_the_metropolitan_water_plan)

### ***New South Wales Acts and legislation applying to MAR***

- i) The Water management Act 1979*
- ii) Water Management (Water Supply Authorities) Regulation 2004*
- iii) Sydney water Act 1994*
- iv) The Environmental Planning and Assessment Act 1979*
- v) Local Government Act 1993*
- vi) The Protection of the Environment Operations Act 1997*
- vii) Dam Safety Act 1978*

- viii) *The Fisheries Management Act 1994* (Works in a watercourse)
- ix) *Rivers and Foreshores Improvement Act 1948* (piped stormwater exempt)
- x) *Environmental Guidelines: Use of Effluent by Irrigation* (NSW Department of Environment and Conservation) (2004)
- xi) *Threatened Species Conservation Act 1995*
- xii) *National Parks and Wildlife Act 2003* (Predominately protection of Aboriginal Heritage)
- xiii) *Public Health Act 1991*
- xiv) *Food Act 2003*
- xv) *The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse* (EPHC Draft May 2008)
- xvi) *The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge* (EPHC Draft May 2008).

## 5.6. Tasmania

### Key points

1. At the time of publication, Urban water reform prioritises demand management and capacity building (DPIW 2005, 2006).
2. There are no declared Groundwater Areas in Tasmania, allowing free access water stored in an aquifer as part of an MAR operation.

	Policy	Comment
1 Capture Zone	i) WM Act 1999 ii) WSI Act 2008 iii) LUPA Act 1993	Legislation does not specify provisions for stormwater
2 Pre-treatment	iv) v) vi), vii), viii)	
3 Recharge		There are no declared Groundwater Areas in Tasmania, allowing free access water stored in an aquifer as part of an MAR operation
4 Subsurface storage		There are no declared Groundwater Areas in Tasmania, allowing free access water stored in an aquifer as part of an MAR operation
5 Recovery		There are no declared Groundwater Areas in Tasmania, allowing free access water stored in an aquifer as part of an MAR operation
7 End use	iv) v) vi), vii), viii)	

Numbers in the policy column refer to corresponding legislation listed below.

### Key Documents

Tasmanian Water Act (WMA)

[http://www.austlii.edu.au/au/legis/tas/consol\\_act/wma1999166/](http://www.austlii.edu.au/au/legis/tas/consol_act/wma1999166/)

Department of Primary Industries and Water (2005) Water Governance arrangements for Tasmania: a report to the NWC. Hobart

[http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6KY3CM/\\$FILE/Water%20Governance%20Tasmania.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6KY3CM/$FILE/Water%20Governance%20Tasmania.pdf)

Department of Primary Industries and Water (2006) Implementation plan for the NWI Tasmania. Hobart [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6VQ6MS/\\$FILE/Tas%20NWI%20Implementation%20Plan.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6VQ6MS/$FILE/Tas%20NWI%20Implementation%20Plan.pdf)

### **Tasmanian Acts and legislation applying to MAR**

- i) *Water Management Act 1999*

- ii) *Water and Sewerage Industry Act 2008*
- iii) *The Land Use Planning and Approvals Act 1993*
- iv) *Environmental Management and Pollution Control Act 1994*
- v) *Public Health Act 1997*
- vi) *State Policy on Water Quality Management 1997*
- vii) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- viii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

## 6. INTERNATIONAL REGULATORY FRAMEWORKS FOR MAR

Kalita Marsh and Professor Jim Saltzman of Duke University provided the policy analysis of MAR regulations and legislation in the United States Regulatory Frameworks for MAR in the USA<sup>15</sup>

### 6.1. Regulatory Frameworks for MAR in the USA

Managed aquifer recharge (MAR) is a suite of relatively new technologies that have rapidly expanded in urban areas since ASR was first used in the United States in 1969 in Wildwood, New Jersey. As of July 2006 there were more than 150 ASR systems in operation or development in the United States, spread across nearly 20 states (Pyne, 2003) in addition to numerous infiltration basins, soil aquifer treatment and riverbank filtration systems.

The ownership and allocations rules applicable to managed aquifer recharge are regulated differently state by state through the application of state statutes and regulations, common law, and judicial precedent. The legal and policy doctrine that a state adopts for its groundwater rights has both clear and important implications for the right to recapture water supply from a MAR (Thornson, 1978). For example, whether a landowner can prevent another from storing water under his property and whether a landowner can be compensated for the use of the space beneath his property as storage for water depends on the his right to groundwater.

Many western states claim ownership of groundwater and allocate the resource through an appropriative system. Usually water rights are allocated based on each aquifer's sustainable yield, so once all the rights are granted no more permits will be issued (in some states the permits can be bought, sold, or leased). Generally eastern states follow a riparian doctrine (overlying rights). There are five doctrines of groundwater allocation that are the basis of each state's specific law and policy, which are: absolute ownership, reasonable use, correlative rights, prior appropriation, and regulated riparianism.

#### 6.1.1. Types of Groundwater Rights

##### ***Absolute Ownership***

The absolute ownership doctrine comes from the English-common rule set in *Acton v Blundell*<sup>16</sup>. Under this doctrine landowners own what is below their land and above their land. Thus a landowner overlying an aquifer can pump as much groundwater as they choose from the aquifer without compensating other landowners who overlie the aquifer (Bruggink, 1992). Very few states still follow this doctrine because it only works well where water resources are plentiful. Connecticut, Georgia, Indiana, Louisiana, Maine, Massachusetts, Mississippi, Ohio, Rhode Island, and Texas still follow the absolute ownership doctrine, but most have a permit system in place (USDA, 2005).

##### ***Reasonable Use***

---

<sup>15</sup> For additional details on American water policy and groundwater management see:

a) Colby B. and Jacobs, K (2007) *Arizona Water Policy: management innovations in an urbanizing, arid region*. Resources for the Future, Washington DC, United States.

b) Blomquist, W., Schlager, E. and Heikkila, T. (2004) *Common Waters, Diverging Streams: linking institutions and Water Management in Arizona, California and Colorado*. Resources for the Future, Washington DC, United States.

c) National Research Council (2008) *Prospects for managed underground storage of recoverable water* (p183-222); Committee on sustainable underground storage of recoverable water. National Academies Press, Washington D.C United States.

<sup>16</sup> *Acton v Blundell* [1843] 152 Eng Rep Exch 1223

The reasonable use doctrine is an American rule developed in the 19th century in reaction to the ineffectiveness of the absolute ownership doctrine (Bruggink, 1992). Under the reasonable use doctrine usage of overlying landowners must be “reasonable,” beneficial, and not wasteful. The reasonableness standard is based on different variables like location, use of water, amount of water, and the placement of the water (USDA, 2005, p. 6). States that follow the reasonable use rule, most with a permit system to track usage, include: Alabama, Florida, Illinois, Kentucky, Maryland, New York, North Carolina and Tennessee.

### ***Correlative Rights***

The correlative rights doctrine was also developed in the 19th century and continues to develop. Under this doctrine, each user has an equal right to use of the groundwater regardless of who the first user was (Bruggink, 1992). Furthermore, when the supply of water in an aquifer does not meet the needs of all users, then each user is required by the judiciary or by statute to reduce their usage on a pro rata basis until the overuse ends. On the other hand, when there is a surplus of available water to overlying landowners, then the water can be appropriated for use on non-overlying land by the appropriator proving that a surplus exists (USDA, 2005, p. 7). States that use the correlative rights doctrine include Arkansas, California, Delaware, Minnesota, Missouri, Nebraska and New Jersey.

Of all the doctrines discussed thus far, the correlative rights doctrine provides the strongest argument for the public having the right to use excess underground water storage because the “storage space occupied by excess waters available for appropriation would arguably be public” (Thorson, 1978). Then it follows that, “if overlying landowners have no property interest in artificially stored water beneath their land, they seemingly have little basis for claiming a property interest in the storage space occupied by the artificially stored water” (Thorson, 1978).

### ***Prior Appropriation***

The prior appropriation doctrine gives priority to appropriators who first use the water supply (“first in time, first in right”) (Bruggink, 1992). States usually require, by statute, that appropriators obtain permits to establish who has priority used (USDA, 2005, p. 7). The following states apply this doctrine in some form: California (only in regards to surplus water), Idaho, Kansas, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, and Wyoming. Colorado, Kansas, Montana, Nebraska, Nevada, New Mexico, Washington, and Oregon have create a hybrid prior appropriation system where areas designated as critical prohibit new pumping and where areas with existing pumping are limited to preserve an acceptable amount of groundwater.

It is often argued that the right to store water is public in states where groundwater rights are based on prior appropriation, so it follows that “an appropriator has no inherent right to capture artificially stored groundwater present under his land, or at least no right to capture stored water in excess of the amount granted by his appropriation” (Thornson, 1978).

### ***Regulated Riparianism***

The regulated riparianism doctrine requires that appropriators obtain a permit from a state agency obtained prior to withdrawing water. Permits can have varying conditions and durations and therefore carry different rights to the water, but the usage by the permit owners must be considered “reasonable.” The permits, thus rights to the groundwater, can be transferred to non-riparian lands (Thornson, 1978). Most eastern states have water policies and statutes that fall under the regulated riparianism doctrine because of the abundance of available water resources.

### 6.1.2. Some State Groundwater Policy and Law

#### **Arizona**

Arizona groundwater law is based on the prior appropriation doctrine. The allocation and ownership rights to MAR are regulated by Arizona's statutory derivative of the doctrine of prior appropriation and are set forth in Title 45 of the Arizona Revised Statutes<sup>17</sup>. Under this statute, pre-1980 water rights are grandfathered with a permit system and Arizona limits the extraction of ground water from aquifers to a rate that will keep the aquifer restored at an appropriate level (USDA, 2005).

#### **California**

In California the state owns all water and individuals can only obtain the right to use the water. California's water law can be found in Title 23 of the California Code of Regulations. Water from an aquifer is considered percolating groundwater in California (Bureau of Land Management, 2001). California further classifies percolating groundwater as either overlying land use or surplus groundwater. The correlative rights doctrine applies to these types of water. Thus, all property owners above a common aquifer possess a shared right to reasonable use of the groundwater aquifer. During times of shortage, overlying rights are shared equally on a pro rata basis. Non-overlying uses and public uses are considered appropriate ("first in time, first in right" basis) and so long as these uses do not result in overdraft they are allowed. California does not implement a permit system to use groundwater from aquifers (Bureau of Land Management, 2001a).

#### **Colorado**

Colorado is often called the "pure appropriation" state because it has an active water market, freely allows for transfer of water rights, and both surface and groundwater are regulated (Archer and Patrick, 1995). The allocation and ownership rights to MAR are regulated by Colorado's statutory derivative of the doctrine of prior appropriation<sup>18</sup>, <sup>19</sup>. There are seven water courts, the Colorado Groundwater Commission, and the State Engineer who all work together to administer and distribute rights to groundwater (Bureau of Land Management (2001b)).

The Colorado Groundwater Commission is responsible for establishing appropriate pumping levels for the aquifers to prevent them from being overdrawn. By law, all wells which divert groundwater from aquifers must have a well permit, which can be obtained from the State Engineer. But, the permit itself does not constitute a groundwater right, a right to the water can only be obtained through a formal application with the water court after a permit has been obtained. Once a water right has been established then it can be transferred (bought, sold, or leased) through application with a water court and proof that the transfer will not injure the water rights of others.

### 6.1.3. State policy and law specific to managed aquifer recharge

The laws that apply to managed aquifer recharge constitute a new and rapidly changing area of law in the United States because managed aquifer recharge is a rather new technology. The ownership of stored water is an important issue because the project proponent needs the legal right to store and use water and also to exclude other competing users from withdrawing recharged water (otherwise their economic investment is not protected). The general position is that if a water user has a right to the water prior to the water recharge, then he also has a right to recover that water (Pyne, 2005).

<sup>17</sup> ARIZ REV STAT, title 45, ch. 3.1 (2008).

<sup>18</sup> COLO REV STAT, State Constitution Article XVI sect. 5-6, articles 80-92.

<sup>19</sup> *Ground Water Management Act* (1965) COLO REV STAT.

California explicitly protects the rights of those who recharge water to withdraw it. Those who recharge aquifers have rights to exclusively withdraw that groundwater from the aquifer (National Research Council). This right was established through case law *Los Angeles v San Fernando*<sup>20</sup> and *Alameda County Water District v. Niles Sand and grave Co.*<sup>21</sup>

In Colorado, rights to store water in aquifers depend on the specific rules and regulations for the permitting of that particular aquifer (Bryner and Purcell, 2003). Case law stipulates that if water is stored in an aquifer and enters portions of an aquifer underneath a neighbouring property there is no grounds for trespass and consequently permission of overlying property owners is not needed for the operation of a MAR facility. Adjacent landowners are essentially barred from withdrawing any water that an overlying landowner has stored in an aquifer that lies on adjacent land, because the diversion of groundwater from aquifers requires a permit and the adjacent landowner would only be permitted to withdraw the amount of water their permit allowed.

In Oregon, statutes protect and allow aquifer storage recovery (Water Resources Department, 2007). The relevant state statutes allow water users to use existing water rights to store water in an aquifer. But first, a limited license is required for MAR testing to ascertain if the recovery of water from the aquifer is possible. This limited license stipulates that the use of any recovered water must be for the same purpose as the water which was originally diverted for storage in the aquifer. After limited licensing and successful water quality testing, a MAR project can obtain a full permit that will allow the permit holder to store a specific quantity of water allowed under a right (a maximum diversion rate). First, a permit is required to appropriate the water and recharge it. Then, a second permit is required to pump the recharged water from the aquifer. Each application for a license and/or permit is evaluated on the basis of several factors. These include potential effect on ground water quality, whether the diversion of water for recharge and the use of the recharged water are in the public interest, and whether existing aquifer users may be injured. Strict accounting of quantities of water used and stored are also required in order to keep the licenses and permits. Washington also has very similar statutes to protect and allow MAR projects (Washington State Legislature, 2003)

Arizona requires two permits in order for water to be stored, saved, and recovered from an aquifer (Bryner and Purcell, 2003, P. 10). The first permit is an underground storage facility permit that allows for the operation of the storage facility (Bryner and Purcell, 2003, p. 11). The second permit is a ground water savings facility permit that requires a contractual agreement with the recipient of the recovered water that for every gallon of water received from the MAR, they will reduce their groundwater withdrawals from other sources by one gallon. Just like Oregon and Washington, Arizona requires strict reporting on the MAR.

#### **6.1.4. Arizona water banking**

A water bank has been operating in Arizona for approximately 10 years enabling the exchange of water between members with a demand for water (water debits) and members able to supply water (water credits). The Arizona Water Banking Authority is a legislatively created Government entity that uses Arizona's storage and recovery program to meet water policy objectives and future water needs (Megdal 2007). A water bank represents a collectively organised arrangement for the storing and exchange of surplus water and unexercised entitlements. Such an arrangement supports and facilitates water transfers. By acquiring water entitlements or producing and storing surplus supplies, and making these available to acquire and use, the water bank effectively reduces the transaction costs of

<sup>20</sup> *Los Angeles v San Fernando* [1975] 14 Cal. 3d 199, 537 P.2d 1250

<sup>21</sup> *County Water District v Niles Sand and grave Co.* [1975] 37 Cal. App.3d 924, 112 Cal. Rptr. 846 (1974), cert. denied, 419 U.S. 869.

informational search, bargaining and negotiated exchange (Blomquist *et al.* 2004). Exchange occurs at a market price that includes the investment costs of providing the current portfolio of infrastructure or water savings projects. Capital costs are covered by a pool of investors and dividends are paid through water sales at wholesale level. New developments are required to surrender sufficient water entitlements to account for the developments future water demand. Developer requirements to underwrite the cost of sourcing water for a new subdivision can be met through purchasing an entitlement at the water bank, and thereby contribute to the capacity to expand water supplies. Alternatively an investment in the water bank can be made in anticipation of a need for future entitlements. This is in addition to current developer contributions to infrastructure to connect to mains water, sewers and stormwater systems. The project portfolio selected by the water bank for investment meets economic efficiency principles and also meets a range of government policy objectives, for example those related to water security, water quality, environmental protection and other current externalities to the water supply market. This arrangement has been in place in Phoenix for ten years and has been critical to the ongoing rapid growth of a desert city whose traditional water supplies are under increasing stress.

A requirement for a water bank is that water from various sources is storable and interchangeable. In Arizona this is possible because of an extensive aquifer which underlies most of the growing urban areas, such as Phoenix. Water may be banked by Managed Aquifer Recharge into the aquifer and recovered by any other entitled user within an extensive area because the aquifer is so transmissive that pressure fluctuations caused by recharge and extraction are relatively small and considered transferable within the aquifer. Although the water physically does not move from the site of the recharge project to the point of abstraction, the water quality put into the aquifer is required to be the similar to or higher quality than water already in the aquifer.

Entitlements are limited in time. In Arizona a credit may be stored and redeemed up to 100 years later, developing credit in a water bank in a city characterised by rapid growth, recognising that future water will be at a premium price. This has created an environmental benefit in an over-exploited aquifer.

Thus the laws and policies in regards to MAR vary state by state. Each state's laws and policies reflect directly on the abundance of water resources available there and also on the doctrine of groundwater rights followed by the state. These laws and policies are not static and will continue to develop and evolve because the ownership of stored water is an important issue as MAR proponents need to be assured that they have adequate protection of their investments in their facilities and operations. In coming years, laws and policies in regards to MAR will continue to change in order to protect the economic investment of MAR developers and facilities. The trend will continue to be to increasingly protect the legal right to store and use water and to exclude other competing users from withdrawing recharged water.

## 6.2. Regulatory framework for MAR in France

*Refer to Ward, J, Dillon, P and Grandgirard A. (2008) Aquifer storage and recovery: a framework to compare opportunities for market based policy approaches in Australia and France 13<sup>th</sup> IWRA World Water conference Montpellier 1-4<sup>th</sup> September*

In contrast to the Australian endorsement of market exchange transferable water rights vested in the individual, French water policy relies on regulatory and planning instruments combined with various degrees of negotiated agreement. Water management is subject to compliance with three tiers or jurisdictions of water policy: the European Union, the National level and at the level of the hydro-graphic basin.

European Union directives on drinking water and waste water treatment increased the demand for water quality and treatment and were subsequently incorporated into French law in 1992 (and guided by the statutes of the French *Water Act 1964*, establishing six jurisdictions based primarily on hydrographic catchments managed by an *Agence de l'Eau*" (water agency) as the operational executive). The 2003 European Union Water Framework Directive (WFD) introduced the statutory basis for the conjunctive management of groundwater and surface water. The key aims of the Directive (incorporated into French law in 2004) seek to expand the scope of water protection to all waters, surface waters and groundwater at the scale of river basins; to achieve an approved water use status for all waters by specified dates; to combine emission limits and quality standards; to establish pricing based on full cost accounting; to employ participatory approaches and to deploy protocols to expedite the formulation of new legislation and policy implementation.

In synthesizing the intent and obligations of the various echelons that influence French Water policy, management is defined by the State in partnership with local communities and users. Water policy is administered at three jurisdictional levels conditioned by directives of the European Union: the national, water basin and local water commission levels. National policies are required to simultaneously consider consumptive water use requirements and the non-consumptive needs of aquatic ecosystems, surface and groundwater quantity and quality.

Masterplans for Water Development and Management (*Schéma Directeur d'aménagement et de gestion des eaux SDAGE*) and Local Water Development and Management Plans (*Schémas d'aménagement et de gestion des eaux SAGE*) guide both the coordination of diverse and competing water users and operational implementation. Both seek to establish partnerships and to coordinate the actions of Public Authorities and private developers (see Piegay *et al.* 2002 for a review on the implementations of these plans). Economic incentives are restricted to mobilizing specific financial resources and accounting conventions in accord with the "polluter pays" principle. Water in France is considered "national common heritage" and managed according to a regime of either State or Common property rights and as a corollary is characterized as a common good, non-tradable resource. Sovereign rights to water remain with the State whilst local needs and resource parameters determine the details of access exclusion and use, expressed as a mosaic of common pool and regulatory property right regimes.

The organization of water provisioning and services is based on a tripartite relation between the community, water users and the service provider (the provider can be either a public or private entity). The local community retains sovereign authority for the organization of water provision through elected representation and assured delivery through association with advisory commissions and regulatory agencies. When service management is delegated to a private provider, the community retains overarching responsibility and infrastructure ownership remains with the community. The supplier-user relationship is ratified via contractual water service and provisioning arrangements. In summarising French water policy, Dubois (2001, p.89) states, "*There is no strict water resource management today in France, but an ensemble of management actions which converge in a more or less coherent and efficient way.*"<sup>1</sup>. In accord with Dubois, Launay (2003) argues for the need of improved coordination (p.35).

There are relatively few operating MAR schemes in France at the time of publication. The management of four French MAR sites at Flins Aubergenville, Croissy, Dunkerque and Dijon has been delegated to a private company. There are also two MAR sites that are managed directly by communities: in Lyon (Crepieux Charmy) and near the River Garonne. Sites at the river Durance and La Reunion are also under consideration. For future MAR schemes

The European directive *Eaux Résiduaires Urbaines 1991*, transcribed into the French water law of 1992, is the legislative basis for stormwater and aquifer management. French Water

law provides for two water management regimes: authorisation and declaration. The appropriate water management regime is determined according to the area of the source water capture and the flow rates for recharge and recovery. Declaration is less constrained than authorization, and applies when the total harvesting surface area (“superficie totale desservie”) is greater than 1ha and less than 20ha. Harvesting approval is granted on submission of documentation. The granting of an Authorisation for areas greater than 20 ha is conditional on the results of preliminary environmental studies and assessments complying with prescribed water condition standards<sup>22</sup>. Table 6 summarises the specifications that determine whether a MAR scheme is to be administered either by declaration or authorization.

French water legislation articulates statutory prescriptions and proscriptions at the EU, national and local basin level for harvesting, aquifer storage and extraction applicable to ASR. Both the European Union WFD and the French incorporation of the directive, seek to establish science based rules to define the consumptive and non-consumptive “pools” for water management, partially fulfilling the first instrument of robust separation. The *Water Act 1964* and pursuant legislation, prescribes water quality standards that represent the hazard control points necessary for reliable MAR. Volumetric determinations, however, are at the whole of basin scale, and based on the proposed separation of the urban water cycle, do not provide sufficient precision for non-contentious share entitlements for a localised MAR operation.

**Table 6 Policy framework of French MAR schemes**

MAR element	Declaration	Authorization	Nomenclature <sup>1</sup>
Capture or retention of stormwater in surface water or in infiltration pounds	total surface concerned (“superficie totale desservie”) of more than 1Ha but less than 20Ha	Total surface concerned of more than 20Ha	5.3.0
Re-injecting (in the same aquifer) water which was taken for geothermal, mining or building use	Re-injected for a total capacity of more than 8 m <sup>3</sup> /h but less than 80m <sup>3</sup> /h Capacity under 8 m <sup>3</sup> /h	Total capacity of re-injection of more than 80 m <sup>3</sup> /h Capacity of 8 m <sup>3</sup> /h or more	1.3.1 5.1.1.0 1.3.1.0
Injection into an aquifer subject to permanent quantitative restrictions		yes	1.2.0
Other types of release in the soil or sub-soil			
Installations allowing an extraction in an aquifer	total flow-rate of more than 8 m <sup>3</sup> /h but less than 80m <sup>3</sup> /h	Total flow-rate of more than 80 m <sup>3</sup> /h	1.1.0

<sup>1</sup> Elaborated from the « Décret n°93-743 du 29 mars 1993 relatif à la nomenclature des opérations soumises à autorisation ou à déclaration en application de l'article 10 de la loi n° 92-3 du 3 janvier 1992 sur l'eau » (revised in March 2007).

<sup>22</sup> Directive 80/68/CEE du Conseil du 17 décembre 1979 concernant la protection des eaux souterraines contre la pollution causée par certaines substances dangereuses (pollution)  
Directive 200/60/CE du 23 octobre 2000 établissant un cadre pour une politique communautaire dans le domaine de l'eau (promotion of an integrated water management)  
Circulaire DE/SDGE/BRGE-DCH/04 n°7 du 16 mars 2004 relative a la gestion quantitative de la ressource en eau et a l'instruction des demandes d'autorisation ou de déclaration des prélèvements d'eau et des forages. (extraction)  
Décret n°2006-881 du 17 juillet 2006 modifiant le décret n°93-743 du 29 mars 1993 relatif a la nomenclature des opérations soumises a autorisation ou a déclaration en application de la loi n°92-3 du 3 janvier 1992 sur l'eau et le décret n°94-354 du 29 avril 1994 relatif aux zones de répartition des eaux (all actions dealing with water)

The minima and maxima that trigger declaration or authorisation standards do not account for regional heterogeneity of stormwater or aquifer characteristics. Similarly the legislation does not provide instruments to define an independently managed process to periodically allocate the amount of water to each share. Without clear specification, the assignment of risk and circumstances of compensation remain poorly defined. The detection protocols and efficacy of corrective instruments to manage non-water quality externalities (e.g. subsidence, increased pumping costs) also remain obscure. It has been difficult to determine the capacity of French water policy to fulfil the third instrument of robust separation; stipulating the obligations of final water use.

Robust separation in the Australian context articulates a property right regime that facilitates secure, economically efficient and low cost trading and administration. However, when water is characterised as a common pool resource, price signals are not sufficiently precise or the conditions for effective markets are not met, and so market approaches may not be an appropriate policy strategy.

The evaluation of French Water Policy indicates that the application of the robust MAR governance framework has merit in both a market based approach (Australia) and one reliant on negotiated social contracts (France). We propose that regardless of a market based or a negotiated, regulatory ensemble of instruments to coordinate water use, adherence to the principles of robust separation applied to MAR provides the prerequisite information to coordinate individual actions into socially beneficial collective outcomes.

The robust MAR governance framework resolves the resource allocation tension between consumptive use and the environment for each operational element of an MAR scheme. The process allows for the equitable distribution of consumptive shares, assigns risk and the process of redress, accounts for allocations in a changing world, addresses the rights of independent third parties and does so in concert with issues related to distribution and use.

## 7. APPLYING THE PRINCIPLES OF ROBUST DESIGN TO MAR

To conform to NWI objectives (CoAG 2004), the management of MAR in urban water systems is required to facilitate markets and market incentives when appropriate. Effective market exchange is contingent on fully specified property rights, sufficient market participants and hydrologic connections and water supply considerations that permit the exchange of either tradeable water entitlements or allocations.

A unified and systematic governance framework combining the operational elements of MAR with the principles of the robust separation of water interests has been described in preceding sections of the report. Systematic governance allows for the independent and flexible management of MAR processes or elements characterised by separate and potentially exclusive policy objectives.

According to the decision framework, source water harvesting, recharge and recovery require the specification of a unit share entitlement of a defined consumptive pool, and independently managed rules to establish periodic allocation, enforcement and the conditions of use.

Final application of recovered water is subject to a water use licence. License conditions recognise the rights of third parties including the environment and subject to regulatory instruments and minimum standards.

The following section describes two examples of MAR operations as though they were managed according to the developed governance framework. The two examples focus on Adelaide in response to the broad endorsement of MAR by regional councils and the State Government. Both examples depict an MAR scheme sourcing stormwater, a brackish low transmissive aquifer subject to abstraction by existing groundwater users. These characteristics typify MAR schemes in Adelaide and introduce hydrological and biophysical context to the examples described. Both MAR schemes are fashioned according to robust separation principles

The first example describes the supply of non-potable water characterised by limited localised trading of recovered water. The second example describes a MAR scheme supplying potable water. Expanded trading opportunities are enabled through aquifer water banking, rules for yearly carry over of stored water and access arrangements with the operators of existing mains infrastructure.

### 7.1. Example one; Stormwater MAR for localised water supply

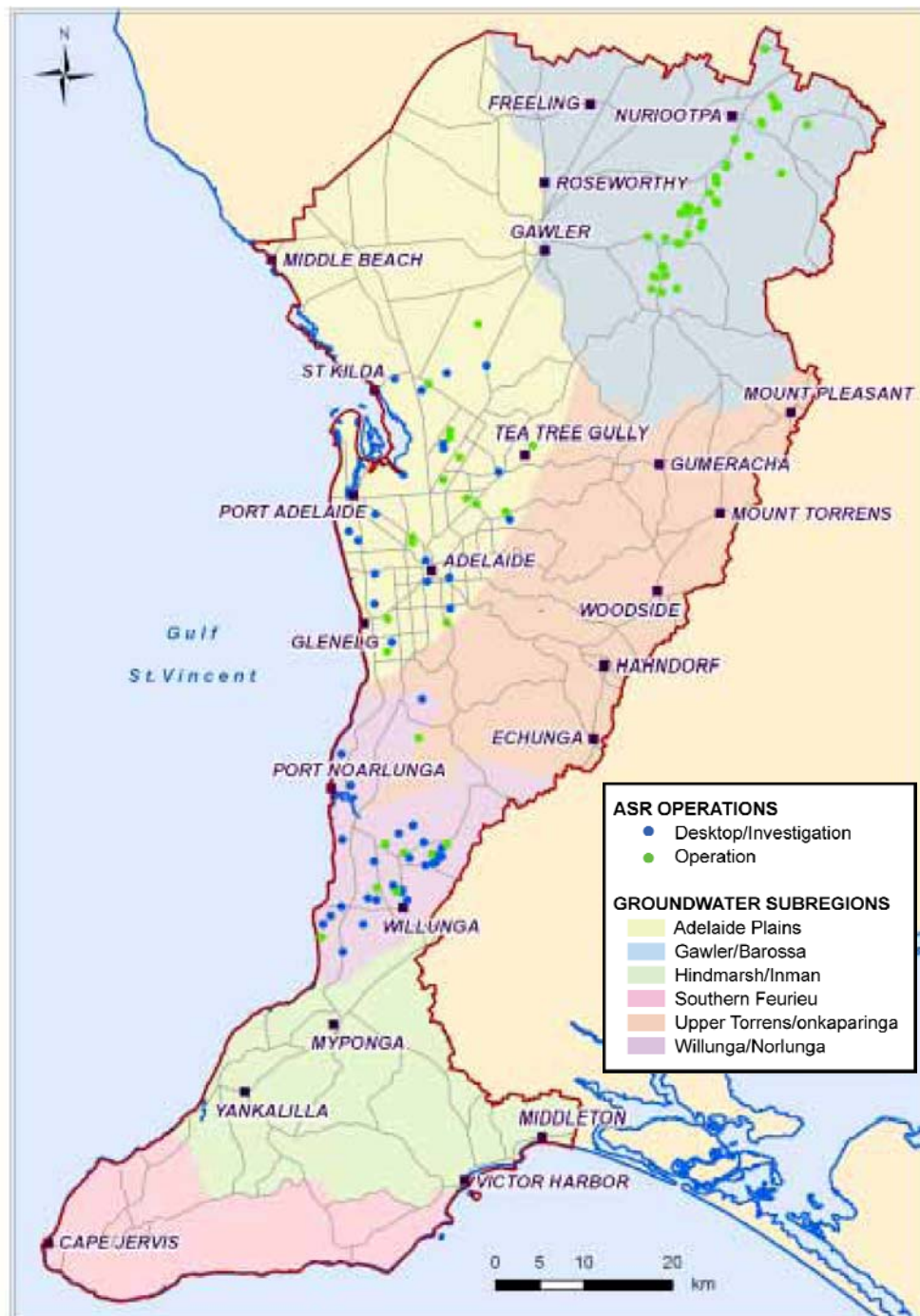
#### Existing MAR in the Greater Adelaide region

The Adelaide and Mount Lofty Ranges State of the Region Report (AMLR NRMB 2008) identifies 74 ASR operations or sites under investigation in the Adelaide Plains, Willunga and Gawler Barossa groundwater subregions. Operational schemes harvest stormwater runoff from within urban catchments and incorporate wetlands as a mechanism for pre-treatment of the stormwater prior to injection. Most of the ASR schemes located in Figure 4 typically target the Tertiary limestone / sandstone aquifers (T1 and T2 aquifers). Typically the aquifers contain groundwater that is too brackish for irrigation unless stormwater has been injected to freshen it. A number of projects occur in hard rock aquifers composed of fractured quartzite and shale. Recovered water is used for irrigation, industrial supplies and to dilute recycled water in third pipe supplies for toilet flushing and gardens.

The potential for MAR as a water resources management option, aiding stormwater management, reducing the reliance on reticulated water and providing significant community

assets in the form of wetlands, has been recognised by the three main councils that occupy this area: Salisbury, Playford and Tea Tree Gully. Additional MAR sites are under consideration with recovered ASR water intended for irrigation and industrial supplies, highlighting the need for a consistent policy approach.

The State of the Region Report notes that MAR using reclaimed water from the Bolivar Waste Water Treatment Plant (WWTP) is also under consideration across the Northern Adelaide Plains prescribed wells area, targeting the T1 and T2 aquifers. Approximately 25 to 35 GL of reclaimed water may be available annually; however, aquifer capacities may be insufficient to contain an annual cycle of this magnitude without exceeding piezometric head constraints. Constraints to expand ASR operations were identified as localised increases in groundwater pressures from winter recharge, which are likely to result in increased upward leakage through nearby wells and to local flow systems (AMLR NRMB 2008).



**Figure 4 ASR operations in the Adelaide Mount Lofty Ranges management region (Source: AMLR NRMB 2008)**

For simple exposition, the examples typify the characteristics of the Adelaide ASR described by Pavelic *et al.* (2006a, b). They are:

- a stormwater source,
- a brackish confined aquifer of low transmissivity,
- winter recharge and summer recovery via an injection well;
- localised freshening zones of 100-200 m radius,
- a community of currently extracting end users of brackish water, and,
- potential non-potable industrial and agricultural end use.

### Harvesting stormwater

The proposed South Australian *Local Government (Stormwater Management) Amendment Act 2007* defines stormwater as surface water, thus subject to prescription as a water resource. Stormwater is prescribed when a local council stormwater management plan, subject to approval by a regional Natural Resource Management Board, has been approved. In accordance with the *Natural Resources Management Act 2004*, a water plan specifies the minimum flow required to sustain ecosystems dependent on stormwater, although the *Act* does not explicitly state this as a science based determination. Surface water, and hence stormwater, is not included in the proposed Central Adelaide Prescribed Wells Act. Current legislation provides for free, non-exclusive access to stormwater. Security of entitlement is currently denied to those operators who choose to invest in stormwater as the primary water source for MAR.

We assume that the regional NRM board will have determined the relative annual contributions of both stormwater and natural catchments to dependent ecosystems for each stormwater plan and as a corollary, the residual consumptive pool. Establishing the environmental pool is antecedent to establishing the consumptive stormwater pool and subsequent harvesting entitlements.

Consider a connected stormwater network as an administratively feasible, hydrological spatial unit for a stormwater management plan, characterised by a common, low cost and accurate monitoring point of minimum environmental flow. The *Stormwater Management Act* indicates a local council network as the most likely management unit, although aggregations of connected council stormwater networks may provide more cost effective administration and shared monitoring costs. Common pool aggregations of a small number of councils introduce the potential for inter-jurisdictional cooperatives as a means of cost effective stormwater management (see Ostrom 1998, Bromley 2000).

The prescribed environmental pool sets the lower boundary condition of the consumptive stormwater “pool”, whilst the upper bound is set by infrastructure capacity. A primary function of stormwater management is flood mitigation, avoiding intermittent peak flow events that breach diversion capacity. Additional functions reduce the load of suspended solids and nutrients discharging to the Gulf of St Vincent, to increase the productive use of water to reduce stress on Adelaide water supplies and to increase urban amenity and land value. Defining the consumptive pool offers additional stormwater management strategies that utilise markets to increase economic efficiencies (i.e. the net benefit of water use). For effective stormwater markets, the consumptive pool is the basis of entitling each legally defined unit share of a stormwater management plan equal access to stormwater harvesting. We briefly discuss two alternative governance strategies.

The first strategy entitles a single unit share to stormwater access to a managing Council. South Australian Metropolitan councils are responsible for the maintenance of the

stormwater network. As stormwater increasingly assumes an economic value, Councils have an incentive to assume all consumptive unit shares and act as sole stormwater harvesters. Contingent on compliance with water quality and treatment standards, council harvested stormwater may be either used for direct municipal use, or to convert peak flows to a more reliable base flow, diverted to retention ponds or constructed wetlands for storage and biological treatment.

These benefits may be augmented by storage in aquifers, particularly when faced with limited land availability, prohibitive costs of surface water storage (e.g. wetland construction), surplus peak flow volumes or excessive evaporation losses. A variant of the sole unit share scheme is the granting of fee paying stormwater harvesting licences or negotiating contractual harvesting arrangements with commercial interests. Such arrangements may be more administratively feasible, minimise transaction costs and maximise net benefits. Councils could also receive stormwater rents as upfront revenue in the way of licensing fees.

The second strategy assigns multiple volumetric unit shares, entitling operators stormwater access to a specified proportion of system capacity. If transaction costs of markets are low relative to benefits or they are likely to generate persistent stormwater management innovations, councils have an option of distributing unit harvesting shares to multiple commercial interests. The potential for additional net benefits gained by combining stormwater offsets and harvesting markets is one example. Tietenburg (1998) appraises the relative merits of alternative entitlement distribution mechanisms of auctions or grandfathering.

Young and McColl (2007) propose stormwater offsets as an approach to reduce the need to construct additional stormwater infrastructure to prevent flooding. Offsets can operate as an incentive for developers and land owners to maximise runoff retention before entering the stormwater system, reducing stormwater flow rates and volumes. Stormwater harvesters however seek to maximise stormwater flow for eventual treatment, storage and resale. If such a scheme were in operation, the strategic placement of stormwater detention for flood mitigation can also generate additional revenue opportunities for harvesters through the production of stormwater offsets. Cost effective offsets can be traded with developers, to meet their stormwater reduction obligations. Combined with ASR, the offset scheme outlined by Young and McColl (2007) illustrates a comprehensive market approach to stormwater management, providing incentives to both reduce infrastructure demands and augment water supplies.

Harvesting by non-council interests is contingent on a stormwater unit share entitlement. Hilmer (1993) recommended that control of infrastructure cannot be used to restrict access by independent commercial entities. Under the Commonwealth *Trade Practices Act*, (1974) third parties can apply for access to a capacity constrained monopoly infrastructure under reasonable rights and conditions, with a right to binding arbitration if agreement cannot be reached (ACIL Tasman 2005, Marsden Jacobs 2005). If there are additional benefits to be gained by extended private access, councils breach the *Trade Practices Act* if they were to attempt to monopolise stormwater infrastructure.

Young (2006) proposes a 5 year moving average of rainfall as one example of a transparent reference for the announcement of annual harvest allocations for share holders in a groundwater extraction system. Accounting for unpredictable, peak stormwater events creates additional challenges, however, the 5 year allocation proposal provides a basis for stormwater harvesters to plan for seasonal and climatic variability. Allocations managed by an agency independent of access entitlements are recommended, possibly by the Stormwater Management Authority. Section s56 of the *NSW Water Management Act 2000* provides a template for the allocation announcement, which states that a defined share entitles the holder to take water at a specified rate, time, circumstance or location and may be expressed as a specified volume or proportion of available water in a storage structure or storage inflow.

Harvesting stormwater is necessarily opportunistic, and the risk of intermittent, variable harvest allocations should be assigned wholly to the unit shareholders, precluding the right to seek redress or compensation, avoiding controversial settlement. Harvesters also assume the risk of system leakage, although with the economic value of stormwater established, there is an ongoing incentive to minimise leakage. As an example of entitlement obligation, continued harvesting rights would be conditional on the regulated disposal of concentrated retention pond contaminants and waste (subject to for example EPA regulations).

Colby (1995) proposes a cautious approach to developing ground-water markets, arguing that the cardinal nature of water and the heterogeneous demands placed on it makes standardised, immediate and anonymous market transactions potentially undesirable and improbable. The detrimental aspects ascribed to incomplete markets are compounded and complicated when measures of water quality are included in the transaction protocols. For example different users can tolerate different water qualities and the same consumer can tolerate different qualities when applied to different uses.

The characteristics to which Colby refers describe stormwater systems, which are highly heterogeneous systems typified by interacting water quality and volumetric parameters. They are typified by intermittent, highly episodic and variable flow regimes, with heterogeneous concentrations of contaminants. Variance occurs both spatially and temporally, for example first flush stormwater pollutant levels are considerably higher than subsequent flows. Quantity and quality heterogeneity is likely to be expressed as variance in marginal capture and treatment costs as well as differences in marginal benefits. Entitlements are therefore unlikely to be unit shares in the capacity of a homogenous “consumptive pool”.

We therefore recommend a cautious and considered approach to designing stormwater entitlements and consider this an area of important future research.

### **Aquifer recharge, storage and recovery**

From the *NRM Act 2004*, it is unclear whether brackish aquifers are defined as a prescribed water resource and subject to a water plan. The Central Adelaide Prescribed Wells plan provides for groundwater and for expository purposes we assume the aquifer management is described by a water plan.

In the example an aquifer water plan defines the ambient environmental pool expressed as the range of allowable piezometric heads, or aquifer storage capacity. The unit share represents the storage or aquifer warehousing entitlement, defined as a quantum of the net storage capacity. The recharge entitlement therefore defines the right to actively store additional water or the right to raise the water table.

The clear separation of source water harvesting and aquifer storage rights provides increased flexibility in system operation. Injectors with recharge entitlements may either own a unit share in stormwater harvesting or may choose to procure via market exchange stormwater or alternate injectant sources for storage and future extraction. Alternatively, recharge entitlement holders may choose to trade the right to store stormwater to those needing cost effective stormwater offsets. A traded recharge entitlement is assumed to be on a permanent basis. Conversely a traded allocation only confers the proportional volume nominated for the allocation period and is considered a temporary trade.

To monitor net storage capacity, volumes of aquifer injection by individual interests must be audited and entered in a central, double entry register or accounting system, maintained and administered by the agency responsible for groundwater resources management.

Holding a recharge entitlement does not automatically confer the right to inject water in the aquifer. An allowable annual volume of stormwater injection, equally apportioned to all unit access entitlements and contingent on the aquifer storage level, is calculated as the net

product of non-ASR ambient infiltration and total existing extractions. The 5 year moving average of past groundwater levels provides an initial equitable basis for determining the annual storage allocation, with scope for planning by ASR investors to account for climate variance and future demand. The risk that the annual allocation will vary is borne by the unit share holder, not the aquifer manager. Independently determined allocations may vary from zero in flood years (high levels of ambient infiltration and low extraction volumes) to 100% for extended dry periods or drought (as in Figure 2). In a given year the dominant constraint on recharge volume will be either available storage capacity, the amount of source water allocation for recharge or the actual volume of harvestable water.

Defined entitlements to aquifer storage introduce the potential for inter period water banking, debit and credit accounting systems and water quality exchange rates. The banking system proposed for groundwater extraction by Young (2005) acts as a template for water banking, mindful that here the ASR “bank” accounts refer to additional recharge, not resident groundwater. Injectors are able to store long term water deposits, but are subject to a temporal depreciation function for future extractions that reflects aquifer retention characteristics.

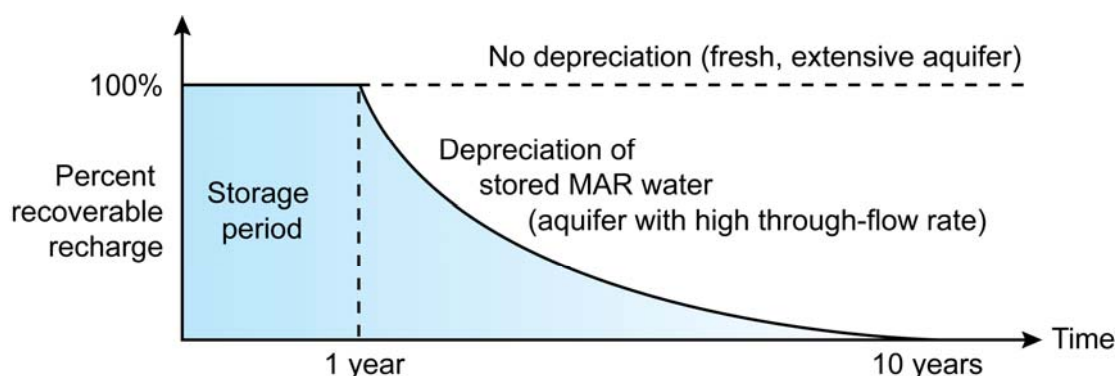
Managed aquifer recharge projects in brackish aquifers have a storage depletion rate and after a number of years of storage the injected fresh water cannot be recovered at a salinity level that meets requirements for use. In transmissive coastal aquifers discharge to the sea will deplete the recoverable volume of recharged water.

Figure 5 illustrates how a system might operate when the MAR proponent carries forward recharged water into the subsequent accounting period. The period up to one year accounts for a minimum period of storage to enable pathogen and contaminant attenuation. A 100% recovery rate of injected water at the end of the one year accounting period is indicative only, acknowledging that a non-depreciating recharge for a defined period is a strong incentive for MAR development. A non-depreciating accounting convention applies to banking water in aquifers suited to long term storage and to provide emergency and drought supplies.

Policies that define proportional recovery rates less than the recharge volume reflect recharge operations characterised by accelerated discharge of fresh water from the aquifer. Proportional recovery rates represent an attempt to ensure either there is sufficient stored water at the well head or to accelerate replenishment of over allocated aquifers. South Australian guidelines (e.g. McLaren Vale) nominate extraction as 75%-80% of aggregate storage in brackish aquifers to account for mixing of recharge and native groundwater<sup>23</sup>. Less than the full volume of recharge can be recovered at a salinity fit for intended use. This is described as recovery efficiency (EPHC 2008c ch6.2). The accounting convention of inter period banking quantifying injectant migration is analogous of the evaporative losses in a surface water dam managed according to a capacity sharing regime.

---

<sup>23</sup> The National Groundwater Action Plan has funded MAR schemes in Adelaide using stormwater sources. Rechargers have been entitled to an increase in their allocated extraction volume from 80% to 100% of the recharge volume on the Northern Adelaide Plains. Metering determines the volume of injection and recovery, which is normally a permit condition for an MAR operation. In one case where a 100% allocation has been assigned, 20% of this may be withdrawn remotely from another aquifer which although more saline, is fit for purpose. Transfers of allocations can only occur up-groundwater gradient. That is a transfer of allocations to extract groundwater occurs away from an established the cone of depression.



**Figure 5 Example of the depreciation of stored MAR water**

Alternatively a 100% recovery rate for a prolonged storage period may act as an added incentive to promote MAR schemes providing compensation for the provision of the public benefits of improved groundwater quality, reduced pumping costs, reduced salt water intrusion and reserve urban supplies.

The National Water Initiative (c. 48, c.49) specifies the assignment of risk of future reductions or less reliable water allocations between the Government, agencies and the holders of water access entitlements. Clause 48 (i-iii) states that reductions arising from natural events such as climate change, drought or bushfire are to be borne by entitlement holders. Clause 49 (i-iii) describes the rules and proportional water reductions borne by users and Government arising from bona fide improvements in knowledge about a water systems' capacity to sustain particular extraction levels. The risk of reductions arising from changes in government policy not previously provided for would be borne by governments (c. 50). Clause 51 allows for a different risk assignment model to be implemented based on voluntary agreements between relevant State or Territory governments and entitlement holders.

The general principles set out in the NWI to assign risk are consistent with the standard economic approach, which requires that risk be allocated to the party best able to manage it. Quiggin (2007 p. 9)<sup>24</sup> notes that there are serious problems in the implementation of assigned risk for water reform and argues "...*(f)or instance, suppose that long-term average rainfall declines in line with the predictions of climate change models. It will be difficult to determine whether the reduction is in fact due to climate change, or merely represents a run of dry years. Although the risk in both cases is supposed to be borne by water users, it is likely that the appropriate response and the resulting allocation of costs between users will differ. Implementation of the principles of the National Water Initiative might therefore be difficult, or even impossible, in the absence of the information needed to distinguish between the two types of impacts*".

To effectively manage MAR, proponents need to be able to reliably evaluate the implications of their management decisions prior to implementation and to monitor progress against specified targets. For example, the rate of dispersal of MAR recharge water and the proportion available for recovery is crucial to investment and management decisions.

The notion of developing rules to assign risk between agencies and operating interests applies to MAR, albeit decisions are likely to be subject to an additional factor. The processes of MAR are costly to proponents and are likely to produce both private and public benefits. Private benefits are realised through market transactions whilst public benefits are realised as improved reliability in urban water supplies and for example may result in a reduced severity or duration of water restrictions. The monetised valuation of the public benefit may be unrevealed or imprecise, implying that MAR operators incur the entire cost without compensation.

<sup>24</sup> <http://johnquiggin.com/wp-content/uploads/2007/02/CEDA0702.pdf>

The relative assignment of risk and compensation between public and private MAR interests to achieve desired water security levels is likely to affect the rate and extent of MAR development, requiring focussed research and careful policy design<sup>25</sup>.

In general, aquifer injection of water of a higher quality than ambient groundwater may confer considerable benefits to existing or contiguous groundwater users. Reduced pumping costs, improved water quality (dependant on the dimensions of the freshened zone), pathogen attenuation and amelioration of salt intrusion may all reduce the costs incurred by existing users. Potentially a future market could be developed that provides a means for injectors to be compensated for the introduced cost reductions, mindful that the effectiveness and adoption of a market approach is highly dependent on the magnitude of transaction costs relative to benefits associated with formal exchange mechanisms. In aquifers of low transmissivity the number of transacting interests is likely to be low. Informal, voluntary, cooperative approaches, such as compacts between ground water user groups outlined by Ostrom (1998) and Bromley (2000), are likely to provide pragmatic, cost effective and acceptable solutions, whereby injectors contribute a public benefit to the common pool community.

Low transmissivity is likely to act as a potent determinant of well location. Consideration of the potential non-linear effects of proximate MAR consortiums, (viz. increased freshening zones or adversely, increased hydraulic pressures on vulnerable aquitards, increased recharge and recovery costs and reduced recovery efficiency due to interference effects) will affect the spatial location of wells. The conditions of the recharge entitlement will specify well location and characteristics in accord with the spatial differentiation of storage capacity. In times of high piezometric pressures, a possible condition of the recharge entitlement will require MAR operators to cease recharge to maintain aquifer integrity and comply with prescribed piezometric head constraints.

The transmission of water is an important economic function of aquifers. In transmissive fresh water aquifers the recovery of stored MAR water does not depend on the dilution of native groundwater by the recharged water. Contingent on recharge water being of equivalent or better quality than the native groundwater, stored water may be recovered remotely from the recharged location. In this case the aquifer acts as a water distribution system that only requires access by a well to recover water at any location. In the brackish aquifers typical of Adelaide, the transmission value is negligible (Dillon *et al.* 2009).

Existing water reform institutions are concerned primarily with water extractions, pertaining to both surface and groundwater, with limited reference to storage rights. Dudley and Musgrave (1988) and recently revised by Brennan (2007), were the first to propose a capacity share; a single water interest representing a combination of water storage and extraction entitlements. Cognisant of transaction costs and the encouragement of scheme adoption, Dudley and Musgrave (1988) and Young and McColl (2003a) recommend parsimony in institutional design and care in the temporal sequencing of instruments.

With the likelihood of a limited number of MAR proponents (i.e. thin markets) and to maintain consistency with the current administration processes, a recharge entitlement will confer rights to recover stored water, expressed as a proportional relationship of current period injection and net accumulated aquifer storage. As the number of MAR schemes increases,

---

<sup>25</sup> The NWC Annual Report (2008 p.18) states: "Decisions to invest in urban water infrastructure involve trade-offs between cost and reliability of supply. The Commission recommends that levels of urban water security be more clearly articulated in plans and that governments explore the feasibility of a national minimum reliability benchmark for water supply in major centres, specifying expected frequency and severity of water restrictions. The Commission recommends that the minimum reliability benchmark be developed in consultation with the community".

expertise in MAR and trading improves and the relative cost of transactions decreases, the potential of further efficiency gains and innovation may warrant the unbundling of recharge and recovery entitlements.

Transmissivity combined with brackish receiving waters assumes a key role when establishing spatial opportunities for the exchange of extraction entitlements or allocations. We assume as in surface water transactions, entitlement exchange implies a permanent transfer of recharge rights whereas allocation transactions are temporary. High transmissivity rates confer increased opportunities for the exchange of extraction entitlements between spatially dispersed interests. The recharge of high quality water is available to distant pumping interests within the allocation accounting period (e.g. 12 months), without depressing water tables or affecting other distant aquifer interests. Adelaide metropolitan aquifers are characterised by low transmissivity, restricting injectant mobility to approximately 100-200 m freshening zones per well within the annual accounting period. In the absence of additional piping and pumping costs or access to existing reticulation infrastructure, trade in higher quality recovered water is likely to be constrained to pumping interests within the injection zone; effectively from injection wells. Table 7 summarises possible entitlements, allocations and use conditions of a hypothetical MAR scheme operating in Adelaide that has been designed according to robust separation principles.

**Table 7 Managed aquifer recharge operating according to robust design principles**

MAR governance instrument:	1 Capture Zone	3 Recharge	5 Recovery	7 End use
<b>Entitlement</b>  managed by Water Resource Agency	<ul style="list-style-type: none"> <li>• Stormwater differentiated as several management areas</li> <li>• A single unit share in the management areas stormwater consumptive pool held by a local council.</li> <li>• Licensing to private operators</li> </ul>	<ul style="list-style-type: none"> <li>• Right to recharge and access a unit share of aquifer's storage capacity</li> <li>• Subject to depreciation rate</li> <li>• Right to exchange subject to spatial constraints</li> <li>• Well placement subject to spatial constraints</li> </ul>	<ul style="list-style-type: none"> <li>• Recovery of stored water a function of individual managed recharge.</li> <li>• Subject to depreciation rate through time</li> <li>• Right to transfer to existing or new aquifer user</li> </ul>	
<b>Periodic allocation</b>  managed by NRM agency	<ul style="list-style-type: none"> <li>• Periodic allocation rules determined as 5 year moving average</li> <li>• Potential for additional stormwater or offsets</li> <li>• Right to exchange or transfer allocations subject to spatial constraints</li> </ul>	<ul style="list-style-type: none"> <li>• Annual right to alter piezometric head subject to total abstraction</li> <li>• Right to transfer allocations</li> </ul>	<ul style="list-style-type: none"> <li>• Extraction volume contingent on piezometric head, natural recharge and spatial constraints</li> </ul>	
<b>Obligations and enforcement</b>  managed by NRM agency	<ul style="list-style-type: none"> <li>• 3rd party rights of access to infrastructure for stormwater and sewage</li> <li>• Required to manage stormwater debris, concentrates and wetland sediment</li> </ul>	<ul style="list-style-type: none"> <li>• Requirement not to interfere with entitlements of other water users and water bankers</li> </ul>	<ul style="list-style-type: none"> <li>• Water quality must meet prescribed fit purpose</li> </ul>	<ul style="list-style-type: none"> <li>• Water use licence subject to regional obligations and conditions, for use and disposal</li> </ul>

## 7.2. Example two: MAR and a water security fund for drinking water supplies

The second example describes an MAR scheme with the same stormwater harvesting and aquifer characteristics as Example 1. The exception is that recovered water complies with drinking water standards. Example 2 is characterised by expanded opportunities for a water trading market, facilitated by water treated to potable standards, defined MAR water recovery entitlements and a water security fund necessitating contracted access to the existing mains water infrastructure.

The relative marginal costs of treatment of recovered MAR water and community acceptance are two fundamental aspects of MAR and recycled water in general that need to be addressed.

Dillon *et al.* (2008b, 2009) support the cost effectiveness of MAR with stormwater to produce potable water. They describe a harvested stormwater aquifer storage, transfer and recovery demonstration project in Adelaide capable of producing recovered water at potable standards. Stormwater is treated in a reed-bed wetland before injecting into wells in a limestone aquifer 160 to 180m below ground. Measurements indicate that water treated using pre-treatment and sufficient residency time in the aquifer to allow attenuation processes to occur achieves potable standards that are cost effective compared to other supply options (Dillon *et al.* 2008b,c).

Leviston *et al.* (2006) provide evidence to indicate community acceptance of recycled water subject to annual aquifer residency and attenuation processes. A 500-person survey in metropolitan Perth outlining a MAR scheme for recycling reclaimed water to drinking water standards in 2006 found that more than 78 % of people were unopposed. Additionally the Australian Guidelines for Water Recycling (EPHC 2008a, 2008c) will do much to increase knowledge and give confidence in the risk management of MAR for drinking water supplies regarding human health and environmental protection.

### Developing a water security fund

The proposed water security fund is analogous to the Independent Procurement Entity recommended by the Western Australian Economic Regulation Authority (ERA 2007) and the Arizona Water Banking Authority. A primary objective is to separate the role of a State owned water authority controlling infrastructure from those as bulk water supplier. Conflicts of interest arise when a sole water supplier is commissioned with water conservation by reducing demand. Failure to address these conflicts is likely to lead to impediments and disincentives for the private sector to develop alternative innovative water supply options. Breaking the nexus between the contestable and non-contestable elements of urban water supply is recommended as a fundamental first step (Productivity Commission 2008).

An independent bulk water supply manager operating under such a scheme is one option that reduces the risk of political interference, clarifies the role of government and provides the basis to reduce institutional uncertainty for private water operators.

Mains water and sewerage infrastructure and environmental and public health are the non-contestable components of urban water management and generally best managed by regulatory instruments and minimum standards. Opportunities for market approaches in the contestable areas of alternative bulk water supply remain relatively unexplored in Australian cities. The bulk water supply manager is one possibility that activates those opportunities for the supply of bulk urban water from diverse and competing water providers, including MAR.

A State Water Commission is assumed to be responsible for determining water supply targets, future needs and supply security requirements. Water quality is regulated through

policy standards and guidelines and alternative supply options are activated through individually vested unit shares or entitlements and allocations. Water pricing and competition are determined at the State level in accord with NWI principles. Enforcement and annual allocations are managed independently of the agency granting entitlements.

Based on State Water Commission indications of supply and security targets, the bulk water supply manager would identify future water supply shortfalls and seek ways to meet these shortfalls through competitive supply augmentations developed by both the private sector and public utilities. The model allows for greater competition in the identification of alternative supply options ensuring that all possible alternatives are considered and subsequently the least cost combination of options developed. Ideally least cost options are expressed as reduced water charges for consumers whilst meeting environmental and social equity obligations.

An effective multi source water supply requires water that is storable, interchangeable through water quality equivalence and cost effective supplies have equal opportunity to be distributed. Participation of all alternative potable water supplies, including MAR requires both the assigning of entitlements to recovered water in concert with third party access to mains distribution. Access to mains water distribution overcomes the physical and commercial constraint of brackish or low transmissivity Adelaide aquifers. The bulk water supply manager is assumed to have the statutory capacity to ensure access is not impeded.

Adelaide aquifers although extensive, mostly contain brackish water. Low transmissivity means that high quality water stored in the aquifer can only be recovered at an acceptable quality in close proximity to the point of recharge. Thus, without access to a connected reticulation system, it is not possible to develop a geographically dispersed market for stored water based on the aquifer alone. Water stored and recovered with access to the mains distribution system has the same effect as if the water was drawn from a reservoir. The effective reservoir capacity is expanded by MAR where the quality of recovered water meets drinking water requirements and can be blended without adverse consequences on water quality or asset life (Dillon *et al.* 2009)

MAR projects in brackish Adelaide aquifers have a storage depletion rate and after a number of years of storage the volume of injected fresh water that can be recovered at a salinity level that meets drinking water criteria diminishes. The depreciation rate is dependent on aquifer characteristics and the management regime.

The Water Security Fund is a privately managed legal entity that can operate either independently or in cooperation with the Bulk Water Supply manager. The Water Security Fund represents a collectively organised arrangement for the storing and exchange of water supply and demand entitlements. MAR is likely to be among the cost effective supply options for the Water Security Fund. By acquiring water entitlements or producing and storing surplus supplies, and making these available to acquire and use, the Water Security Fund effectively reduces the transaction costs of informational search, bargaining and negotiated exchange. Exchange occurs at a market price that includes the investment costs of providing the current portfolio of infrastructure or water savings projects. Capital costs are covered by a pool of investors and dividends are paid through water sales at a wholesale level.

New developments are required to surrender sufficient water entitlements to account for the development's future water demand. Developer requirements to underwrite the cost of sourcing water for a new subdivision can be met through purchasing an entitlement at the Water Security Fund, and thereby contribute to the capacity to expand water supplies or the developer can purchase through the Bulk Supply Manager. Alternatively an investment by the developer in the Water Security Fund can be made in anticipation of a need for future entitlements. These arrangements are in addition to current developer contributions to infrastructure to connect to mains water, sewers and stormwater systems, nominally made to the Grid Manager. The project portfolio selected by the Water Security Fund for investment

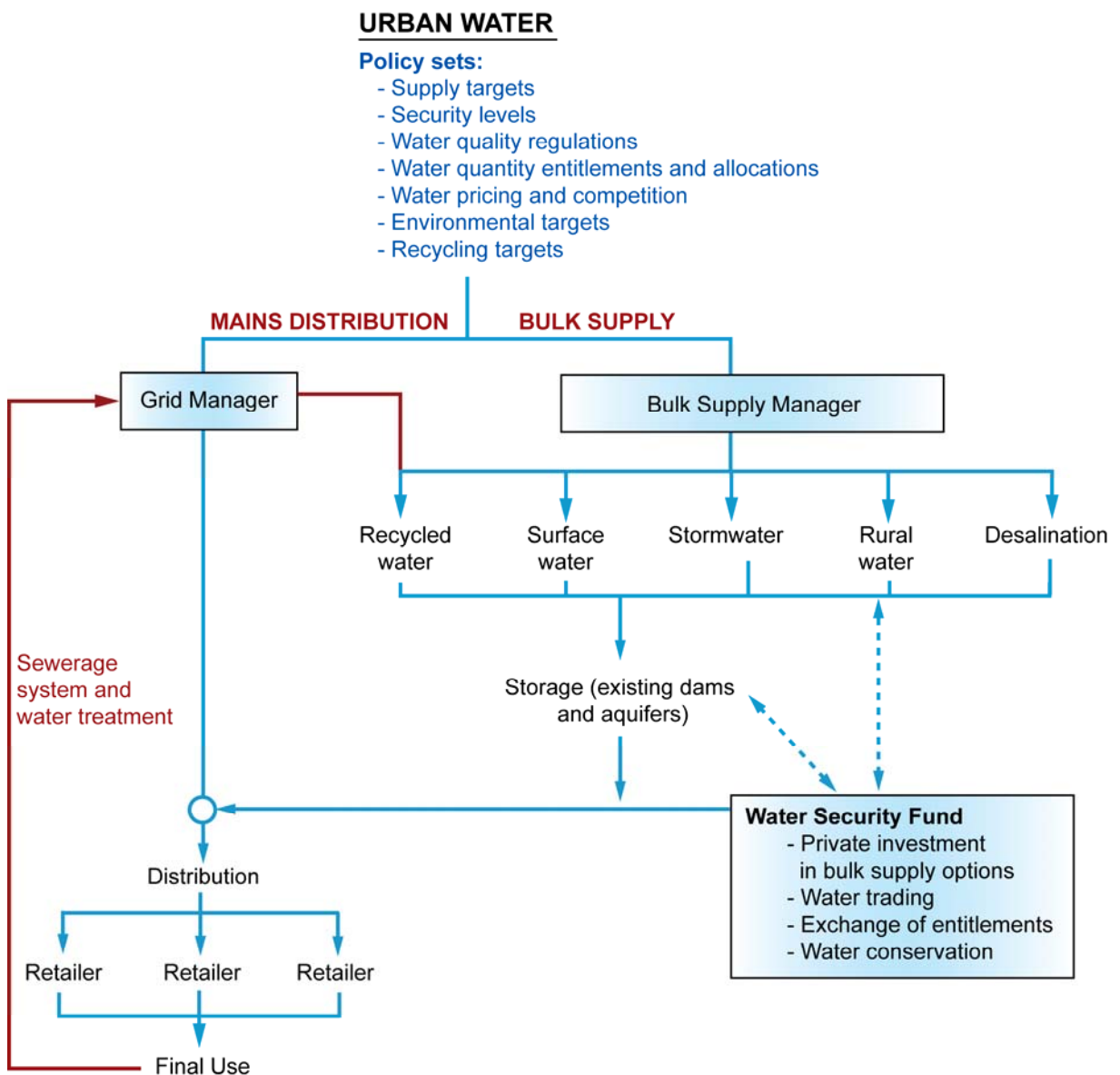
meets economic efficiency principles and also meets a range of government policy objectives, for example those related to water security, water quality, environmental protection and other externalities specific to the water supply market. Figure 6 illustrates the management and operation of an urban water supply and distribution scheme that includes MAR designed according to robust design principles and a Water Security Fund.

The proposed water supply scheme operates in the following manner.

1. Bulk water supply is managed independently of mains and sewerage infrastructure. Infrastructure is operated by a Grid Manager and its contractors. A Bulk Water Manager operates and manages supply.
2. A State Water Commission is appointed to estimate predicted urban water supply requirements and future shortfalls. The Bulk Water Manager seeks ways to meet these shortfalls via supply augmentations and demand management options developed by both the private sector and Government owned utilities. The Bulk Water Manager has the legal capacity to ensure access to water distribution infrastructure is not impeded and water quality and quantity of all parties comply with prescribed standards and guidelines. .
3. Urban water suppliers, utilities or retailers are required to have entitlements for the water they take from catchments and aquifers. According to robust separation principles we assume that access entitlements have been assigned and are defined as unit shares in the respective consumptive pool. The rules for periodic allocations have also been established and accepted, including enforcement and conditions for redress and compensation. An independent NRM agency manages and enforces the determined rules. Water conservation and demand management is recognised as a means of creating water entitlement credits to trade.
4. Water entitlements and allocations are secure, fully defined, exclusive, enforceable and thus tradeable and have been developed for all supply options including MAR operational processes.
5. Entitlements represent a unit share or quantum of the defined consumptive pool; in the case of MAR, a recovered water entitlement is a function of the recharged water volume subject to the depletion rate. The allowable volume of recoverable water for the year is determined according to the allocation rules. We assume it is an average year therefore the allocation for recovery is 100% of recharged water. Both can be traded: allocations represent temporary trades and entitlements represent a permanent transfer of the unit share.
6. The conditions necessary for effective markets to operate do not always exist: Insufficient numbers of market participants, incomplete markets, capital constraints or high transaction costs relative to benefits are possible impediments to a functioning market. In that case the Bulk Water Manager operates as the sole water supplier.
7. We assume that the conditions for an effective market are satisfied and the Water Security Fund is in operation in parallel with the Bulk Supply Manager. The Fund pays a conveyance fee at commercial rates for access to mains distribution.
8. New subdivisions and industries increase the demand for water implying the utilities' water entitlements have to be increased by the amount of the new demand. We assume that the entitlements for existing Adelaide urban water supplies are fully assigned. The Water Security Fund operates as either an investor in new supply infrastructure producing new water supply shares or can purchase bulk water entitlements from the most cost effective water supply projects. All suppliers must comply with environmental and social equity criteria.

9. In the case of MAR the majority of water supply to the Water Security Fund will consist of supplies from the Fund's infrastructure investments in addition to traded yearly allocations of recovered water, nominally under long term contract to ensure security of supply and facilitate investment planning. The Bulk Water Manager and the Fund would be required to review supply contracts for example every 5 years.
10. These are sold to the developer, a number of water retailers, or possibly even directly to large customers to meet current demand and ensure future supplies.
11. Market pricing of bulk entitlements will be cost reflective, meaning that price signals reflect the scarcity of water, account for externalities, include the costs of distribution and allow for research contributions to meet the objectives of urban water management.

**Figure 6 Urban water management including a Water Security Fund and robust designed MAR**



## REFERENCES

- AATSE (2004) *Water Recycling in Australia*. ISBN 1875618805, Australian Academy of Technological Sciences and Engineering, Melbourne.
- ACIL Tasman (2005) *Research into access to recycled water and impediments to recycled water investment: Report prepared for the Australian Government Department of Agriculture, Fisheries and Forestry*. ACIL Tasman, Melbourne.
- ACT Government (2006) 'Think Water, Act Water: Strategy for sustainable water resource management in the ACT', 2004-2005 Progress Report, ACT Government, Canberra. Accessed online [14 Nov 08] at < [www.thinkwater.act.gov.au/documents/TWAW04-05progress\\_report\\_web.pdf](http://www.thinkwater.act.gov.au/documents/TWAW04-05progress_report_web.pdf) >
- AMLR NRMB (2008a) 'Concept Statement: Central Adelaide Prescribed Wells Area', Adelaide and Mount Lofty Ranges Natural Resource Management Board, Government of South Australia. Accessed online [14 Nov 08] at < [http://www.amlrnm.sa.gov.au/Portals/1/Our\\_Plans/Docs/WAP/Central%20Adel/CAPW-A-WAP\\_Concept\\_Statement\\_April08.pdf](http://www.amlrnm.sa.gov.au/Portals/1/Our_Plans/Docs/WAP/Central%20Adel/CAPW-A-WAP_Concept_Statement_April08.pdf) >
- AMLR NRMB (2008b) *Creating a sustainable future: an integrated natural resources management plan for the Adelaide Mount Lofty Ranges – Volume A the State of the Region Report*. Adelaide Mount Lofty Ranges Natural Resources Management Board and the Government of South Australia, Adelaide.
- Archer, K and Patrick, K (1995) 'A Comparison of State Groundwater Laws', *Tulsa Law Journal*, vol. 123
- ARMCANZ and ANZECC (2000) *National water quality management strategy: Australian and New Zealand Guidelines for fresh and marine water quality*. Canberra.
- Australian Natural Resource Policies and Programs Committee (2007) *Response to the National Market Based Instrument Pilot Programme: Building capacity for market based instruments, scoping study*. NAP, Canberra Australia.
- Blomquist, W., Schlager, E. and Heikkila, T. (2004) *Common Waters, Diverging Streams: linking institutions and Water Management in Arizona, California and Colorado. Resources for the Future*, Washington DC, United States.
- Bowles, S. and Gintis, H. (2002) *Social capital and community governance*. *The Economic Journal* 112 (483) F419-436.
- Brennan, D. (2007) *Missing markets for storage and their implications for spatial water markets*. Paper presented to AARES Conference, Queenstown, NZ, 14th February 2007.
- Brennan, D. and Scoccimarro, M. (1999) *Issues in defining property rights to improve Australian water markets*. *Australian Journal of Agricultural and Resource Economics* 43, pp.69-89.
- Brodie, R., Sundaram, B., Tottenham, R., Hostetler S. and Ransley T. (2007) *An Overview of tools for assessing groundwater-surface water connectivity*. Bureau of Rural Science, Canberra.
- Bromley, D. (1991) *Environment and economy: Property rights and public policy*, MA: Blackwell.
- Bromley, D. (2000) *Property regimes and pricing regimes in water resource management*. In: Dinar, A., (Ed.) *The Political economy of water pricing reforms*, pp.29-49. New York: Oxford University Press for The World Bank
- Brown, R.R. (2005) *Impediments to Integrated Urban Stormwater Management: The Need for Institutional Reform*. *Environmental Management* 36 (3):455-468. 0364152x.

- Brown, R.R. (2008) Local Institutional Development and Organizational Change for Advancing Sustainable Urban Water Futures. *Environmental Management* 41 (2):221-233. 0364152x.
- Bruggink, T (1992) Third Party Effects of Groundwater Law in the United States: Private Versus Common Property, *The American Journal of Economics and Sociology*, vol. 51, no. 1, pp 1-17.
- Bryan, B.A. Ward, J.R., and Hobbs, T. (2008) An assessment of the economic and environmental potential of biomass production in an agricultural region. *Land Use Policy* 25 pp533-549
- Bryner, G and Purcell, E (2003) *Groundwater Law Sourcebook of the Western United States*, Natural Resources Law Center, University of Colorado School of Law.
- Bureau of Land Management (2001a) California: Water Rights Fact Sheet, available online [14 Nov 08] at < <http://www.blm.gov/nstc/WaterLaws/california.html> >
- Bureau of Land Management (2001b) Colorado: Water Rights Fact Sheet, available online [14 Nov 08] at < <http://www.blm.gov/nstc/WaterLaws/california.html> >
- Coase, R. (1960) The problem of social cost. *Journal of Law and Economics* 3, pp.1-44.
- Colby, B. (1995) Regulation, imperfect markets, and transaction costs: the elusive quest for efficiency in water allocation. In: Bromley, D., (Ed.) *Handbook of environmental economics*, pp.475-502, Cambridge USA: Blackwell.
- Colby B. and Jacobs, K (2007) *Arizona Water Policy: management innovations in an urbanizing, arid region*. Resources for the Future, Washington DC, United States.
- Commons, J. (1924) *Legal foundations of Capitalism*, Madison, Pa.: University of Wisconsin Press.
- (CoAG) (2004) Intergovernmental Agreement on a National Water Initiative, Council of Commonwealth Governments, available online [14 Nov 08] at [www.nwc.gov.au/resources/documents/Intergovernmental-Agreement-on-a-national-water-initiative.pdf](http://www.nwc.gov.au/resources/documents/Intergovernmental-Agreement-on-a-national-water-initiative.pdf)
- Connor, J., Ward, J., Clifton, C. Proctor., and Hatton MacDonald, D. (2008) Designing, testing and implementing a trial dryland salinity credit trade scheme *Ecological Economics*; 67(4), pp. 574-588
- Cuncliffe, D and Stevens, M (2003) Success of HACCP In the Drinking Water Industry – Can It Be Adapted To Reuse Schemes? *Water Recycling Australia 2nd National Conference* 1-3 September, 2003 Brisbane, Australian Water Association, Sydney.
- Demsetz, H. (1967) Toward a theory of property rights. *American Economic Review* 57, pp.347-59.
- Department of Sustainability and Environment (2006) A framework for alternative urban water supplies: managed aquifer recharge (MAR): A discussion paper. Government of Victoria [http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/c5fa02c8a18b8174ca25723b000e4644/\\$FILE/Discussion%20paper%20-%20Managed%20aquifer%20recharge.pdf](http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/c5fa02c8a18b8174ca25723b000e4644/$FILE/Discussion%20paper%20-%20Managed%20aquifer%20recharge.pdf)
- Department of Sustainability and Environment Melbourne, (2005) *Our Water Our Future*, Victorian Government Melbourne ISBN 1 74152 227 3
- Dickey , S. and Reznikov, K. (2008) *Aquifer Storage and recovery: Legal Issues*. Paper presented at Saving the Last Drop: water scarcity and the law. Environmental Defenders Office, March 13th, Adelaide.
- Dillon, P (2005) Future management of aquifer recharge. *Hydrogeology Journal*, 13 (1) 313-316.

- Dillon, P and Toze, S (eds) (2005) *Water Quality Improvements During Aquifer Storage and Recovery*. American Water Works Assoc. Research Foundation Report 91056F
- Dillon, P., Ward, J. and Cunliffe, D. (2007). *Innovation in Governance of Managed Aquifer Recharge*. p1-14, Procs. ISMAR6, Phoenix 28 Oct-2 Nov 2007, ed. P. Fox, Acacia Publishing, Phoenix, Arizona. [www.iah.org/recharge](http://www.iah.org/recharge).
- Dillon, P, Pavelic, P, Beringen, H, Page, D, Vanderzalm, J, Toze, S, and Ward, J (2009) *Managed Aquifer Recharge: An Introduction*. Waterlines Report No 13, National Water Commission, Canberra Australia, Feb 2009.
- Dillon, P. and Jimenez, B. (2008) *Water reuse via aquifer recharge: intentional and unintentional practices*. In (Eds) Jimenez, B. and Asanao; *Water reuse: and international survey of current practice, issues and needs*. IWA Publishing, London
- Dillon, P., Page, D., Vanderzalm, J., Pavelic, P. Toze, S., Bekele, E., Sidhu, J. Prommer, H., Higginson, S., Regel, R., Rinck-Pfeiffer, S., Purdie, M., Pitman, C. and Wintgens, T. (2008a). *A critical evaluation of combined engineered and aquifer treatment systems in water recycling*. *Water Science and Technology* 57(5) 753-762.
- Dillon, P., Page, D., Pavelic, P., Toze, S., Vanderzalm, J., Barry, K., Levett, K., Regel, R., Rinck-Pfeiffer, S., Pitman, C., Purdie, M., Marles, C., Power, N. and Wintgens, T. (2008b). *City of Salisbury's progress towards being its own drinking water catchment*. Proc. IWA Water Congress, Singapore, 23-27 June, 2008.
- Dinar, A., (Ed.) *The Political economy of water pricing reforms*, pp.29-49. New York: Oxford University Press for The World Bank.
- DPIWE (2005) 'Water Governance Arrangements for Tasmania', Report to the National Water Commission, Water Resources Division, Department of Primary Industries, Water and Environment, Government of Tasmania, Hobart. Accessed online [14 Nov 08] at < [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJY-6KY3CM/\\$FILE/Water%20Governance%20Tasmania.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJY-6KY3CM/$FILE/Water%20Governance%20Tasmania.pdf) >
- Dubois, D. (2001) *Mission d'étude et de réflexion sur l'organisation des pouvoirs publics dans le domaine de la protection de l'environnement*. Paris, Premier Ministre: 116 p.
- Dudley, N. and Musgrave, W. (1988) *Capacity sharing of water reservoirs*. *Water Resources Research* 24, pp.649-658.
- Dyson, M. (2008) *Regulatory framework for stormwater re-use: Presentation to The Stormwater Re-user Workshop, 19<sup>th</sup> September, Adelaide*
- EPHC, NHMRC, NRRMC (2008a) *Australian Guidelines for water recycling: managing health and environmental risks. Augmentation of Drinking Water Supplies*. Environment Protection and Heritage Council, National Health and Medical Research Council and the Natural Resource Management Ministerial Council. Canberra
- EPHC, NHMRC, NRRMC (2008b) *Australian Guidelines for water recycling: managing health and environmental risks. Stormwater Harvesting and Reuse (Public Consultation Draft May 2008)*. Environment Protection and Heritage Council, National Health and Medical Research Council and the Natural Resource Management Ministerial Council. Canberra
- EPHC, NHMRC, NRRMC (2008c) *Australian Guidelines for water recycling: managing health and environmental risks. Managed aquifer recharge (Public Consultation Draft May 2008)*. Environment Protection and Heritage Council, National Health and Medical Research Council and the Natural Resource Management Ministerial Council. Canberra
- ERA (2007) *Inquiry on competition in the water and wastewater services sector*. Western Australian Economic Regulation Authority, Perth  
<http://www.era.wa.gov.au/cproot/6743/2/20080725%20Final%20Report%20Inquiry%20>

on%20Competition%20in%20the%20Water%20and%20Wastewater%20Services%20Sector.pdf

- Fisher, D.E. (2000) *Water Law*. LBC Information Services, Sydney.
- Government of South Australia (2005) 'Water Proofing Adelaide', The Government of South Australia, Adelaide. Accessed online [14 Nov 08] at <  
[www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa\\_Strategy.pdf](http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa_Strategy.pdf) >
- Government of Western Australia (2003) 'A State Water Strategy for Western Australia', Government of Western Australia, Perth. Accessed online [14 Nov 08] at <  
[http://portal.water.wa.gov.au/portal/page/portal/PlanningWaterFuture/StateWaterStrategy/Content/State\\_Water\\_Strategy\\_complete\\_001.pdf](http://portal.water.wa.gov.au/portal/page/portal/PlanningWaterFuture/StateWaterStrategy/Content/State_Water_Strategy_complete_001.pdf) >
- Grafton, Q. and Kompas, T. (2006) Pricing Sydney water. *The Australian Journal of Agricultural and Resource Economics*, 51, pp. 227-41.
- Hartman, L. and Seastone, D. (1970) *Water transfers: economic efficiency and alternative solutions*, Baltimore: John Hopkins Press for Resources for the Future.
- Hatton Macdonald and Dyack (2003) *Exploring the institutional impediments to conservation and water use-national issues*. CSIRO S/04/221, Adelaide.
- Hilmer, F., Rayner, M. and Taperell, G. (1993) *National Competition Policy report of the independent committee of inquiry*, AGPS, Canberra, 25 August.
- Hodgson, G (2006) 'What are institutions', *Journal of Economic Issues*, vol. 40. no. 1, pp. 1-25
- Jimenez, L. (2007) *The need for an integrated urban stormwater legislative framework*. Paper presented at OzWater 2007, 4-8 March, Sydney.
- Jiminez, B. and Asanao; (2008) *Water reuse: and international survey of current practice, issues and needs*. IWA Publishing, London
- Khan, S.J., Stuetz, R.M. and Anderson , J.M. (2007) *Water Reuse and Recycling* . University of NSW Publishing, Sydney.
- Land and Water Australia (2001) *National Land and Water Resources Audit: Australian dryland salinity assessment 2000:extent, impacts, processes, monitoring and management options*. Land and Water Australia, Canberra.
- Launay, J. (2003). *Rapport d'information fait au nom de la Délégation à l'aménagement et au développement durable du territoire, sur la gestion de l'eau sur le territoire*. Paris, Assemblée Nationale: 92 p.
- Leviston Z, Nancarrow B, Tucker D, Porter N. (2006). *Predicting community behaviour: Indirect potable reuse of wastewater through Managed Aquifer Recharge*. CSIRO Land and Water Science Report 29/06. CSIRO, Perth, Western Australia. 73 pp.
- Lumb, K. (2006) *Alternative urban water supplies; regulatory review of managed aquifer recharge (MAR) technical report*. Hyder Consulting for the Victorian Government, Report No VC 02161-01-MAR. Melbourne.
- Marsden Jacob Associates (2005) *Third party Access in water and Sewerage Infrastructure: implications for Australia*. Marsden Jacob and Associates, Melbourne: paper prepared for the "Water recycling and third party access symposium", 14th December 2005.
- Marsden Jacob Associates (2008) *National Snapshot of Current and Planned Water Recycling and Reuse Rates'*, Final Report prepared for the Department of the Environment, Water, Heritage and the Arts, Melbourne.

- Megdal, S. (2007) Arizona's recharge and recovery programs; in (eds) Colby and Jacobs, *Arizona Water Policy: management innovations in an urbanizing, arid region*. Resources for the Future, Washington DC, United States.
- Mundell, R (1960) 'The monetary dynamics of international adjustment under fixed and flexible exchange rates', *Quarterly Journal of Economics*, no. 74, pp. 227-257.
- Musgrave, W. and Kaine, G. (1991) Property rights and environmental water rights. In: Pigram, J. and Hooper, B., (Ed.) *Water allocation for the environment*, Armidale: Centre for Water Policy Research.
- National Research Council (1994) *Ground Water Recharge: Using Waters of Impaired Quality*, Committee of Ground Water Recharge, National Academies Press, Washington D.C. United States.
- National Research Council (2008) *Prospects for managed underground storage of recoverable water*; Committee on sustainable underground storage of recoverable water. National Academies Press, Washington D.C. United States.
- North, D (1990) 'Institutions, Institutional Change and Economic Performance', Cambridge University Press, Cambridge.
- NSW DEC (2006) *Managing urban stormwater: harvesting and reuse*. NSW Department of Environment and Conservation, Sydney. ISBN 174137875 3
- NSW DWE (2007) *Interim guidelines for Management of private recycled water schemes*. NSW Department of Water and Energy, Sydney. Accessed online [09 Nov 08] at < [www.waterforlife.nsw.gov.au/\\_\\_data/assets/pdf\\_file/0005/9923/Management\\_of\\_Private\\_Recycled\\_Water\\_Schemes.pdf](http://www.waterforlife.nsw.gov.au/__data/assets/pdf_file/0005/9923/Management_of_Private_Recycled_Water_Schemes.pdf) >
- NSW Government (2006) 'Metropolitan Water Plan 2007 Progress Report', Water for Life, New South Wales Government, Sydney. Accessed online [14 Nov 08] at < [www.waterforlife.nsw.gov.au/\\_\\_data/assets/pdf\\_file/0019/9505/MWP\\_Progress\\_Report\\_07.pdf](http://www.waterforlife.nsw.gov.au/__data/assets/pdf_file/0019/9505/MWP_Progress_Report_07.pdf) >
- NWC (2007) *Institutional and regulatory models for integrated urban water management: issues and scoping paper* (National water initiative Urban Reform Action; paragraph 92iv). National Water Commission, ISBN 10: 1 921107 29 4, Commonwealth of Australia, Canberra
- NWC (2007a) *Approaches to urban water pricing*. Waterlines report no 7, National Water Commission, Canberra ISBN: 978-1-921107-64-1
- NWC (2008a) *Update of progress in water reform; input into the Water Sub-Group (WSC) stocktake report*. 15<sup>th</sup> Feb 2008 <http://www.nwc.gov.au/resources/documents/COAG-Update-WR-150208.pdf>
- NWC (2008) *Annual Report 2007-2008*. National Water Commission, Canberra. ISBN: 978-1-921107-63-4
- Ostrom, E, Gardner, R and Walker, J (1004) 'Rules, Games and Common-Pool Resources', The University of Michigan Press, Ann Arbor.
- Ostrom, E. (1998). 'A behavioral approach to the rational choice theory of collective action.' *American Political Science Review*: 92(1), pp. 1-22
- Page, D, Barry, K, Pavelic, P, Dillon, P and Chassagne, A. (2008) *Preliminary quantitative risk assessment for the Salisbury stormwater ASTR project*. CSIRO: Water for a Healthy Country National Research Flagship.
- Pavelic, P., Dillon, P. and Barry, K. (2006a) Hydraulic evaluation of aquifer storage and recovery (ASR) with urban stormwater in a brackish limestone aquifer. *Hydrogeology Journal*, 14: 1544-1555.

- Pavelic, P. Dillon, P. and Simmons, C. (2006b) Multi-scale characterization of a heterogeneous aquifer using an ASR operation. *Groundwater*: 44(2): 155-164.
- Piegay H., Dupont P., Faby J.A. (2002). Questions of water resources management. Feedbacks on the implementation of the French SAGE and SDAGE plans (1992-2001). *Water policy* (4) pp. 239-262
- Productivity Commission (2008) *Towards Urban Water Reform: A Discussion Paper*. Productivity Commission, Melbourne.
- Pyne, R.D.G. (2003) 'Aquifer Storage Recovery Forum: Water Resourcing', available online [14 Nov 08] at < <http://www.asrforum.com/frames/whatfr1.html> >
- Pyne, R.D.G. (2005). *Aquifer Storage Recovery: A guide to groundwater recharge through wells*. 2nd Edition. ASR Press, Gainesville, Florida.
- Queensland EPA (2005) *Queensland Water Recycling Guidelines*. Queensland Environment Protection Agency. December 2005.
- Queensland Water Commission (2007) *Our Water: urban water supply arrangements in South East Queensland*. Final Report. Queensland Water Commission, Brisbane Queensland.  
[http://www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban\\_Water\\_Supply\\_Arrangements\\_in\\_SEQ.pdf](http://www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban_Water_Supply_Arrangements_in_SEQ.pdf)
- Queensland Water Commission (2008) 'Strategic Plan, 2008-2012', Queensland Government, Brisbane. Accessed online [14 Nov 08] at < [http://www.qwc.qld.gov.au/myfiles/uploads/Strategic%20plan/D%2008%20006968%20%20strategic%20plan%20%20long%20version%20updated%20values%20\(QWC0000451\)\(3\).pdf](http://www.qwc.qld.gov.au/myfiles/uploads/Strategic%20plan/D%2008%20006968%20%20strategic%20plan%20%20long%20version%20updated%20values%20(QWC0000451)(3).pdf) >
- Quiggin, J. (1986) Common Property, private property and regulation; the case of dryland salinity. *Australian Journal of Agricultural Economics*, vol. 30, pp.103-117.
- Quiggin, J. (2006) 'Key Issues in Australian Water Policy', School of Economics and School of Political Science and International Studies, University of Queensland.
- Radcliffe, J. (2004) *Water recycling in Australia*. Australian Academy of Technological Sciences and Engineering. Melbourne.
- Radcliffe J. (2007) 'Advances in water recycling in Australia 2003-2007', pp 387-406 in *Water reuse and recycling*. Khan, S.J., Stuetz, R.M. and Anderson, J.M.(Eds); University of New South Wales, Sydney.
- Radcliffe, J. (2008) Public policy and institutional capacity building: opportunities for innovation in recycling. In (eds) Jiminez, B. and Asanao; *Water reuse: and international survey of current practice, issues and needs*. IWA Publishing, London.
- Randall, A. (1981) Property entitlements and pricing policies for a mature water economy. *Australian Journal of Agricultural Economics* 25, pp.195-220.
- Randall, A. (1987) *Property rights, efficiency and the distribution of income*, New York: Wiley and Sons.
- Rauch, W., Seggelke, K., Brown, R. and Krebs, P. (2005) *Integrated Approaches in Urban Storm Drainage: Where Do We Stand?* *Environmental Management* 35 (4):396-409. 0364152x.
- Reimers, I and Clunes, T. (2007) The re-use dilemma-changing the accepted paradigm for reuse; in *Water reuse and recycling*. Khan, S.J., Stuetz, R.M. and Anderson, J.M.(Eds); University of New South Wales, Sydney. Pp419-426.
- Rinck-Pfeiffer, S., Pitman, C. and Dillon, P. (2005). *Stormwater ASR in practice and ASTR (Aquifer Storage Transfer and Recovery) under investigation in Salisbury, South Australia*. p151-159 in *Proc. ISMAR5, Berlin, June 2005*.

- Rix, S. (1993) The political context of public sector reform debate. In: Johnson, M. and Rix, S. (Ed.) *Water in Australia: managing economic, environmental and community reform*, pp.166-184. Sydney: Pluto Press.
- Roy, A.H., Wenger, S.J., Fletcher, T.D., Walsh, C.J., Ladson, A.R., Shuster, W.D., Thurston, H.W. and Brown, R.R. (2008) Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States. *Environmental Management* 42 (2):344-359.
- SA EPA (2004) Code of practice for aquifer storage and recovery. SA Environmental Protection Agency, Government of South Australia, ISBN 1876562552.
- SA NRM (2007) Stormwater management Planning Guidelines. South Australian Stormwater Authority and the Natural Resources Management Council. Adelaide. [http://www.lga.sa.gov.au/webdata/resources/files/Stormwater\\_Management\\_Planning\\_Guidelines\\_July2007.pdf](http://www.lga.sa.gov.au/webdata/resources/files/Stormwater_Management_Planning_Guidelines_July2007.pdf)
- Schlager, E. and Ostrom, E. (1992) Property right regimes and natural resources: an empirical analysis. *Land Economics*68(3) 249-262.
- Smith V. L. (2002) Method in experiment: rhetoric and reality. *Experimental economics*: 5, pp 91- 110.
- South Australian EPA (2004) Code of practice for aquifer storage and recovery. SA Government, ISBN 1876562552
- South Australian Government (2005) Urban Stormwater Management Policy for South Australia. Adelaide, May 2005.
- South Australian Government (2005a) Waterproofing Adelaide: a thirst for change, 2005-2025. Government of South Australia, ISBN 0646450131, Adelaide
- Stormwater Management Authority (2007) 'Stormwater Management Planning Guidelines', Natural Resources Management Council, Government of South Australia. Accessed online [14 Nov 08] at < [www.lga.sa.gov.au/webdata/resources/files/Stormwater\\_Management\\_Planning\\_Guidelines\\_July2007.pdf](http://www.lga.sa.gov.au/webdata/resources/files/Stormwater_Management_Planning_Guidelines_July2007.pdf) >
- Swierc, J. Page, D. Van Leeuwen, J. and Dillon, P. (2005) Preliminary Hazard Analysis and Critical Control Points Plan (HACCP) - Salisbury Stormwater to Drinking Water Aquifer Storage Transfer and Recovery (ASTR) Project. CSIRO Technical report 20/05, Adelaide.
- The McLaren Vale Water allocation Plan 2007
- Thorson, N (1978) 'Storing Water Underground: What's the Aquifer-Fer?', *Nebraska Law Review*, vol. 57, no. 3, pp. 581-632.
- Tietenburg, T. H. (1998) Ethical influences on the evolution of the US tradable permit approach to air pollution control. *Ecological Economics* 24(2-3), p.241-257
- Timms, W.A., Acworth, R.I. and Badenhop, A.M. (2007) Managed Aquifer recharge in the Botany sand aquifer-part of the treatment train for water reuse? In (eds) Khan, S.J., Stuetz, 'Water Reuse and Recycling', University of NSW Publishing, Sydney.
- Tinbergen, I. (1950) On the theory of economic policy, Elsevier, North Holland
- Tisdell, J. Ward, J. and Grudzinski (2002) The development of water reform in Australia. CRC for Catchment Hydrology, Technical Report 5. ISBN 1 876006 71 4
- USDA (2005) 'Forest Service Sourcebook of State Groundwater Laws in 2005', United States Department of Agriculture, Washington.
- Vatn, A. (2005) *Institutions and the Environment*. Edward Elgar, Cheltenham UK.

- Veblen, T (1919), 'The Place of Science in Modern Civilisation and Other Essays', Huebsch, New York.
- Victorian EPA (2006) A Framework for Alternative Urban Water Supplies: Managed Aquifer Recharge (MAR) Department of Sustainability and Environment and Department of Human Services. Government of Victoria, Melbourne.
- Victorian Government (2004) 'Securing Our Water Future Together, Victorian Government Department of Sustainability and Environment, Melbourne. Accessed online [14 Nov 08] at < <http://www.ourwater.vic.gov.au/programs/owof> >
- Victorian Competition and Efficiency Commission (2007) Inquiry into reform of the Metropolitan Retail water Sector. Issues Paper Melbourne
- Ward, J., Connor, J. and Hatton MacDonald, D. (2008) Designing tradable credit policy for diffuse source salinity ex ante (2008) *Society and Natural Resources* 21(10) pp930-943
- Ward, J., Connor, J. and Tisdell, J. (2008). Aligning policy and real world settings: An experimental economics approach to designing and testing a cap and trade salinity credit policy. In T. Cherry, Kroll, S. and J. Shogren (eds). *Environmental Economics, Experimental Methods*. Routledge, Oxford.
- Ward, J, Dillon, P. and Grandgirard, A (2008a) Designing tradeable rights to manage aquifer recharge according to robust separation principles, *Water, Science and Technology: Water Supply* 8(4).
- Ward, J, Dillon, P and Grandgirard A. (2008b) Applying robust separation to compare the opportunities for market based policy approaches for aquifer storage and recovery in Australia and France 13th IWRA World Water conference Montpellier 1-4th September
- Washington State Legislature (2003) 'Reservoir permits, Secondary permits, Expedited processing, Underground artificial storage and recovery project standards and rules, Exemptions, Report to the legislature', Government of Washington, available online [14 Nov 08] at < <http://apps.leg.wa.gov/RCW/default.aspx?cite=90.03.370> >
- Water for Life (2006) Metropolitan Water Plan, NSW Government ISBN 0731332687 [http://www.waterforlife.nsw.gov.au/\\_\\_data/assets/pdf\\_file/0015/1446/wfl2006.pdf](http://www.waterforlife.nsw.gov.au/__data/assets/pdf_file/0015/1446/wfl2006.pdf)
- Water Resources Department (2007) 'Artificial Ground Water Recharge', Government of Oregon, available online [14 Nov 08] < [www.oregon.gov/OWRD/mgmt\\_gw\\_recharge.shtml](http://www.oregon.gov/OWRD/mgmt_gw_recharge.shtml) >
- Western Australian EPA (2005) Strategic Advice on MAR using treated wastewater on the Swan Coastal Plain. Bulletin 1199; Western Australian Government Perth
- Western Australian Department of Water (2008) Managed Aquifer Recharge: Water Quality Note. Western Australian Government. Perth
- Whiteoak, K., Boyle, R. and Wiedemann, N. (2008) National snapshot of current and planned water recycling and reuse rates. Report prepared by Marsden Jacob Assoc. for the Department of Environment, Water, Heritage and the Arts, Canberra. 12/10/2008 <http://www.environment.gov.au/water/publications/urban/national-recycling-snapshot.html>
- Young M. (2007) Water Futures: looking back on Australasian water policy from 2027. Invited address; AARES conference, Queenstown, N.Z. 15th Feb 2007.
- Young, M (2005) *Sharing Groundwater: Options for the introduction of shares as a means to define groundwater entitlements in the South East of South Australia*. CSIRO Adelaide, ISBN 0643092706
- Young, M. and McColl, J. (2003) Robust reform; the case for a new water entitlement system for Australia. *Australian Economic Review*: 36(2); 225-34.

- Young, M. McColl, J. and Fisher, T. (2007) Droplet no.5: Urban Water pricing; how might an urban water trading scheme work, University of Adelaide.
- Young, M. and McColl, J. (2007a) 'Droplet no.10: Pricing your water: is there a smart way to do it?' The University of Adelaide.

# APPENDIX 1

## South Australia

### Key Points

1. The *Local Government Stormwater Management Amendments Act 2007* set out the inclusion of stormwater infrastructure within defined surface waters, making explicit the provisions and capacity to regulate the capture of stormwater. South Australia is the only state to specify provisions for stormwater in this manner.
2. Surface water, including stormwater is not currently prescribed for Central Adelaide and the northern Adelaide plains. According to the current legislative framework, stormwater can be harvested, diverted and stored in Adelaide and surrounding suburbs without the need for a water licence.
3. Aquifers intentionally recharged via percolation are likely to represent a prescribed activity of environmental significance (Schedule 1, 4(2) of the *Environment Protection Act 1993*). Direct injection via a well is subject to the provisions of the *Natural Resources Management Act 2004*. The EPA Code of Practice (p.2) states that “many ASR will not need a licence; however the conditions for exemption are not made explicit.
4. MAR granted approval under either the *Environment Protection Act* or the *Development Act* (both of which apply to large scale MAR schemes) may confer exemption from the provisions of the *Natural Resources management Act*.
5. Source water assumes the status of groundwater when intentionally recharged into an aquifer. Extraction of stored water will require a licence and allocation for groundwater in a prescribed wells area, including the proposed Central Adelaide prescribed Wells area (*Natural Resources management Act 2004* s.146 and s. 152). It is unclear that stored water can be extracted independently of the provisions of a prescribed groundwater area when that area is deemed as under threat (s.132).
6. Dickey and Reznikov (2008) argue that there remains a risk that other (groundwater) users will be granted licences to take stored water. ... as with ASR schemes outside prescribed wells areas, the operator of an ASR scheme has no proprietary right to the water stored under the scheme.
7. The lack of clarity regarding instruments to protect stored water from third party influences is likely to act as a strong impediment to the commencement of commercial MAR operations. The *Waterproofing Adelaide (SA Gov 2005)* seeks to review the legal issues surrounding ownership access rights to surface and groundwater resources to provide appropriate levels of security and certainty for potential stormwater users (Strategy 50).

	<b>Policy</b>	<b>Comment</b>
<b>1</b> Capture Zone	i) LGSMA Act 2007	Uncertain status of access to stormwater in metropolitan Adelaide despite stormwater prescribed as surface water.
	ii) NRM Act 2004	Provides for prescribed watercourses
	xi) CoP EPA 2004	Guidelines for source water quality
	vi) D Act 1993	Provides for retention ponds and wetlands
<b>2</b> Pre-treatment	iii) , iv), viii), xi), xii) and xiii)	
<b>3</b> Recharge	iii) E P Act	Provides for MAR as prescribed activity of environmental significance and stormwater discharge
	vii) D R 2008	Provides for construction of wells and bores
<b>4</b> Subsurface storage	ii) NRM Act 2004	Permit required to inject into aquifer
	ii) NRM Act 2004	Provides for aquifer storage: may be exempt with authorisation from EP Act or D Act
	iv) EPA 1993	Discharge of stormwater
<b>5</b> Recovery	xi) CoP EPA 2004	Notes many ASR will not require licensing but exemption conditions not explicit
	ii) NRM Act 2004	Rights to water vested with the state. MAR stored water not differentiated from native groundwater. Licence and allocation required in prescribed water areas
<b>7</b> End use	iii) , iv), viii), ix), xi), xii) and xiii)	

Numbers in the policy column refer to corresponding legislation listed below.

### **South Australian Acts and legislation applying to MAR**

- i) *Local Government (Stormwater Management) Amendment Act 2007*
- ii) *Natural Resource Management Act 2004*
- iii) *Environment Protection Act 1993*
- iv) *Environment Protection (Water Policy) Policy 2003*
- v) *Planning and Environment Act 1987*
- vi) *Development Act 1993*
- vii) *Development Regulations 2008*
- viii) *Public and Environmental Health Act 1987*
- ix) *Food Act 2001*
- x) *Local Government Act 1989*
- xi) *Code of Practice for Aquifer Storage and Recovery (EPA 2004)*
- xii) *The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)*
- xiii) *The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).*

## Key References

Dickey, S. and Reznikov, K. (2008) Aquifer Storage and recovery: Legal Issues. Paper presented at Saving the Last Drop: water scarcity and the law. Environmental Defenders Office, March 13th, Adelaide.

Dyson, M. (2008) Regulatory framework for stormwater re-use: Presentation to The Stormwater Re-user Workshop, 19<sup>th</sup> September, Adelaide

Waterproofing Adelaide: a thirst for change 2005-2025. Government of South Australia.

[http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa\\_Strategy.pdf](http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa_Strategy.pdf)

## Source water harvesting and capture

### ***Local Government (Stormwater Management) Amendment Act 2007***

The *Local Government Stormwater Management Amendments Act* commenced in 2007, with provisions to amend the *Natural Resources Management Act 2004*. Amendments set out the inclusion of stormwater infrastructure within defined surface waters, making explicit the provisions and capacity to regulate the capture of stormwater. The Act states that flood mitigation and prevention remain a priority. The objectives of the Stormwater Management Amendment are:

- a) to ensure the proper operation of the Stormwater Management Agreement –
  - (i) by the creation of the Stormwater Management Authority referred to in the Agreement; and
  - ii) by putting in place administrative and funding arrangements, and conferring powers, necessary for the proper discharge of State and local government responsibilities relating to stormwater management as stated in the Agreement;
- (b) to ensure that environmental objectives and issues of sustainability are given due consideration in the discharge of State and local government responsibilities relating to stormwater management as stated in the Agreement.

The Stormwater Management Planning Guidelines<sup>26</sup> supplement the Act by providing direction to agencies managing stormwater to develop management plans at the catchment scale (SA NRM 2007). The Urban Stormwater Management Policy for South Australia (SA Gov 2005) advocates the adoption of a multi-objective approach to the management of stormwater from urban areas within the State. Section 3.2 of the guidelines sets out the principle objectives of stormwater management, with acknowledgement that appropriate strategies will be required to account for variable levels of urban development. The principles are:

- Flood risk to existing and future development is minimised;
- Stormwater use opportunities are maximised;
- Adverse impacts on watercourses and receiving waters are reduced; and
- Desirable development planning outcomes associated with open space, recreation and amenity are achieved.

<sup>26</sup>

[http://www.lga.sa.gov.au/webdata/resources/files/Stormwater\\_Management\\_Planning\\_Guidelines\\_July2007.pdf](http://www.lga.sa.gov.au/webdata/resources/files/Stormwater_Management_Planning_Guidelines_July2007.pdf)

Catchment plans are required to specify stormwater management objectives which (Section 2.5) as a minimum, set goals for:

- An acceptable level of protection of the community and both private and public assets from flooding;
- Management of the quality of runoff and effect on the receiving waters, both terrestrial and marine where relevant;
- Extent of beneficial use of stormwater runoff;
- Desirable end-state values for watercourses and riparian ecosystems;
- Desirable planning outcomes associated with new development, open space, recreation and amenity;
- Sustainable management of stormwater infrastructure, including maintenance.

The principles articulate goals that seek to promote stormwater as an economic resource characterised by multiple values. The principles seek to encourage commercial development to augment existing water supplies whilst acknowledging the legitimate claim of the environment.

Section 1.4 of the Stormwater Management Planning Guidelines notes that the delineation of catchment boundaries should reflect hydrological parameters, be policy relevant and administratively feasible. In concert with s.2.2, the guidelines require councils to consult and gain agreement with the local NRM board on the establishment of catchment boundaries. The consultative process may result in variable interpretations of “boundaries” partially dependent on agency objectives and the metrics employed. Risk analysis and planning by MAR proponents or commercial operations considering stormwater harvesting are likely to be contingent on resolving uncertainty surrounding catchment boundaries and their formal definition.

Section 43 of the Waterproofing Adelaide strategy<sup>27</sup> sets out a collaborative approach to the development and implementation of the Australian Guidelines for Stormwater harvesting and reuse (EPHC 2008c) and the Guidelines for Managed Aquifer recharge (EPHC 2008b). As a signatory to the National Water Initiative, the South Australian Government will also consider these as a reference for achieving water quality, environmental and health objectives of stormwater management and reuse. The Australian Guideline(s) standards and strategies for ensuring water quality for captured source water, aquifer recharge and final reuse follows the hazard analysis and critical control points plan (HACCP) of Cunliffe and Stevens (2003) and Swierc *et al.* (2005). Critical control points are likely to be managed using a suite of regulatory instruments in contrast to market based approaches.

Dickey and Reznikov (2008) note the Waterproofing Adelaide (Strategy 50) recommends the review of legal issues surrounding ownership and access rights to surface and groundwater resources. Articulated access rights and entitlements are required by potential commercial stormwater users to provide an appropriate level of security and certainty. Prescription of water resources is considered to provide the highest level of security and certainty. The *Local Government Stormwater Management Amendments Act* sets out provisions to include stormwater infrastructure within defined surface waters, making explicit the provisions and capacity to regulate the capture of stormwater.

### **Natural Resources Act 2004**

Permissions to take source waters from a watercourse are determined by the Natural Resources Management Act. A water resource means a watercourse or lake, surface water,

<sup>27</sup> [http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa\\_Strategy.pdf](http://www.waterproofingadelaide.sa.gov.au/NR/rdonlyres/C79D0A6F-0788-4545-806A-5773BF61F3CD/0/wpa_Strategy.pdf)

underground water, stormwater (to the extent that it is not within a preceding item) and effluent. Water is “taken” if (inter alia) actions stop, impede, divert or direct the flow of water for the purpose of collection.

If the watercourse is a prescribed watercourse for the purposes of the NRM Act, the water can only be taken from the watercourse pursuant to a water licence and water allocation granted under the Act or via a ministerial authorisation granted under section 128 of the NRM Act (s 127(1)).

If the watercourse is not prescribed for the purposes of the Act, any person with lawful access to the watercourse (being an occupier of land through which the watercourse runs or land adjoining the watercourse) may take water from the watercourse to the extent that the taking will not:

- detrimentally affect the ability of another person to exercise a right to take water from the watercourse (for instance, a downstream user); or
- detrimentally affect the enjoyment of the amenity of water in the watercourse by the occupier of land that adjoins the watercourse or through which the watercourse runs; ss 124(3) and 127(2)

The South Australian EPA<sup>28</sup> has developed the *Code of Practice for Aquifer Storage and Recovery 2004*, enforceable by way of an environmental protection order. The document states that an “aquifer water storage and recovery scheme is specifically defined to mean a scheme involving the injection of stormwater into an aquifer for the purpose of storage and subsequent recovery”. Although MAR source waters may be abstracted from either a groundwater or surface water resource, a clear preference and focus has been placed on stormwater as a source for MAR operations. The Code of Practice is explicit in stating that it does not apply to the injection of wastewater (viz. non-stormwater sources). Stormwater is listed as a water resource in the Act, although it is not explicitly defined. Reference is made to:

- Stormwater infrastructure, which is defined as infrastructure established for the purposes of stormwater management. Infrastructure more generally includes dams, reservoirs, embankments, channels, culverts, buildings, roads and pipes.
- Surface water, which includes water (flowing over land and rain) that is contained in any stormwater infrastructure

A surface water prescribed area is defined as a part of the State declared to be a surface water prescribed area under section 125 (including, if relevant, any stormwater infrastructure within that area). Prescribed areas<sup>29</sup> relevant to urban water management in Adelaide refers to a concept statement for groundwater and surface water in the Western Mount Lofty Ranges, excluding the plains, that was completed in 2006 and due for Ministerial adoption in December 2008. The prescribed area for Central Adelaide is due for adoption in mid 2009; prescription includes groundwater and prescribed wells, but excludes surface water.

Stormwater is *taken* if the flow is impeded for the purpose of collecting water, or any water is extracted from stormwater infrastructure.

Water can only be taken from stormwater infrastructure in a prescribed surface water area (except where the circumstances are excluded by regulation) pursuant to a water licence and water allocation granted under the Act, or via a ministerial authorisation granted under section 128 of the NRM Act (s 124(3), and s 127(2)). No exempt circumstances have yet been prescribed (Dickey and Reznikov (2008)). In all other cases, water can be taken from

<sup>28</sup> [http://www.epa.sa.gov.au/pdfs/cop\\_aquifer.pdf](http://www.epa.sa.gov.au/pdfs/cop_aquifer.pdf)

<sup>29</sup> [http://www.dwlbc.sa.gov.au/assets/files/Prescribed\\_areas\\_table\\_June\\_08.pdf](http://www.dwlbc.sa.gov.au/assets/files/Prescribed_areas_table_June_08.pdf)

stormwater infrastructure for any purpose by the occupier of the land containing the infrastructure (s 124(2)).

Surface water, including stormwater is not currently prescribed for Central Adelaide and the northern Adelaide plains. According to the current legislative framework, stormwater can be harvested, diverted and stored in Adelaide and surrounding suburbs without the need for a water licence. This policy interpretation is consistent with Dickey and Reznikov (2008).

### **Source water retention: ponds and wetlands**

Retention ponds and wetlands constructed for the purpose of storing source water prior to intentional aquifer infiltration, potentially via well injection, are likely to be regulated under the purview of *The Development Regulations 2008* under *The Development Act 1993*. According to Schedule 3 (s 10), structures that do not require approval are:

The excavation or filling (or excavation and filling) of land for the purposes of a dam, other than—

1. where a levee or mound with a finished height greater than 3 metres above the natural surface of the ground is to be formed; or
2. where a retaining wall which retains a difference in ground levels exceeding 1 metre is to be used or formed; or
3. where the dam is in the Hills Face Zone, in a Watercourse Zone, Flood Zone or Flood Plain delineated by the relevant Development Plan, or in any other zone or area shown as being subject to flooding or inundation in the relevant Development Plan; or
4. where the dam is to have a capacity exceeding 5 megalitres.

### **Aquifer recharge**

Aquifers can be intentionally recharged via a retention pond, wetland or galleries via percolation or gravity infiltration. MAR is a prescribed activity of environmental significance (Schedule 1, 4(2) of the *Environment Protection Act 1993*) for discharge of stormwater from areas greater than 1 ha to aquifers, and requires licensing by the EPA. Activities of environmental significance are listed for referral under the *Development Regulations 2008* s. 5 (7 vi). These include dams, bores, stormwater drainage and services connected with the management of water and are deferred to the EPA for assessment. Retention ponds and wetlands for the purpose of storing source water will fall into this category. As large scale MAR operations are likely to be classified as a prescribed activity, environmental authorisation for, expressed as an environmental licence (*Environment Protection Act* s.36), will be required.

The EPA Code of Practice (p.2) states that “many ASR will not need a licence, however the conditions for exemption are not made explicit.

Direct injection via a well is the alternative to passive, gravity infiltration for aquifer recharge. Aquifer access and well infrastructure are subject to the provisions of the *Natural Resources Management Act 2004*.

Aquifers are defined as underground water, defined as a) water occurring naturally below ground level; or b) water pumped, diverted or released into a well for storage underground. A permit is required under the Act (s. 127(3a, b) to drill, repair, replace and alter a well. The Act defines a well as:

- a) an opening in the ground excavated for the purpose of obtaining access to underground water;

- b) an opening in the ground excavated for some other purpose but that gives access to underground water;
- c) a natural opening in the ground that gives access to underground water.

A permit to drain or discharge water into the well is also required by the provisions of the Act (s. 127(c)). Considerations by a relevant authority for a permit application and the granting of a permit must be consistent with the State NRM plan and must take into account the provisions of the relevant regional NRM plan (s. 135(3,4)). The permit will be refused if the MAR application is inconsistent with the NRM plan.

S 135(13) provides that a permit can be varied if an NRM plan has been varied so that the permit is not inconsistent with the plan, and can be revoked if that is not possible (s 135(14)). A permit can also be revoked if the rising level of underground water is damaging soil, rock or other structures; or damaging ecosystems; or affecting the natural drainage of surface water (S 135 (15)). If the contamination levels of receiving waters are deemed to be of risk to human health the permit to drill a well can be revoked (s. 137).

Dickey and Reznikov (2008 p. 5-6) set out an important policy insight into the granting of well permits for MAR operations. The argument as to permit exemption for large scale MAR is as follows.

1. The discharge of stormwater into an aquifer from a catchment area of greater than one hectare is a prescribed activity of environmental significance. Hence, proponents of large-scale MAR operations utilising stormwater<sup>30</sup> that have already obtained EPA licences for the discharge of the water into the aquifer, will be exempt from the requirement to obtain a discharge permit pursuant to the NRM Act.
2. As the EPA is not required to have regard to the applicable NRM Plan or Water Allocation Plan when determining an application for a licence, the obligations imposed in respect of discharge permits under the NRM Plan or Water Allocation Plan will not apply to schemes using stormwater as a source.
3. The term 'development' is defined in the *Development Act* 1993 to include a change in use of the land. The conversion of previously occupied (or even vacant) land into an MAR facility will amount to a change in use of the land. Consequently, every ASR scheme will be 'development' for the purposes of the *Development Act* and will require development authorisation under that Act.
4. If a proponent of an ASR scheme obtained development authorisation for use of the site for aquifer storage and recharge, it is at least arguable that the act of discharging water into the aquifer as part of the operation of the ASR scheme would be authorised by that development authorisation. The exemption to subsection 127(3)(c) of the *Natural Resources Act* 2004 would apply and it would not be necessary to obtain a separate permit pursuant to the NRM Act for the discharge into the injection well.
5. The relevant authority determining an application for development authorisation is not required to have regard to the applicable NRM Plan or Water Allocation Plan in making the decision or imposing conditions. With respect to discharge permits, authorised schemes would be exempt from the obligations imposed under the NRM Plan or Water Allocation Plan.

---

<sup>30</sup> Clause 4(2) of the Environmental Protection (Water Quality) Act 2003 does not apply to MAR source water from a watercourse, recycled water, desalinated water or otherwise treated water: As an EPA discharge licence is not required, the scheme would not be exempt under 127(3c). However these schemes would be authorised by the Development Act and be entitled to exemption.

Dickey and Reznikov (2008 p. 6) argue that “if this is not the intention of the legislation, it may be necessary to amend the exemption so that it expressly does not apply to ASR schemes.”

All large scale MAR operations will also be subject to the notion of “general environmental duty” (s. 25(1)) of the Act, regardless of source water and the means of recharge. The section provides that a person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm. The response to non-compliance will consider:

- a) The nature of the pollution or potential pollution and the sensitivity of the receiving environment;
- b) The financial implications of the various measures that might be taken as those implications relate to the class of persons undertaking activities of the same or a similar kind;
- c) The current state of technical knowledge and likelihood of successful application of the various measures that might be taken.

Compliance can be enforced using an environmental protection order, with provisions for the monitoring of source and stored water, pre-treatment of source water and system shutdown (also an operational and design recommendation in the EPA ASR code of practice 2004).

### **Recovery of recharged water**

The recharge element of MAR operations seeks access and management entitlement of the aquifer storage space in excess of ambient infiltration and recharge. That is the right to raise the water table subject to legislative provisions to protect natural drainage of shallow aquifers, protect dependent ecosystems and avoid degradation of soils and geological structures.

Ideally, recharge water could be distinguished at low cost from native groundwater with sufficient precision to allow independent management. With such technical feasibility, the potential improvements to brackish groundwater via high quality injectant and pathogen and contaminate attenuation would remain with the MAR operator.

Due to mixing of existing groundwater and recharged source water, delineation or differentiation of water available for extraction is likely to be technically infeasible and costly. Hence the recovery element of MAR is more likely to rely on an entitlement to a share of aggregate groundwater, comprised of “new” MAR recharged source water and native groundwater.

Aquifer composition in the Adelaide Geosyncline is heterogeneous (Pavelic *et al.* 2006a, b) and of low to moderate transmissivity. The spatial dimension of an injection lens is likely to be constrained and as a consequence groundwater extraction will use the injection well or one in close proximity.

Section 127 (1) under s. 128 of the *Natural Resources management Act 2004* refers to the granting of a water allocation and applies to MAR recovery operations. MAR extraction operations located in a prescribed wells area are required to obtain a water licence (under the provisions of s.146) and water allocation (s.152). The granting or variation of an allocation attached to the water licence is contingent on the conditions imposed being consistent and not seriously at variance with the relevant water allocation plan<sup>31</sup>.

<sup>31</sup> According to the Act, a relevant water allocation plan means the water allocation plan for the water resource from which the water is to be allocated and includes the water allocation plan of another water resource (if any) that includes provisions relating to the taking, or the taking and use, of water from the first mentioned water resource.

The concept statement for the Central Adelaide Water Allocation Plan<sup>32</sup> provides for determination of the allocations for MAR and seeks to identify the MAR activities requiring permits. A current example is Section 7 of *The McLaren Vale Water Allocation Plan 2007*, which details the provisions for aquifer storage and recovery. Recharge is to be by gravity infiltration. Unless specified, dependent ecosystems and other wells are at a minimum distance of 300 metres. An entitlement to take water for a 5 month period is determined as 100% of recharge volumes for effluent or imported source water and 75% for surface water or roof run off. Between year carry over of recharge entitlements are restricted. Provisions for transfers between wells and between properties are set out in s. 6, including a limit of 3 years on temporary transfers.

Subsection 132 of the *Natural Resources management Act 2004* states that if water systems are deemed to be threatened, the Minister can prohibit or restrict the quantity of water extracted from the aquifer or direct that modifications be made to infrastructure. An assessment of the demand for water includes the claim of water dependent ecosystems. Intervention is invoked if the rate at which water is taken from a well (whether prescribed or not) is such that the quantity of water available can no longer meet the current or predicted future demands, affects aquifer quality or the aquifer is likely to collapse or suffer any other damage.

The Central Adelaide Prescribed Wells Concept Statement (AMLRB 2008b p. 1) states that the “sedimentary aquifer system of the CAPWA and the Northern Adelaide Plains Prescribed Wells Area are one and the same and groundwater flows in and between these two management areas.”

The boundaries of Prescribed Well Areas may not necessarily coincide with homogenous aquifer characteristics. Allocation plans for a Prescribed Well Area (PWA1) are required to ensure that water extraction does not threaten water systems. Contingent on uncertain levels of aquifer connectivity and heterogeneity, including aquifer stress, prescribed extraction allocations from an unstressed aquifer in PWA 1 may impose additional threats on stressed aquifers proximate prescribed boundaries (in PWA 2). The additional threat may invoke prescriptions to reduce extractions affecting MAR operations in PWA 2, introducing the prospect of trans-boundary externalities and conflicts. In the absence of proprietary rights to stored water, third party MAR operations may be subject to the influence of the Water Allocation plan of a contiguous PWA.

Dickey and Reznikov (2008 p. 4) state that similar tensions may arise for third party rights within a prescribed wells area. They argue that:

“Within a prescribed wells area other landowners/occupiers must obtain licences and allocations to take water. As such, there is an opportunity for a regulator to exert some control over where, when and how much water is taken from an aquifer. .... even in light of these licensing powers, the relevant authority must act consistently with the relevant Water Allocation Plan in determining any allocation, and conditions to imposed via the licence must not be seriously at variance with the terms of the relevant Water Allocation Plan [s 152 NRM Act]. There does therefore remain a risk that other users will be granted licences to take stored water. ...as with ASR schemes outside prescribed wells areas, the operator of an ASR scheme has no proprietary right to the water stored under the scheme.”

The lack of clarity regarding instruments to protect stored water from third party influences is likely to act as a strong impediment to commencement of commercial MAR operations. The Waterproofing Adelaide (SA GOV 2005) seeks to review the legal issues surrounding

<sup>32</sup>[http://www.amlnrm.sa.gov.au/Portals/1/Our\\_Plans/Docs/WAP/Central%20Adel/CAPWA-WAP\\_Concept\\_Statement\\_April08.pdf](http://www.amlnrm.sa.gov.au/Portals/1/Our_Plans/Docs/WAP/Central%20Adel/CAPWA-WAP_Concept_Statement_April08.pdf)

ownership access rights to surface and groundwater resources to provide appropriate levels of security and certainty for potential stormwater users (Strategy 50).

### **Final use of recovered water: environmental and public health compliance**

Final use of recovered MAR water will generally be fit for use based on a suite of water quality variables. Water quality in turn is dependent on a vector of conditions including the quality of injectant, aquifer residency time, the degree of pathogen and contaminant attenuation and the efficiency of the method deployed to treat recovered water. The attendant water quality standards corresponding with the designated final use are subject to the provisions of one or more of the following Acts or Guidelines.

- i) Public and Environmental Health Act 1987*
- ii) Environment Protection Act 1993,*
- iii) Environment (Water Quality) Policy 2003,*
- iv) Food Act 2001,*
- v) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (Draft May 2008)
- vi) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (Draft May 2008).
- vii) The Code of Practice for Aquifer Storage and Recovery (SA EPA 2004)

## Victoria

### Key Points

1. Injected water (whether reclaimed or not) is not distinguished from native groundwater and is classed as groundwater post recharge. Therefore sovereign rights are transferred to the State and subject to licensing arrangements of prescribed groundwater allocations.
2. The *Water Act 1989* identifies who has rights to the use of water in waterways. Recycled water (defined as sewage intended for reuse) is excluded from the obligations of licensing, although the Act is not specific as to the “recycled” status of stormwater.
3. Stormwater management is not specified in the *Catchment and Land Protection Act (1994)*, although it may comprise inflows to either a special area water catchment, or contribute to downstream aquatic habitats.
4. Specifying volumes of harvested stormwater as a component of Melbourne Water's flood management plan may be one area of MAR source waters that is consistent with regulatory requirements for sustainable management, albeit indirectly.
5. Melbourne Water accepts responsibility for management areas greater than 60 hectares and local councils are responsible for areas less than 60 hectares. When stormwater assumes resource value, subject to uncertain interpretation of the 60 hectare bound, it is unclear where agency for entitlement will lie.

	Policy	Comment
<b>1</b> Capture Zone	i) W Act 1989 xi) CLP Act 1994 xi) EPA 1970 ii) WI Act 1994; iii) WG Act 2006 and ix) LG Act 1989 viii) SEPP WA 2003 vi) P and D Act 1987	Provides for exemption of recycled water and sewage: stormwater not specified May provide for stormwater as inflow to special water catchment Provides for licensing of scheduled premises: compliant effluent and stormwater exempt May provide for stormwater: jurisdiction for stormwater catchment s<60 Ha unclear May provide for stormwater Stormwater may require approval via EP Act
<b>2</b> Pre-treatment	iii), v), viii), xi), xii) and xiii)	
<b>3</b> Recharge	i) W Act 1989 viii) SEPP GWV and WoV 2003	Does not provide for MAR recharge but likely to apply as prescribed activity Provides for maintaining water quality but likely to apply for construction of wells and bores and injection. Consideration of conjunctive use applies

4 Subsurface storage	i) W Act 1989	Provides for extraction of recharged water aquifer
	viii) SEPP GWV	Provides for relaxed water quality attenuation zones that are likely to apply to MAR
	vi) P and E Act 1987	MAR may be considered as special area plan
5 Recovery	i) W Act 2004	Rights to water vested with the state. MAR stored water not differentiated from native groundwater. Licence and allocation required in prescribed water areas
7 End use	iv), v), viii), xii), xiii), xiv), xv), xvi) and xvii)	

Numbers in the policy column refer to corresponding legislation listed below.

In a State review and appraisal of MAR in Victoria, Lumb (2006) and the Victorian EPA (2006 p.26) recommend that the nature and extent of entitlements of water injectors and water used for MAR schemes and recoverable volume may require:

- amendments to the *Water Act* to give priority entitlements to injected water to operators of MAR schemes;
- provision that existing rights to water can coexist with entitlements to injected water;
- entitlements to be expressed as a percentage of the water injected;
- clarification of entitlements to recharge and entitlements to recover and use groundwater from MAR schemes; and
- provision to trade and transfer as appropriate.

Establishing allocation may require consideration of the water injected into aquifers for reuse. Possible options for resolution are:

- amend the Water Act to allow allocation limits to take into account water injected into aquifers;
- express entitlements as a share; and
- amend groundwater management plans

### Key References

Lumb, K. (2006) Alternative urban water supplies; regulatory review of managed aquifer recharge (MAR) technical report. Hyder Consulting for the Victorian Government, Report No VC 02161-01-MAR. Melbourne.

Department of Sustainability and Environment (2006) A framework for alternative urban water supplies: managed aquifer recharge (MAR): A discussion paper. Government of Victoria

[http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/c5fa02c8a18b8174ca25723b000e4644/\\$FILE/Discussion%20paper%20-%20Managed%20aquifer%20recharge.pdf](http://epanote2.epa.vic.gov.au/EPA/publications.nsf/2f1c2625731746aa4a256ce90001cbb5/c5fa02c8a18b8174ca25723b000e4644/$FILE/Discussion%20paper%20-%20Managed%20aquifer%20recharge.pdf)

### **Victorian Acts and legislation applying to MAR**

- i) *Water Act 1989*
- ii) *Water industries Act 1994*
- iii) *Water Governance Act (2006)*
- iv) *Health Act 1958*
- v) *Environment Protection Act 1970*
- vi) *Planning and Environment Act 1987*
- vii) *Building Act 1993*
- viii) *State Environment Protection Policy (Waters of Victoria 2003 and Ground Waters of Victoria)*
- ix) *Local Government Act 1989*
- x) *Melbourne and Metropolitan Board of Works Act 1958 (repealed such that Melbourne Water now derives waterway, drainage flood mitigation direction from the Water Governance Act 2006).*
- xi) *Catchment and Land Protection Act 1994*
- xii) *The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)*
- xiii) *The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).*
- xiv) *Guidelines for the use of reclaimed water 2003*
- xv) *Health Act 1958*
- xvi) *Safe Drinking Water Act 2003*
- xvii) *Food Act 1984*

## **Source water harvesting and capture**

### ***Environment Protection Act 1970***

The *Environment Protection Act 1970* provides the Environment Protection Agency (EPA) with the responsibility of all activities relating to the protection and improvement of the environment. Section 3(2) of the Act states that where there are inconsistencies with any other Act, the provisions of the Environment Protection Act will prevail. Based on principles of integration, equity, precaution and cost effectiveness, the Act provides the legislative framework, amongst other objectives, to manage the discharge of wastes into the environment and the prevention and control of pollution.

The EPA is required to recommend *State Environment Protection Policies*, in the case of stormwater destined for MAR these are the *Waters of Victoria* and *Industrial Waste management Policies*. The *Waters of Victoria Policy* (Clauses 17, 18, 46) requires that artificial stormwater drains and wetlands are designed and managed in a manner that ensures that they are not harmful to humans or animals, and minimise pollution to both surface and ground water. Jimenez (2007) argues that whilst the policy identifies the need for the EPA to coordinate with local councils to minimise stormwater runoff and contaminate loads, the implementation of stormwater management plans at council level remains unclear.

The EPA has developed a set of guidelines for the use of reclaimed water (VIC EPA 2003), which are now superseded by the Australian Guidelines for stormwater harvesting and reuse

(NRMCC 2008). The EPA<sup>33</sup> states “Although there are no specific laws that dictate what stormwater can be used for or what quality standards stormwater must meet, individuals and organisations responsible for stormwater schemes do have a duty of care to make sure their scheme will not place people or the environment at risk” Specifically the guidelines relate to the quality of stormwater and the associated management controls that need to be in place in proportion to the level of risk. Regardless of site use, Class A or B reclaimed water and nutrient reduction should be considered where there is high potential for reclaimed water runoff offsite. Water quality specified as Class A+ (potable), A (suitable for irrigation), B (non-potable) and C is specified in AGSHR (2008) which defers to the ARMCANZ and ANZECC (2000) Water Quality Guidelines. The EPA continues...“This would apply to schemes without runoff collection or recycling systems, and/or where there are high quality surface waters adjacent to the scheme, unconfined high quality groundwater/aquifers at the site, or sensitive neighbouring land uses (for example, protected flora and fauna sites). Nutrient reduction may also be necessary for reuse schemes having potential for runoff and off-site adverse impacts”.

The EPA (2003) notes that the Department of Human Services is responsible for individually assessing and endorsing schemes that involve the use of Class A water. This is the quality of reclaimed water required for high exposure uses including those in residential developments (e.g. 'third pipe' systems for toilet flushing and garden use), the irrigation of public open spaces where access is unrestricted, and the irrigation of crops that are consumed raw or unprocessed”.

The *Environment Protection Act* details the characteristics of premises and activities that are scheduled and therefore subject to approval and licensing. Effluent reuse that is undertaken in a manner acceptable to the EPA is exempt, as are activities involving the capture and use of stormwater and rainwater.

Hence whilst the quality of stormwater and recycled water is subject to regulation and recommended guidelines (e.g. Clauses 27–29 and 43 of *Waters of Victoria*), statutory powers to specify and manage the volumes of harvested stormwater and subsequent use are absent. Clause 41 of the *Waters of Victoria* states that “the advances made in the allocation of environmental flows are not negated by new diversions.” For some water systems, It is likely that stormwater is an important contributor to environmental flows, and harvesting may invoke the provisions of Clause 41. The EPA (2008) notes that the right to harvest stormwater and the construction of stormwater schemes may be subject to regulation, and may require approval or a permit from the local council under the *Planning and Environment Act 1987* or *Building Act 1993*.

### **Water Act 1989**

The Water Act 1989 articulates the rules for the orderly, equitable and efficient use of ground and surface waters in Victoria. In doing so, The Act provides for the protection of catchments, and assigns the powers to (and functions of) water authorities for the management of drainage and flood mitigation. An Authority is defined as a person holding a water licence, any council that supplies water under the Local Government Act 1989, a Catchment Managing Authority and the Melbourne Water Corporation.

The *Water Act* (Resource Management 2005) amendments articulate the setting aside of water for the environment (Environmental Water Reserve), ascertains permissible consumptive volume, determines the regulatory process to gain access to water via entitlements, and the processes to enable sustainable water planning. Investment in infrastructure for the delivery of recycled water is included as part of the sustainable water strategy.

<sup>33</sup> <http://www.epa.vic.gov.au/water/stormwater/stormwater-harvesting.asp>

Part 2 (s.4) states “The environmental water reserve objective is that the environmental water reserve be maintained so as to preserve the environmental values and health of water ecosystems, including their biodiversity, ecological functioning and quality of water and the other uses that depend on environmental condition”. Section 22A describes the permissible consumptive volume that can be extracted from a water system and applies to both surface and groundwater. Access to an aquifer may be subject to the *Groundwater Act 1969* as well as the *Catchment and Land Protection Act 1994*, the *Flora and Fauna Guarantee Act 1988*, the *Heritage Rivers Act 1992*, the *Planning and Environment Act 1987* or the *Environment Protection Act 1970*.

A designated waterway is defined as occurring within the jurisdiction of the Melbourne Water Corporation’s management district with exceptions noted in sections 188 and 188(a). With reference to stormwater management, *Section 84 (2)* states Melbourne Waters obligation is to construct and maintain all main drainage works within its jurisdiction in addition to improving stormwater quality. The *Water Industries Act 1994* governs water retailers within metropolitan Melbourne and is to be read in concert with the *Water Act* (Lumb 2006). According to the statement of obligations, in addition to improving stormwater quality, Melbourne Water is required to develop programs with the long term aim of reducing the risk of flood mitigation in priority areas. Jiminez (2007) argues that the principle objective of Melbourne Water’s participation is to maintain the consistency of proposed schemes with it’s planning for sustainable water management. Specifying volumes of harvested stormwater as a component of Melbourne Water’s flood management plan may be one area of MAR source waters that is consistent with regulatory requirements, albeit indirectly.

Part 4 (Division 1A) states an environmental entitlement can be granted to the Environment minister water (other than recycled water) in any works of an Authority; or the Melbourne Water Corporation. Users of recycled water are also exempted from obligations to apply for a license to access water from a scheduled waterway.

Section 7 stipulates that the sovereign rights to the flow, use and control of water, including groundwater are vested in the State and assume precedence over individual or private rights. As a corollary most water related actions are accommodated through a licensing arrangement. The *Water Act 1989* identifies who has rights to the use of water in waterways. Recycled water (defined as sewage intended for reuse) is excluded from the obligations of licensing, although the Act is not specific as to the “recycled” status of stormwater.

Jiminez (2007) discusses the significance to stormwater of a 1927 resolution specifying the management area of the predecessor of Melbourne water, the Melbourne and Metropolitan Board of Works. In accord with the resolution, Melbourne Water accepts responsibility for management areas greater than 60 hectares and local councils are responsible for areas less than 60 hectares. As a corollary, councils may act as de facto Water Authorities for the purpose of drainage. Jiminez (2007) raises an important insight in relation to stormwater management as a MAR water source.

Sections 198 to 201 of the *Local Government Act 1989* make provision for the Council management of municipal drains and sewers not vested in another council, minister or authority. Councils may construct, operate and control drainage schemes according to section 216 of the *Water Act* (section 201). Contributions and tariffs for those affected by the drainage scheme are prescribed according to the *Planning and Environment Act 1987*. When stormwater assumes resource value, subject to uncertain interpretation of the 60 hectare bound, it is unclear where agency for entitlement will lie.

### ***Catchment and Land Protection Act (1994)***

The purpose of the *Catchment and Land Protection Act 1994* is to establish a framework for the integrated management and protection of catchments and to encourage community participation in the management of land and water resources. The Act provides for the

establishment of two Authorities that can influence source water harvesting: the Victorian Catchment Management Council and the Catchment Management Authorities.

Catchment management Authorities are required under Sections 12 and 23 – 24 to produce regional catchment strategies and implement coordinated programs of environmental improvement. A catchment strategy must include an assessment of land and water resources, the causes, extent and severity of degrading processes and remedial actions where needed. Metrics for monitoring programme performance, emphasising the quality of land and water are also required.

Section 27 describes special area plans, whereby an Authority can recommend areas of special interest be declared, revoked or amended. In its recommendation the Authority may classify the area as a special water supply catchment. Deliberations must consider the likely adverse effects on the quality and condition of land; on water quality or aquatic habitats; and aquifer recharge or discharge areas. Lumb (2006) states that a large scale MAR is likely to be included as a special area plan and Jiminez (2007) argues that stormwater harvesting is likely to be considered under this section.

Stormwater management is not specified in the Act, although it may be comprised of inflows to either a special area water catchment, or contribute to downstream aquatic habitats.

## **Aquifer recharge and recovery**

### ***Water Act 1989***

Section 3 of the Act defines groundwater as any water occurring in or obtained from an aquifer and includes any matter dissolved or suspended in any such water. Water injected or introduced into an aquifer, including reclaimed source waters, assumes the status of groundwater. According to Section 7 of the Act, the rights to the use, flow and control of groundwater remain vested in the State and assume precedence over individual or private rights. As a corollary most groundwater water related actions are accommodated through a licensing arrangement. The Act infers that the license exempt status of reclaimed MAR source waters changes to one of license obligations when used to recharge an aquifer. Generally there is an embargo on the issuing of new groundwater access licenses. However the *Water Act 1989* does not explicitly define the licensing arrangements of MAR operators who intentionally increase groundwater volumes by utilising the aquifer warehousing capacity with the intention of future withdrawal.

Section 22A describes the Ministerial determination of the permissible consumptive volume of water that can be extracted from a groundwater system. The permissible consumptive volume represents an estimate of net water balance that accounts for ambient inflows and extractions based on sustainability principles. The Section does not clarify the circumstances whereby the permissible consumptive volume can be altered due to intentional aquifer recharge. Hence the distribution and entitlements of unaccounted water, that is water in excess of the prescribed extraction volume, are not defined.

If MAR is commercially viable for one operator, then it is also likely to be viable for a number of operators in the same aquifer or with the same water source. Commercial viability for MAR proponents requires certainty in their entitlements to store, manage, exclude and withdraw intentionally injected water. In the absence of coordination or cooperation, each operator potentially impinges on the access to water, on the total available aquifer storage volume, and in confined aquifers, on the groundwater pressures at the sites of other proximal operators.

As a signatory, Victoria is obliged to comply with the National Water Initiative. Sections 37 and 28 recommend that water access entitlements be specified as unit shares of a defined

consumptive pool, and periodic water supply (allocations) and the impacts of use be managed independently.

The *Water Act* 1989 does not entitle MAR operators to access recharged groundwater. In contrast, operators must obtain a license to extract from a specified water body or system and are subject to the conditions, allocations and obligations associated with those licensing arrangements.

### ***State Environmental Protection Policy Groundwaters of Victoria 1997***

The objective of the policy is to maintain and where necessary improve groundwater quality in order to protect existing and potential beneficial uses of groundwaters throughout Victoria. The policy recognises that groundwaters are generally undervalued and the protection of aquifers is fundamental to the protection of the environmental quality of surface waters. The principles of intergenerational equity, the precautionary principle and polluter pays guide the objectives set out in the policy. The majority of regulations in the *Groundwaters Policy* refer to the water quality measured as a vector of contaminants, nutrient loads and pollutants. The policy requires that all practicable measures are to be undertaken to prevent the pollution of groundwater.

S. 17 refers to groundwater attenuation zones, defined as a volume or designated area of the aquifer where specified water quality objectives are relaxed. Attenuation zones are designated to account for leachate from municipal landfills, evaporation basins associated with salinity management, ash ponds and waste water irrigation. Generally groundwater quality objectives are established with reference to guidelines (Table 3 in the *Policy*, ANZECC 2000, or EPHC 2008). In contrast, Pavelic *et al.* (2006), Dillon (2005) and Pyne (2005) *inter alia*, note that ambient groundwater quality may improve in attenuation zones associated with MAR recharge zones. Management actions that improve water quality are not specified in S. 17.

S. 20 states that: “There must not be any direct discharge of waste to any aquifer by means of a bore, underground mine workings, infiltration basin, evaporation basin or other similar structures, except for the purpose of –

- (1) Aquifer recharge, irrigation drainage, backfilling of underground mine workings with tailings, or storm water disposal, where the relevant protection agency is satisfied that the groundwater quality objectives of this policy specified in Table 3 will be met, and there will be no detriment to any beneficial use of groundwater, land or surface water;
- (2) Groundwater remediation projects involving the injection of uncontaminated water or re-treated water to the aquifer, where the authority is satisfied that –
  - (a) the groundwater quality objectives specified (in Table 3 of the *Policy*) will be met at the completion of the project; and
  - (b) there will be no detriment to any beneficial use of groundwater, land or surface waters beyond the boundaries of the premises on which the project is being conducted.”

As noted by Vic EPA (2006) S. 20 does not specifically address MAR, but is pivotal to water quality considerations relevant to MAR operations.

S. 21 refers to provisions to account for rising water tables, with clear relevance to MAR operations. The section states that any proposal to discharge waste to land where the discharge may cause detriment to groundwater quality must include an assessment of:

- a) background rate of rise of the water table

- b) any rise in the water table expected to be caused by the recharge induced by the discharge
- c) the impact of any rise of the water table on the sustainability of-
  - i) the proposal
  - ii) the surrounding land use
  - iii) the nearby ecosystem

Water quality provisions may limit the ability to raise the water table above ambient levels (cognisant of impacts on proximate ecosystems) by recharge with reclaimed water. Variable interpretations of the Section may influence MAR schemes where aquifer infiltration is achieved via reclaimed water retention ponds or constructed wetlands.

### ***State Environmental Protection Policy Waters of Victoria* 1997**

The Waters of Victoria policy establishes the uses and values of the water environment deemed as beneficial to the community and Government. By identifying the objectives and indicators of environmental quality required to protect those beneficial uses, the Policy provides guidance to local authorities, agencies and the community to protect local waterways and aquatic ecosystems.

It is important that the conjunctive use and the management of groundwater, excluded from the Waters of Victoria policy area, does not degrade the identified beneficial uses of surface waters. Groundwater provides the base flow for surface waters, which in times of water stress and drought, is the only flow for some of Victoria's waterways. S. 45 states that authorities managing groundwater should act to ensure that groundwater use does not impose a risk to the beneficial uses of adjoining surface waters. This means that groundwater diversions and extractions need to be managed to ensure adequate quantity of water to maintain identified environmental flows of surface waters.

S. 45 does deal with MAR specifically, although reclaimed water is defined as groundwater when recharged into aquifers through MAR operations. MAR water may therefore be subject to the same restrictions on groundwater extraction imposed on the entire aquifer during times of water stress. These are the periods that MAR schemes can augment existing water supplies and for commercial operators may realise the highest value of the resource.

### ***Catchment and Land Protection Act* 1994**

The *Catchment and Land Protection Act* describes provisions relevant to source water capture and retention as well as aquifer recharge and storage. Section 27 of the Act describes special area plans, whereby an Authority can recommend areas of special interest be declared, revoked or amended. In its recommendation the Authority may classify the area as a special water supply catchment. Deliberations must consider the likely adverse effects on the quality and condition of land; on water quality or aquatic habitats; and aquifer recharge or discharge areas. A large scale MAR is likely to be included in a special area plan and as a corollary, subject to consideration under the *Water Act* 1989 and the provisions set out in the *Planning and Environment Act* 1987.

### **Final use of recovered water: environmental and public health compliance**

The final use of recovered MAR water will be based on a suite of water quality variables. Water quality in turn is dependent on a vector of conditions including the quality of injectant, aquifer residency time, the degree of pathogen and contaminates attenuation and the efficiency of the method deployed to treat recovered water. The attendant water quality

standards corresponding with the designated final use are subject to the provisions of one or more of the following Acts or Guidelines.

- i) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- ii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).
- iii) Guidelines for the use of reclaimed water 2003
- iv) Health Act 1958
- v) Livestock Disease Control Act 1994
- vi) Food Act 1984
- vii) Occupational Health and Safety 1985
- viii) Safe Drinking Water Act 2003
- ix) *State Environment Protection Policy (Waters of Victoria and Ground Waters of Victoria) 1997*

## Western Australia

### Key points

1. The *Rights in Water and Irrigation Act 1914* does not differentiate MAR source waters from native groundwater. The rights to groundwater are vested with the State. The status of MAR source waters are therefore likely to be classed as groundwater and subject to the licensing obligations and allocations attendant with the aquifer.
2. There appears to be no provision in the *Rights in Water and Irrigation Act 1914* to regulate the infiltration or injection of MAR water in either prescribed or non-prescribed aquifers.
3. There is no specification or provision for the regulation of stormwater or stormwater use for MAR.
4. The *Environmental Protection Act 1986* is the primary Act to regulate water quality. Parts IV and V provide for the regulation of waste water from prescribed premises, including waste water treatment plants. This may be a *de facto* provision to manage MAR infiltration.

	Policy	Comment
<p style="text-align: center;"><b>1</b></p> <p style="text-align: center;">Capture Zone</p>	<p>i) RiWI Act 1914</p> <p>v) SW manual 2007</p> <p>ii) EP Act 1986</p> <p>iii) P and D Act 2005</p>	<p>Rights to all water vested with the Crown. Stormwater and recycled water not specified but may be considered under S.5c. s. 7(2) may apply to MAR source water in the public interest. Primarily water quality: applies to retention ponds and wetlands. Parts iv and v apply to MAR: applies to works and avoiding environmental harm. s.104 may apply to MAR.</p>
<p style="text-align: center;"><b>2</b></p> <p style="text-align: center;">Pre-treatment</p>	<p>ii), v), vii), viii), ix), x) and xi)</p>	
<p style="text-align: center;"><b>3</b></p> <p style="text-align: center;">Recharge</p>	<p>ii) EP Act 2004</p> <p>i) RiWI Act 1914</p>	<p>As above and provides for well construction: MAR managed via hydro-geological assessment. provides for licence to construct a well.</p>
<p style="text-align: center;"><b>4</b></p> <p style="text-align: center;">Subsurface storage</p>	<p>i) RiWI 1914</p>	<p>No provision for water quantity of aquifer infiltration.</p>
<p style="text-align: center;"><b>5</b></p> <p style="text-align: center;">Recovery</p>	<p>i) RiWI Act 1914</p>	<p>no differentiation of native and recharged waters: MAR required to obtain extraction licence and allocation. Temporary extraction allocation application allowed for.</p>
<p style="text-align: center;"><b>7</b></p> <p style="text-align: center;">End use</p>	<p>ii), v), vii), viii), ix), x) and xi)</p>	

Numbers in the policy column refer to corresponding legislation listed below.

### **Key References**

*WA EPA Bulletin 1199 (2005) 'Strategic Advice on MAR using treated wastewater on the Swan Coastal Plain'*

### **Western Australian Acts and legislation applying to MAR**

- i) *Rights in Water and Irrigation Act 1914*
- ii) *Environmental Protection Act 1986 (Parts iv and v)*
- iii) *Planning and Development Act 2005*
- iv) *Groundwater recharge guidelines (Appended to EPA Bulletin 1199)*
- v) *Stormwater management manual 2007*
- vi) *Environmental Protection (Gnangara Mound Crown Land) Policy 1992*
- vii) *Recycled Water Supply Agreement Health Act 1911*
- viii) *Draft Guidelines for the Use of Recycled Water in Western Australia*
- ix) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- x) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

## **Source water harvesting and capture**

### ***Rights in Water and Irrigation Act 1914***

The Stormwater Management Plans, Stormwater Management Manual for Western Australia (Department of Water and Swan River Trust 2007) sets out a comprehensive approach to the management of stormwater. The manual is based on the principle that stormwater is a resource with attendant social, economic and environmental opportunities. Utilising the processes of natural groundwater infiltration is key to a site sensitive planning framework. The manual is likely to guide stormwater management and regulation and hence the volumes, quality, constraints and opportunities for MAR source water.

In relation to water resources, the Act seeks to provide for the sustainable management of water resources to meet the needs of current and future users, and to regulate to avoid detrimental activities to ecosystems and the environment in which water resources are situated. The Act also seeks to promote the orderly, equitable and efficient use of water resources including consultation with and participation of local communities.

S. 5A states that right to the use and flow, and to the control, of the water at any time in any watercourse, wetland or underground water source is vested with the Crown except as allocated under this Act or another written law.

To *take* water is defined as removing water from, or reducing the flow of water in, a watercourse, wetland or underground water source, including by –

- a) pumping or siphoning water;
- b) stopping, impeding or diverting the flow of water;
- c) releasing water from a wetland;
- d) permitting water to flow under natural pressure from a well; or
- e) permitting stock to drink from a watercourse or wetland, and includes storing water during, or ancillary to, any of those processes or activities;

*water resources* are defined as including–

- a) watercourses and wetlands together with their beds and banks;
- b) other surface waters; and
- c) aquifers and underground water;

*water entitlement*, in relation to a licence, means the quantity of water that the licensee is entitled to take under the licence, and includes part of the water entitlement.

S.3. a “watercourse” is defined as:

- a) any river, creek, stream or brook in which water flows;
- b) any collection of water (including a reservoir) into, through or out of which anything coming within paragraph (a) flows;
- c) any place where water flows that is prescribed by local by-laws to be a watercourse, and includes the bed and banks of any thing referred to in paragraph (a), (b) or (c).

For the purposes of the definition in subsection (1) –

- a) a flow or collection of water comes within that definition even though it is only intermittent or occasional;
- b) a river, creek, stream or brook includes a conduit that wholly or partially diverts it from its natural course and forms part of the river, creek, stream or brook; and
- c) it is immaterial that a river, creek, stream or brook or a natural collection of water may have been artificially improved or altered.

S.5C. Licences to take water are issued under s. 5C of the Act. The Act requires a licence to take water from any artesian underground water source, and from non-artesian underground water sources located within proclaimed Groundwater Areas. Licenses are also required for the taking of water from watercourses and wetlands (Division 1B Certain Surface Waters S.6). Exemptions for taking water for stock and garden uses in the State are unlikely to apply to MAR operations. The Act does not specifically refer to stormwater or reclaimed water however S. 5C may be interpreted to apply to MAR source waters including stormwater. The granting of a license is at the discretion of the Department of Water (the Authority administering the Act).

In relation to the application under section 5C, S. 7(2) provides that the Department is to have regard to the ecological sustainability and environmental soundness of the water to be taken. Regard for third party effects are also required. Clause 7(2) also requires the Department of Water to consider the public interest in application deliberations. Commonwealth and State Governments have identified the innovations of water recycling and MAR to be in the public interest.

### ***Environmental Protection Act 1986***

The Environmental Protection Act provides for an Environmental Protection Authority, for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment.

In relation to MAR, the EP Act is the principle environmental legislation, providing primarily for the management of water quality, waste and contaminate streams rather than water quantity. The Act provides for the management of MAR source water wetlands or retention ponds primarily through water quality provisions. Although unlikely, the Act is also likely to be invoked in cases of excess groundwater recharge with attendant degradation of the aquifer or dependent ecosystems. According to the Act:

*beneficial use* means a use of the environment, or of any portion thereof, which is – conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment and which requires protection from the effects of emissions or of activities referred to in paragraph (a) or (b) of the definition of “environmental harm.”

*waste* includes matter –

(a) whether liquid, solid, gaseous or radioactive and whether useful or useless, which is discharged into the environment; or (b) prescribed to be waste

*waters* mean any waters whatsoever, whether in the sea or on or under the surface of the land.

Part IV of The Act provides for the assessment of development proposals and the provisions to regulate in an ongoing manner activities that have the potential to cause environmental harm (set out in Part V). The environmental matters submitted in proposals include regard to waters, waste and the notion of beneficial use (defined above).

s. 38 of the Act states that any proposal, including MAR, that is likely to have a significant effect on the environment must be referred to the EPA. Large scale MAR schemes using treated wastewater, or any trials or MAR proposals in areas of high environmental value are likely to require risk assessment and environmental impact assessment. Part IV provides for the initial environmental assessment process but does not provide for ongoing regulation of MAR.

The Part V provides for works approval and emissions licensing schemes from prescribed premises (s.53 1(b) and s.56 1), and represents ongoing regulation of MAR for water quality. Prescribed premises are set out in Schedule 1 to the Environmental Protection Regulations 1987 and include item 54 (sewage facility of greater than 100 cubic metres per day) and item 85 (sewage facility at which sewage is treated and discharged where between 20 and 100 cubic metres per day). Stormwater and recycled water are not referred to in the Act or the regulations, but may be provided for in r. 2c: discharge of waste as a prescribed class. Emissions from waste water treatment plants are already licensed under Part V and are likely to include waste water treatment plant involved in the MAR.

Clause 11 of the Environmental Protection (Gnangara Mound Crown Land) Policy 1992 provides that a person shall not cause or permit the discharge of any contaminant in the Gnangara Mound unless the person is authorised under the EP Act to do so.

### ***Planning and Development Act 2005***

Stormwater and recycled water are not specified but may fall under the definition of utility services as drainage or water supply services. There appears to be no provision in the ACT for regulating the quantity of reclaimed MAR source waters, apart from s. 104, which states that before making an interim development order that, in the opinion of the Commission or the local government (as the case requires), may affect the functions of a public authority or utility services provider, the Commission or the local government is to–

(a) inform the public authority or utility services provider of the proposal;  
(b) invite that public authority or utility services provider to make submissions on the proposal within 28 days; and

(c) provide the Minister with a copy of any submission received under paragraph (b).

## **Aquifer recharge and recovery**

### ***Rights in Water and Irrigation Act 1914***

The sections of the Act providing for the licensing and taking of water listed under harvesting source water apply to aquifer storage and recovery. The Act does not however address the disposal of water. There appears to be no mechanism to regulate the infiltration or recharge of an aquifer with any MAR source water.

The Environmental Protection Act provides in Parts IV and V for the regulation of water quality from prescribed premises and may de facto regulate for water quantity. This appears not to be specified however and there is not specific reference to stormwater.

s 5A states that right to the use and flow, and to the control, of the water at any time in any watercourse, wetland or underground water source, is vested with the Crown except as allocated under this Act or another written law. The status of MAR source waters are therefore likely to be classed as groundwater and subject to the licensing obligations and allocations attendant to the aquifer.

MAR source waters and native groundwater are not currently differentiated in the Act. S. 26D of the Act requires a licence to construct a well or bore, or alter an existing well, whether for the purposes of investigation, production or monitoring. The drilling of a bore and the associated disturbance to the surrounding area must also comply with the State's Aboriginal Heritage Act, 1972 and the Commonwealth Native Title Act, 1993. If the area is subject to a Native Title claim, the applicant must notify the registered claimant group so they can comment about the proposed activities.

Clause 4(2) of Schedule 1 of the Act provides that an applicant for a licence must provide the Department of Water with any further information that the Department may require in order to assess the application. The information requested by the Department may include a Hydrogeological Assessment (Statewide Policy no.19) of the proposed taking and use of the water, to assist the Department in determining the potential impact of granting a licence under section 5C.

### **Final use of recovered water: environmental and Public Health compliance**

In October 2005, The Environmental Protection Authority released section 16 advice to the Minister for the Environment; Science on MAR using treated wastewater on the Swan Coastal Plain. The report noted that with over 100 Gigalitres of water discharged to the marine environment per annum, treated wastewater has the potential to play an important role in the maintenance of wetlands and caves, reduced salt water intrusion, increased water availability for irrigation use and augmentation of drinking water supplies. Subject to Department of Health approval and EPA referral, the EPA expects that in a number of situations the risks associated with MAR can be managed to negligible or low levels.

The final use of recovered MAR water will depend on a suite of water quality variables. Water quality in turn is dependent on a vector of conditions including the quality of injectant, aquifer residency time, the degree of pathogen and contaminates attenuation and the efficiency of the method deployed to treat recovered water. The attendant water quality standards corresponding with the designated final use are subject to the provisions of one or more of the following Acts or Guidelines.

- i) Part IV, EP Act 1986

- ii) Groundwater recharge guidelines (Appended to EPA Bulletin 1199)
- iii) EPA Bulletin 1199 'MAR using treated wastewater on the Swan Coastal Plain'
- iv) Environmental Protection (Gnangara Mound Crown Land) Policy 1992
- v) Recycled Water Supply Agreement Health Act 1911
- vi) Draft Guidelines for the Use of Recycled Water in Western Australia
- vii) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- viii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

## Queensland

### Key points

1. Institutional structures have been reformed in south east Queensland to address the problem of using multiple water sources collectively to secure water supply over a region. The reforms include the establishment of the Queensland Water Commission (applying to south east Queensland), and provision for the implementation of a whole of system Water Grid administered by an independent Water Grid Manager (QWC 2007, 2008). Bulk water supply is to be comprised of two statutory entities; one being South East Queensland dams and aquifers, the other relevant a manufactured water and treatment facilities. Recommendations include 3<sup>rd</sup> party access to connection rights to mains distribution and water treatment infrastructure by alternative bulk supply options. Three water retailers are proposed to distribute water to end users according to cost reflective pricing.
2. As stated in the Queensland Water Commission Draft water Strategy for South East Queensland (QWC 2008 p.119), aquifer storage and recovery is under investigation on the Gold Coast to store recycled water for irrigation purposes. Such opportunities in SEQ are considered to be limited and need to be assessed on a case-by-case basis<sup>34</sup>.
3. Purified recycled water stored in surface dams and desalination are the preferred options to augment urban water supplies in South East Queensland. QWC (2008) estimates these will supply 30% of the water demand by 2056.
4. The majority of institutional design and reform has focussed on policy related to purified recycled water stored in surface dams (*Water Availability and Entitlements Act 2008*).
5. Stormwater harvesting is currently (*considered*) a boutique solution and must be considered on a case by case merits. Stormwater may be stored in a small dam or reservoir or used to recharge a groundwater aquifer (there are a limited number of suitable aquifers in South East Queensland); (QWC 2008 p.91 inserted italics).
6. The scope for the economic use of stormwater harvesting in an established urban environment requires careful evaluation and would be unlikely to be precluded through ownership remaining with councils. On balance, it is the view of the Commission that stormwater drainage assets and responsibilities should remain with councils. (QWC 2007, p.32)
7. Water from groundwater aquifers will continue to make a small contribution in the delivery of urban supplies. The sustainable abstraction from these aquifers is expected to remain relatively static over time (QWC 2008, p.165).

---

<sup>34</sup> A MAR scheme has been in operation in the Burdekin Delta, Queensland since 1965. The scheme uses episodic and surplus surface water to recharge and replenish the Burdekin Delta aquifer, maintaining water tables and mitigating salt water intrusion. The aquifer is a primary source of water for a substantial irrigation industry. Although operating in a rural district the scheme provides guidance for urban MAR schemes able to utilise surplus or waste water sources, such as stormwater.

	Policy	Comment
1 Capture Zone	x) LG Act 1993 and iii) SER Act 2007  i) W Act 2000 and WA and E Act 2008	Management and hence entitlement of stormwater and infrastructure remains with local councils. Purified Recycled Water is more likely to be deployed for reservoir augmentation than MAR.  All rights to water remain vested with State.
2 Pre-treatment	vi), vii), viii), ix), xi) and xii)	
3 Recharge		
4 Subsurface storage	i) W Act 2000	Applies to storage: limited aquifer suitability
5 Recovery	i) W Act 2000	Recharge and native waters are not differentiated: Generally aquifers are fully allocated. MAR will require licence to recover.
7 End use	vi), vii), viii), ix), xi) and xii)	

Numbers in the policy column refer to corresponding legislation listed below.

### Institutional impediments to water reform

The Queensland water Commission (QWC 2007 p.viii) Identified institutional impediments and barriers to water reform in Queensland. The QWC states:

The current institutional arrangements for urban water supply in South East Queensland suffer from serious systemic weaknesses. In summary these are:

- i) confused accountabilities in terms of the roles and responsibilities of State and Local Governments for water security;
- ii) fragmented ownership arrangements with the bulk supply treatment and transport assets owned by 25 entities in the region;
- iii) a lack of regionally integrated approaches to supply, where councils are focused on issues within their own local government boundaries;
- iv) no means by which the costs of new infrastructure and the water coming from that new infrastructure may be equitably shared across those who benefit;
- v) limited regulation of asset maintenance that has resulted in differing service standards across the region, and in some cases insufficient funds being spent on maintaining assets;
- vi) water prices and the regulation of those prices are not managed in a consistent way; and
- vii) there is no opportunity for consumers to enjoy the benefits of a competitive market particularly at the retail level.

## Key Documents

QWC (2008) Water for Today, Water for Tomorrow. South East Queensland Water Strategy-Draft March 2008.

<http://www.qwc.qld.gov.au/myfiles/uploads/SEQWS/SEQWaterStrategy-Draft.pdf>

QWC (2007) Our Water urban Water Supply Arrangements in South East Queensland

[http://www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban\\_Water\\_Supply\\_Arrangements\\_in\\_SEQ.pdf](http://www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban_Water_Supply_Arrangements_in_SEQ.pdf)

EHA (2006) Groundwater Review of south East Queensland on-shore aquifer systems. Report prepared for the Queensland Department of Natural Resources, Mines and Water: GW 05-25-REP-001.

DNRW (2007) Queensland Urban Drainage Manual Volume 1, 2<sup>nd</sup> edition.

[http://www.nrw.qld.gov.au/compliance/wic/flood\\_risk\\_management.html](http://www.nrw.qld.gov.au/compliance/wic/flood_risk_management.html)

The manual sets out the objectives of stormwater management. It notes that the planning of stormwater systems needs to be integrated with land use planning as well as planning for other infrastructure (e.g. water supply) so as to maximise the benefits of complementary measures and to ensure that conflicting outcomes are avoided. Under the principles of Water Sensitive Urban Design, stormwater planning should be integrated with water supply and wastewater planning as well as the management of ground waters. The Drainage manual sets out the provisions and legislative requirements for stormwater management in Queensland: see Summary Tables 2.03 and 3.08.

DNRW (2008) Recycled water management plan and validation guidelines.

[http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft\\_rwmp\\_validation\\_guidelines.pdf](http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft_rwmp_validation_guidelines.pdf)

DNRW (2008) Water quality guidelines for recycled water schemes

[http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft\\_water\\_quality\\_guidelines.pdf](http://www.nrw.qld.gov.au/water/regulation/recycling/pdf/draft_water_quality_guidelines.pdf)

### **Queensland Acts and legislation applying to MAR**

- i) *Water Act 2000*
- ii) *Water Availability and Entitlements Act 2008*
- iii) *South East Water Restructuring Act 2007*
- iv) *Native Title Act 1993*
- v) *Integrated Planning Act 1997*
- vi) *Public Health Act 2005 (Section 57)*
- vii) *Environmental Protection Act 1994*
- viii) *Environmental Protection (Water ) Policy 2000*
- ix) *Model Urban Stormwater Quality Management Plans and Guidelines (EPA 2007).*
- x) *Local Government Act 1993*

- xi) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- xii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

### **Source water harvesting and capture**

QQWC (2008 p. 165) sets out the current objectives for rainwater and stormwater harvesting in South East Queensland. The primary focus is the mandatory planning requirements for rainwater tanks on new developments.

Rainwater tanks and stormwater harvesting are expected to comprise about 7% of the South East Queensland water supply by 2056.

- All new homes in SEQ must meet mandatory water saving targets. Rainwater tanks and stormwater harvesting are options to meet the target.
- From 1 January 2008, most new industrial and commercial buildings will be required to install a rainwater tank.
- Water to top up every pool in SEQ will be sourced from a rainwater tank or downpipe rainwater diverter.
- Stormwater harvesting is a possible solution to achieving the water saving target for new residential developments.
- Supply strategies involving increased recycling and increased capture of rainwater and stormwater will contribute to the improved water quality of waterways and Moreton Bay.

QWC (2007 p.32 section3.2.7) sets out the details of the Queensland Water Commissions deliberations on the management and entitlements regime for stormwater assets in South East Queensland. The Commission states:

“An important area for consideration in defining asset and operational responsibility in the Water Grid is the provision of stormwater services. Consideration has been given to options for the consolidation of stormwater assets and services with other water services. In Queensland, Councils have responsibility for all drainage and stormwater works and services outside of their water service provider functions. Generally Councils recover ongoing costs through the raising of general rates in a similar fashion to other services such as roads. Councils have the ability to levy infrastructure charges on developers to fund new infrastructure to new development areas”.

The Commission has considered whether responsibility for stormwater assets best rests with one of the network service providers (i.e. bulk transport or distribution) or remains with the Councils. It is recognised that most Councils currently provide stormwater services outside of their water service provider activities, and that accordingly costs are recovered through general rates rather than as part of the existing water service cost recovery framework. There is often no readily identifiable charge, and hence revenue stream, associated with individual stormwater assets.

Stormwater services also have significant relevance to other Council functions, particularly road construction and drainage. Some of the assets serve multiple functions (for example some floodways or waterways may serve as green space, parkland or sporting fields) and many of the major stormwater assets are watercourses rather than large pipes or constructed drains.

The Commission has recognised that there are potential benefits for integrated urban water management in stormwater harvesting as a supply source. However, the scope for the

economic use of stormwater harvesting in an established urban environment requires careful evaluation and would unlikely be precluded through ownership remaining with Councils. In conclusion, operational synergies of including stormwater assets with water service provision do not appear to outweigh the issues surrounding the transfer of these responsibilities from Councils. On balance, it is the view of the Commission that stormwater drainage assets and responsibilities should remain with Councils.

### **Aquifer recharge and recovery**

S. 19 of *the Water Act 2000* states that rights in the use, flow and control of water in Queensland are vested in the State. QWC (2008, P.118) describes the likely status of groundwater as a water supply augmentation in South East Queensland.

Groundwater resources in SEQ are almost fully developed. The annual volume used for urban purposes over the next 50 years is expected to remain largely static. The use of groundwater for rural production is also considered fully developed and, in some cases, over-developed. The Moreton Water Resource Plan has established groundwater management areas in Cressbrook Creek, the Lockyer Valley and in the Warrill-Bremer Valley. These areas enable closer management of groundwater in the whole of the Lockyer Valley, and are expected to lead to a reduction in groundwater extraction. Similarly, the groundwater in the Warrill/Bremer alluvial groundwater management area will now be managed and extractions are likely to be authorised under licence.

Groundwater reserves with the potential to supply small quantities of water for urban use in SEQ include:

- The offshore sand dune islands, including North and South Stradbroke, Moreton, Bribie and Fraser islands;
- Localised, onshore sand dune deposits located adjacent to the coastline and extending intermittently from Rainbow Beach in the north to the Gold Coast in the south;
- An extensive system of mostly fractured volcanic rocks associated with what is known geologically as the Gympie Province extending from just north of Nambour to Gympie;
- Sedimentary deposits, mostly sandstones associated with the southern part of the Maryborough Basin and known locally as the Myrtle Creek Sandstone;
- Limited outcrops of relatively young tertiary basalts in the Maleny, Buderim, Sunnybank, Redland Bay and Tamborine Mountain areas; and
- Reasonably extensive tertiary sedimentary deposits outcropping in the Brisbane metropolitan area to the north and south of the city.

### **Final use of recovered water: environmental and public health compliance**

The final use of recovered MAR water will depend on a suite of water quality variables. Water quality in turn is dependent on a vector of conditions including the quality of injectant, aquifer residency time, the degree of pathogen and contaminates attenuation and the efficiency of the method deployed to treat recovered water. The attendant water quality standards corresponding with the designated final use are subject to the provisions of one or more of the following Acts or Guidelines.

- i) *Public Health Act 2005* (Section 57)
- ii) *Environmental Protection Act 1994*
- iii) *Environmental Protection (Water ) Policy 2000*
- iv) *Model Urban Stormwater Quality Management Plans and Guidelines (EPA 2007).*

- v) Local Government Act 1993
- vi) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- vii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

## NSW

### Key Points

1. MAR is not widely promoted as a viable option to augment Sydney water supplies. Referring to stormwater and MAR, the Water for Life: NSW Metropolitan Water Plan p.46 states:
  - a. “As its supply is variable and dependent on rainfall, runoff must typically be stored and usually treated for future use. This can require an urban lake, constructed wetland, aquifer storage or storage tank. In Sydney, aquifers are generally not suitable for this purpose, and the space required for lakes and tanks is often unavailable in urban areas, unless a new development is under way”.
2. In contrast to the Metropolitan Water Plan position on MAR, Timms *et al.* (2007) argue that the Botany Sands aquifer is suitable for large scale MAR. The authors generally favour sewer mining for source waters compared to stormwater, based on improved volume reliability, avoiding the need for retention storages and ready access to advanced water treatment.
3. The Water Plan refers to the role of groundwater to augment Sydney’s urban water supply p.79 “On the basis of the independent expert analysis of the supply and demand balance, the Government has decided that groundwater and desalination will be used only in the event that dam levels fall to critical levels. Thus, groundwater will be used to help Sydney through severe droughts, as this maximises the yield benefit of the groundwater resources. It is intended to use groundwater only during drought periods, when dam levels fall below about 40%, and the groundwater aquifer will be allowed to recharge in non-drought periods”. MAR is not considered for additional groundwater recharge.
4. *The Water Management Act 2000* s.56 defines a water access licence as an entitlement to a specified share in the available water management area from a specified water source (**the share component**). The **extraction component** entitles the licence holder to take water at a specified time, rate, location and circumstance. NSW policy corresponds to the NWI which defines water access entitlements as perpetual unit shares of a defined consumptive volume of a water resource. Periodic allocations are made in accord with annual inflows, storage volumes and in proportion to the number of shares held. Risk is assigned between users and the Government.
5. All rights to water are vested with state. Recharged water is not differentiated from native groundwater and will require a water access licence, works approval and a water supply works approval. The legislation does not specify the status of stored MAR water when aquifers are overdrawn and allocations are 0% of the entitlement.
6. Stormwater reuse opportunities tend to be more cost effective on a small scale, where water is retained and reused as close to its source as possible. Rainwater harvested directly from roofs has a relatively high quality, requiring minimal or no treatment, compared to stormwater collected from drains in an urbanised catchment. For these reasons, priority has been given to rainwater tanks and local opportunities, as these options are the most cost effective, requiring less treatment and distribution.

	<b>Policy</b>	<b>Comment</b>
<b>1</b> Capture Zone	iv) EPA Act 1979 vi) PoEO Act 1997 i) WMAct 2000) v) LG Act 1993 vii) Dams Act 1978	Depending on nature and volume of source water, various Acts or combinations of Acts are invoked. Stormwater is exempt from several Acts  All rights to water remain vested with State.
<b>2</b> Pre-treatment	x), xiii) and xiv), xv), xvi)	
<b>3</b> Recharge	i) WM Act 2000	
<b>4</b> Subsurface storage	i) WM Act 2000 iv) EPA Act 1979	Applies to storage: limited aquifer suitability
<b>5</b> Recovery	i) WM Act 2000	Recharge and native waters not differentiated: Generally aquifers fully allocated. MAR will require licence to recover
<b>7</b> End use	x), xiii) and xiv), xv), xvi)	

Numbers in the policy column refer to corresponding legislation listed below.

### Key documents and Guidelines

NSW Department of Water and Energy (2007) Interim NDSW guidelines for management of private recycled water schemes. New South Wales Government, Sydney. ISBN 978 0 7347 5940 5

[http://www.waterforlife.nsw.gov.au/\\_data/assets/pdf\\_file/0018/11772/Private\\_Recycled\\_Water\\_guideMay2008.pdf](http://www.waterforlife.nsw.gov.au/_data/assets/pdf_file/0018/11772/Private_Recycled_Water_guideMay2008.pdf)

Department of Environment and Conservation (2006) Managing urban stormwater: harvesting and reuse. New South Wales Government, Sydney. ISBN 1 74137 875 3

<http://www.environment.nsw.gov.au/resources/stormwater/managestormwatera06137.pdf>

Metropolitan Water Plan (2006) New South Wales Government, Sydney ISBN 0 7313 32687

[http://www.waterforlife.nsw.gov.au/about/plan/download\\_the\\_metropolitan\\_water\\_plan](http://www.waterforlife.nsw.gov.au/about/plan/download_the_metropolitan_water_plan)

### ***New South Wales Acts and legislation applying to MAR***

- i) The Water management Act 1979*
- ii) Water Management (Water Supply Authorities) Regulation 2004*
- iii) Sydney water Act 1994*
- iv) The Environmental Planning and Assessment Act 1979*
- v) Local Government Act 1993*
- vi) The Protection of the Environment Operations Act 1997*
- vii) Dam Safety Act 1978*

- viii) *The Fisheries Management Act 1994* (Works in a watercourse)
- ix) *Rivers and Foreshores Improvement Act 1948* (piped stormwater exempt)
- x) *Environmental Guidelines: Use of Effluent by Irrigation* (NSW Department of Environment and Conservation) (2004)
- xi) *Threatened Species Conservation Act 1995*
- xii) *National Parks and Wildlife Act 2003* (Predominately protection of Aboriginal Heritage)
- xiii) *Public Health Act 1991*
- xiv) *Food Act 2003*
- xv) *The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse* (EPHC Draft May 2008)
- xvi) *The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge* (EPHC Draft May 2008).

## Source water harvesting and capture

### ***The Environmental Planning and Assessment Act 1979***

Stormwater harvesting schemes are subject to the requirements of *the Environmental Planning and Assessment Act 1979*, which stipulates the requirements for environmental impact assessment for the purpose of development consent.

Development consent is an approval for development issued by a 'consent authority', normally the local council but sometimes the Minister for Planning. Environmental planning instruments will determine if development consent is required for a development proposed for a certain zone. Therefore, depending on the provisions in the relevant environmental planning instruments, constructing a stormwater harvesting and reuse scheme may require development consent.

Development proposals that require development consent are subject to the requirements of Part 3A or 4 of the *Environmental Planning and Assessment Act 1979*. Part 3A specifies the assessment and approval process for major infrastructure and other major projects while Part 4 specifies the process for other proposals requiring development consent.

Schedule 3 of the *Environmental Planning and Assessment Regulation 2000* was amended to provide EIS exemption for sewer mining where treated water is to be used solely for industrial purposes. The schedule primarily refers to water quality but makes allowance for system volumes up to 1500 KLs per day. When proximate to a suitable aquifer, recycled sewage may act as source water for a MAR operation.

Parts 3 and 4 of *The Environmental Planning and Assessment Act 1979* consider development applications to be 'integrated development' where certain licences or approvals are required from bodies other than a consent authority. Applicants must inform the consent authority of any licences, additional approvals or permits required from state agencies other than development consent before lodging their applications. Councils are then required to consult with the relevant state agency and obtain requirements in relation to the development (the Department of Water and Energy and NSW Health acting in an advisory role).

Activities not covered by planning or development control processes, and thus not requiring development consent, fall under Part 5 of *the Environmental Planning and Assessment Act 1979*. Such 'exempt' activities include installations of public utilities undertaken by local councils and government agencies. A review of environmental factors may be required in these circumstances.

Stormwater harvesting schemes would normally be subject to the requirements of the *Environmental Planning and Assessment Act 1979*. The Act sets out the requirements for environmental impact assessment and approvals for development consent purposes.

Development consent relies on environmental planning instruments. These can be broadly interpreted, and depending on the provisions specified in the environmental planning instruments, can in turn invoke *the Local Government Act 1993*, *the National Parks and Wildlife Act 1974* or the *Threatened Species Conservation Act 1995*. Section 5C provides that a reference to *the Threatened Species Conservation Act 1995*, in relation to the critical habitat of fish or marine vegetation, is taken to be a reference to Part 7A of the *Fisheries Management Act 1994*.

***The Protection of the Environment Operations Act 1997*** is the principal legislation governing the protection, restoration and enhancement of the environment in New South Wales. Part 3.1 of the Act requires environment protection licences to be issued for scheduled activities that may cause pollution. Stormwater harvesting schemes do not require such licensing.

Clause 48 of the *Local Government (General) Regulation 2005* provides for approval exemption for the installation and operation of a recycling scheme when the scheme is licensed under the *Protection of the Environment Operations Act 1997*.

Section 68 of the ***Local Government Act 1993*** requires approval from the local council for water supply, sewerage and stormwater drainage work as well as the installation and operation of a sewage management system, including private recycled water schemes that process sewage. Approval is not required when the source of recycled water is stormwater (Part B).

Under s.68, Part C, (5,6) of the *Local Government Act 1993* (the Act), Councils are responsible for issuing approvals to both install and operate systems of sewage management as defined under section 68A. This includes councils in the Sydney Water and Hunter Water areas of operation where councils are not the plumbing and drainage authority.

Division 4 of the ***Local Government (General) Regulation 2005*** details approval requirements. Some privately owned and operated schemes currently being considered by councils are designed to treat sewage from premises normally occupied by more than 10 persons, or with an average daily flow of sewage exceeding 2,000 L. Such a sewage management facility may be exempt from the requirement to be accredited by NSW Health.

The *Local Government Act 1993* sets out in s. 42-47 the requirements and performance standards necessary to operate a recycling scheme for non-stormwater sources.

Local Councils are the approving authority for s.68 with the Department of Water and Energy and NSW Health acting in an advisory role. The Department of Water and Energy is the approving authority when a Council is the proponent (s.60 of the *Local Government Act 1993*).

### ***The Water Management Act 2000***

*The Water Management Act 2000* provides the statutory framework for water extraction from rivers, lakes and estuaries. The Act defines a 'river' to include any watercourse and artificially

improved channel but not a piped drain. The definition of 'lake' includes any body of natural or artificial still water, including a wetland. In an urban context, the Act would apply to any river, creek, (open) drainage channel, lake or pond, but not to schemes that harvests stormwater from a drainage pipe. According to the Act, stormwater harvesting will be defined as water supply works requiring approval at a specified location (s.90).

Water Supply works (s.90) are:

- (a) a work (such as a water pump or water bore) that is constructed or used for the purpose of taking water from a water source, or
- (b) a work (such as a tank or dam) that is constructed or used for the purpose of:
  - (i) capturing or storing rainwater run-off, or
  - (ii) storing water taken from a water source, or
- (c) a work (such as a water pipe or irrigation channel) that is constructed or used for the purpose of conveying water to the point at which it is to be used,

Stormwater harvesting schemes proposed for construction on a 'river' normally require:

- a water access licence (s.56 defines a water access licence as an entitlement to a specified share in the available water management area from a specified water source (**the share component**). The **extraction component** entitles the licence holder to take water at a specified time, rate, location and circumstance.)
- water use approval (s.89)
- a water supply work approval (s.90)

The Department of Natural Resources is responsible for the licensing, although new commercial licenses are generally not being granted (NSW Department of Environment and Conservation 2006, p.19)<sup>35</sup>.

An approval to use water is required before river water may be used at a particular location, such as for irrigation or town water supply. A stormwater harvesting scheme granted development consent under Part 4 of the Environmental Planning and Assessment Act 1979 does not require a water use approval.

A water supply work approval is required for water management works associated with water use, including to:

- extract water from a river or lake
- store water taken from a river or lake (in off-line storages)
- convey water extracted from a river or lake to another location
- retain water in a river (via a weir or in-river dam).

### ***Water Management (Water Supply Authorities) Regulation 2004***

Part 4, Division 3, C.38:

(1) A person must not cause or allow anything (including stormwater) to be discharged, whether directly or indirectly, into a water supply authority's sewerage system otherwise than in accordance with a discharge approval.

### ***Sydney water Act 1994***

Sydney water Act 1994 (88) Part 6, Division 6

s. 48 Illegal diversion of water declares that a person must not: (a) wrongfully take, use or divert any water that is available for supply by the Corporation or that is in any pipe or work used for supply by the Corporation. Stormwater is defined as piped water.

<sup>35</sup> <http://www.environment.nsw.gov.au/resources/stormwater/managestormwatera06137.pdf>

### ***Dams Act 1978 (96) part 3 section 14***

The *Dams Safety Act 1978*, is administered by the Dam Safety Committee. Depending on the dam height, the hazard rating of dam failure and the risk assessment of associated damage and loss, the Act may apply to storages for stormwater harvesting schemes. Prescribed dams are listed in Schedule 1 of the Act. The functions of the Dam Safety Committee are:

- (a) to maintain a surveillance of prescribed dams, the environs under, over and surrounding prescribed dams and the waters or other materials impounded by prescribed dams to ensure the safety of prescribed dams,
- (b) to examine and investigate the location, design, construction, reconstruction, extension, modification, operation and maintenance of prescribed dams, the environs under, over and surrounding prescribed dams and the waters or other materials impounded by prescribed dams,
- (c) to obtain information and keep records on matters relating to the safety of dams,
- (d) to formulate measures to ensure the safety of dams,
- (e) to make such reports or recommendations to the Minister or any other person in relation to the safety of prescribed dams as the Committee considers necessary or appropriate,
- (f) to make reports and recommendations with respect to the prescription of dams for the purposes of this Act,

### **Aquifer recharge and recovery**

#### ***Water Management Act 2000***

Sections 31-33 of the Act provide for controlled activities and aquifer interference activities. Core provisions deal with planning provisions of a management plan for a water management area regarding the following matters:

- (a) identification of the nature of any controlled activities or aquifer interference causing impacts, including cumulative impacts, on water sources or their dependent ecosystems, and the extent of those impacts,
- (b) specification of controlled activities or aquifer interferences which are to require controlled activity approvals or aquifer interference approvals in the area.

s. 33 states that the controlled activity and aquifer interference activity provisions of a management plan for a water management area may also deal with the following matters:

- (a) the undertaking of work for the purpose of restoring or rehabilitating a water source or its dependent ecosystems,
- (b) protecting, restoring or rehabilitating the habitats or pathways of animals and plants,
- (c) specific controls on activities causing unacceptable impacts,
- (d) the preservation and enhancement of the quality of water in the water sources in the area affected by controlled activities or aquifer interference,
- (e) other measures to give effect to the water management principles and the objects of this Act,
- (f) such other matters as are prescribed by the regulations.

The section of the Act is likely to apply to the aquifer recharge and storage operational element of MAR, requiring inclusion in a management plan.

s. 34 and s. 5(2) require environmental projection provisions in management plans. Generally water sources, floodplains and dependent ecosystems (including groundwater and wetlands) should be protected and restored and, where possible, land should not be degraded. In section S. 34(2), *control, development, development consent* and *existing use* have the same meanings as they have in the ***Environmental Planning and Assessment Act 1979***. Aquifer recharge is likely to require development consent under the Act.

s. 349 of the *Water Management Act 2000* and s.346 of the *Water Management Amendment Act 2008*, requires a bore drillers licence to access the aquifer.

S. 345 of the *Water Management Amendment Act* provides for the offence level for intentional harm of an aquifer.

## Recovery of stored water

### ***Water Management Act 2000***

s. 349 of the *Water Management Act 2000* and s.346 of the *Water Management Amendment At 2008*, requires a bore drillers licence to access the aquifer.

s.392 For the purposes of the Act, the rights to the control, use and flow of:

- (a) all water in rivers, lakes and aquifers, and
- (b) all water conserved by any works that are under the control or management of the Minister, and
- (c) all water occurring naturally on or below the surface of the ground, are the ***State's water rights***.

The Act does not distinguish water in an aquifer derived from MAR operations from that of native groundwater. If MAR stored water is classed as groundwater, and part of a management plan, recovery of stored water will require:

- a water access licence (s.56 defines a water access licence as an entitlement to a specified share in the available water management area from a specified water source (**the share component**). The **extraction component** entitles the licence holder to take water at a specified time, rate, location and circumstance.)
- water use approval (s.89)
- a water supply work approval (s.90)

## Final use of recovered water: environmental and public health compliance

The final use of recovered MAR water will depend on a suite of water quality variables. Water quality in turn is dependent on a vector of conditions including the quality of injectant, aquifer residency time, the degree of pathogen and contaminates attenuation and the efficiency of the method deployed to treat recovered water. The attendant water quality standards corresponding with the designated final use are subject to the provisions of one or more of the following Acts or Guidelines.

- i) *Public Health Act 1991*
- ii) *Food Act 2003*

- iii) *Protection of the Environment Operations Act 1997*
- iv) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- v) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).
- vi) *Environmental Guidelines: Use of Effluent by Irrigation* (NSW Department of Environment and Conservation) (2004).

## Tasmania

### Key points

1. Urban water reform prioritises demand management and capacity building (DPIW 2005, 2006)
2. There are no declared Groundwater Areas in Tasmania, allowing free access water stored in an aquifer as part of an MAR operation

	Policy	Comment
① Capture Zone	i) WM Act 1999 ii) WSI Act 2008 iii) LUPA Act 1993	Legislation does not specify provisions for stormwater
② Pre-treatment	iv) v) vi), vii), viii)	
③ Recharge		There are no declared Groundwater Areas in Tasmania, allowing free access to water stored in an aquifer as part of an MAR operation
④ Subsurface storage		There are no declared Groundwater Areas in Tasmania, allowing free access to water stored in an aquifer as part of an MAR operation
⑤ Recovery		There are no declared Groundwater Areas in Tasmania, allowing free access to water stored in an aquifer as part of an MAR operation
⑦ End use	iv) v) vi), vii), viii)	

Numbers in the policy column refer to corresponding legislation listed below.

### Key Documents

Tasmanian Water Act (WMA)

[http://www.austlii.edu.au/au/legis/tas/consol\\_act/wma1999166/](http://www.austlii.edu.au/au/legis/tas/consol_act/wma1999166/)

Department of Primary Industries and Water (2005) Water Governance arrangements for Tasmania: a report to the NWC. Hobart

[http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6KY3CM/\\$FILE/Water%20Governance%20Tasmania.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6KY3CM/$FILE/Water%20Governance%20Tasmania.pdf)

Department of Primary Industries and Water (2006) Implementation plan for the NWI

Tasmania. Hobart [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6VQ6MS/\\$FILE/Tas%20NWI%20Implementation%20Plan.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JMUJ-6VQ6MS/$FILE/Tas%20NWI%20Implementation%20Plan.pdf)

### ***Tasmanian Acts and legislation applying to MAR***

- i) *Water Management Act 1999*

- ii) *Water and Sewerage Industry Act 2008*
- iii) *The Land Use Planning and Approvals Act 1993*
- iv) *Environmental Management and Pollution Control Act 1994*
- v) *Public Health Act 1997*
- vi) *State Policy on Water Quality Management 1997*
- vii) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- viii) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).

The *Water Management Act 1999* is the principle legislation to manage aspects of water resources in Tasmania. The *Act* is part of the State's integrated Resource Management and Planning System and provides for the management of Tasmania's freshwater resources. In particular, the *Act* is to provide for the use and management of freshwater resources in Tasmania having regard to the need to:

1. Promote sustainable use and facilitate economic development of water resources;
2. Recognise and foster the significant social and economic benefits resulting from the sustainable use and development of water resources for the generation of hydro-electricity and for the supply of water for human consumption and commercial activities dependent on water;
3. Maintain ecological processes and genetic diversity for aquatic and riparian ecosystems;
4. Provide for the fair, orderly and efficient allocation of water resources to meet the community's needs;
5. Increase the community's understanding of aquatic ecosystems and the need to use and manage water in a sustainable and cost-efficient manner; and
6. Encourage community involvement in water resources management.

Within the *Act* guidelines are provided for permit holders and existing dam owners of the major matters to be considered in the construction of earth-fill dams. The *Act* provides for the identification and management of water for ecosystems and a clear, consistent and equitable approach for the granting of new winter water allocations while protecting the health of the State's rivers and estuaries. Guidelines and policy are also provided for the trading of water and the enforcement of the provisions of the *Water Management Act 1999* and its subordinate legislation. It sets out the general principles, criteria and measures that the Department will use to enforce the *Act*.

Under the *Water Management Act 1999*, there are two separate sets of regulations, the *Water Management Regulations 1999* and the *Water Management (Safety of Dams) Regulations 2003*.

- The *Water Management Regulations 1999* set limits on the taking of water for specific uses and set fees for water licences. They also set fines for contravention of, or failure to comply with, any regulations.

- The *Water Management (Safety of Dams) Regulations 2003* set the level of competency required for construction teams to be authorised to work on dams of different hazard categories and dimensions.

s. 7. (Abolition and vesting of rights to water) states that:

(1) All rights existing at common law immediately before the commencement of this section to the flow of, or for the taking of, naturally occurring water are abolished.

(2) Except as provided by this Act, all rights to the taking of water from the water resources of Tasmania are vested in the Crown to be administered in accordance with this Act.

"taking", in the case of water from a water resource, includes—

- taking water by pumping or syphoning the water; and
- stopping, impeding or diverting the flow of water over land (whether in a watercourse or not) for the purpose of collecting or storing the water; and
- diverting the flow of water in a watercourse from the watercourse; and
- releasing water from a lake; and
- permitting water to flow under natural pressure from a well, unless the water is flowing from a natural opening in the ground that gives access to groundwater; and
- permitting stock to drink from a watercourse, a natural or artificial lake, a dam or reservoir;

"dam" means a permanent or temporary barrier or structure that stores, holds back or impedes the flow of water and includes—

- any spillway or similar works for passing water around or over the barrier or structure; and
- a pipe or other works for passing water through or over the barrier or structure; and
- water stored or held back by the barrier or structure and the area covered by that water;
- an artificial depression or hole excavated in a watercourse that holds water or impedes the flow of water; and
- an artificial levee or bank that holds back or diverts water in a watercourse

"dispersed surface water" means water flowing over land otherwise than in a watercourse—

- after having fallen as rain or hail or having precipitated in any other manner; or
  - after rising to the surface naturally from underground; or
- (b) water as mentioned in paragraph (a) that has been collected in a dam or reservoir;

### **Source water harvesting and capture**

The implementation plans for Tasmania to meet NWI urban water reform objectives focus on demand management and innovation and capacity building (DPIW 2005, 2006). MAR does not feature in current plans for Tasmanian urban water management. Stormwater, for

example, is not specifically mentioned in the *Water management Act 1999*, but appears to be provided for under the definition of either dispersed surface water or as part of a dam.

S. 137 (2) provides for dam exemptions and includes:

- (b) a dam which is not on a watercourse and holds less than one megalitre of water;
- (c) a dam constructed for the primary purpose of storing waste;

Part 4 (Division 1) provides for the establishment of Water Management Plans, including water courses, water supply channels and groundwater. A licence is required for the taking of water when prescribed in a Water Management Plan. A licence is not required to take water from unless specified by a Water Management Plan. Urban stormwater appears not to be part of a Water Management Plan and is likely to be exempt, allowing free access for commercial MAR operators. If stormwater is to be defined as waste, it may also be exempt according to s.137.

If Stormwater is described as a dispersed surface water and subject to licensing provisions, stormwater harvesting may be exempt under s. 115 (2 and 4) of the Act. There are two conditions regarding the granting of a special licence:

- (2) A special licence must be granted on an application under subsection (1) if the Advisory Committee is satisfied that it would be consistent with the objectives of this Act to do so.
- (4) A special licence may also be granted for a specified purpose on application in writing by a proposed licensee where the Advisory Committee is satisfied that it would be consistent with the objectives of this Act to do so and the licence is to be subject to such conditions as the Committee may determine.

The Water and Sewerage Industry Act 2008 applies to stormwater in Tasmania. S.10 of the Act allows for exemptions:

- (1) Subject to subsections (2) and (3), the Minister may, by order, exempt a person, an activity or a class of activities from any provision of this Act subject to any conditions that the Minister determines.
- (2) The Minister may not make an order granting an exemption if it would be inconsistent with the objective of this Act to do so.

The Land Use Planning and Approvals Act 1993 permits for the development and carrying out of works. S. 60A. provides for exemptions:

- (1) If a permit for dam works, within the meaning of the *Water Management Act 1999*, is in force under that Act, a permit for those works is not required under this Act.

If stormwater is not exempt according to the *Water Management Act 1999*, the *Land Use Planning and Approvals Act* may apply for operations developing stormwater infrastructure as MAR source waters.

Decisions and exemptions must be consistent with the *Environmental Management and Pollution Control Act 1994* and the *Public Health Act 1997*.

Retention ponds or wetlands for stormwater storage may also be exempt according to s.137 of the *Water management Act*.

## Aquifer recharge and recovery

The Department of Primary Industries and Water states that a licence is not required to take water from a well unless specified by a Water Management Plan or unless the well is situated in an area of land declared as a Groundwater Area by the Minister.

(<http://www.dpiw.tas.gov.au/inter.nsf/WebPages/JMUJY-4YAAB6?open>)

A Groundwater Area is an area of land which has been appointed as a Groundwater Area by an order made by the Minister. The purpose of a Groundwater Area is to specifically define limited areas in which the groundwater resources are intensively used and to implement groundwater licensing in those areas in order to equitably and sustainably manage the resource.

As at July 2008, there are no declared Groundwater Areas in Tasmania, allowing free access to water stored in an aquifer as part of an MAR operation. Similar to Western Australia, Tasmanian water legislation also allows for the granting of temporary allocations (s.90 of the *Water Management Act* 1999). The rights to all waters in Tasmania are vested in the State. If an MAR operation relies on an aquifer located in a described groundwater area requiring a licence and allocation to extract stored water, application of a s.90 may resolve conflicts if allocations for native groundwater for a period are 0%.

## Final use of recovered water: environmental and public health compliance

The final use of recovered MAR water will depend on a suite of water quality variables. Water quality in turn is dependent on a vector of conditions including the quality of injectant, aquifer residency time, the degree of pathogen and contaminates attenuation and the efficiency of the method deployed to treat recovered water. The attendant water quality standards corresponding with the designated final use are subject to the provisions of one or more of the following Acts or Guidelines.

- i) Water quality is provided for by *the Environmental management and Pollution Control Act* 1994 and the *State Policy on Water Quality Management* 1997 under the *State Policies and Projects Act* 1993.
- ii) The Public Health Act 1997 will also apply to treatment levels and final use regulations.
- iii) The Australian Guidelines for water recycling: managing health and environmental risks: Stormwater harvesting and reuse (EPHC Draft May 2008)
- iv) The Australian Guidelines for water recycling: managing health and environmental risks: Managed aquifer recharge (EPHC Draft May 2008).



### Contact Us

Phone: 1300 363 400

+61 3 9545 2176

Email: [enquiries@csiro.au](mailto:enquiries@csiro.au)

Web: [www.csiro.au](http://www.csiro.au)

### Your CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.