Aquifer Storage and Recovery

Chapter 9

9.1 Introduction

Aquifer storage and recovery (ASR) is a means of introducing recycled water into underground aquifers (via direct injection (i.e. pumping or gravity) for subsequent extraction and reuse. It can be a low cost water storage alternative compared to surface storages and can minimise loss of water due to evaporation.

The overriding consideration for introducing recycled water to aquifers is to ensure there is no resulting deterioration of groundwater quality (EPA Qld 2004) and that the beneficial uses of an aquifer are protected. The level of treatment of recycled water prior to injection to the aquifer is dependant on the quality of the groundwater and its current uses.

Stormwater ASR systems operate by storing excess treated stormwater flows from urban catchments during wet periods and then subsequent extraction for reuse during drier periods. Urban stormwater must be treated before injection to an aquifer and in most instances, the treatment elements described in these Guidelines (configured into an appropriate 'treatment train') will provide sufficient treatment to protect an aquifer.

The viability of an ASR scheme is dependant on local hydrology, the underlying geology of an area and the presence and nature of aquifers. There is a range of aquifer types that can accommodate an ASR scheme, including fractured unconfined rock and confined sand, and gravel aquifers. In addition, it may be possible to construct an aquifer if the economics allow. Detailed geological investigations are required to establish the feasibility of any ASR scheme. This chapter provides an overview of the main elements of a system and directs readers to more specific guidance documents.

The broad requirements of ASR systems include:

- protecting or improving groundwater quality where ASR is practiced
- ensuring that the quality of recovered water is fit for its intended use
- protecting aquifers and aquitards (fractured rock) from being damaged by depletion or excessive pressure (from over-injection)
- avoiding problems such as clogging or excessive extraction of aquifer sediments
- ensuring reduced volumes of surface water downstream of the harvesting point are acceptable and consistent with a catchment management strategy and environmental flow requirements.

In addition to the broad requirements listed above, appropriate approval from Townsville City Council, the Environmental Protection Agency (EPA) and Department of Natural Resources and Mines (DNRM) may also be required to divert stormwater, install treatment measures and to inject and extract water from an aquifer. A thorough investigation of required permits should be undertaken as part of a conceptual design of an ASR system.

Where the aquifer may be used for extraction of potable water, recycled water must be of Class A+ (EPA Qld 2004). Where there is low risk of ingestion by humans, Class A standard would be appropriate. While the *Queensland Guidelines for the Safe Use of Recycled Water* (EPA Qld 2004) apply to recycled water from a number of sources (including wastewater), this chapter presents design considerations for stormwater ASR systems only.

The following information has been adapted from the *Code of Practice for Aquifer Storage and Recovery* (EPA SA 2004) with the permission of the author, to provide an overview of the main components of an ASR system.

9.2 Components of a Stormwater ASR System

An ASR scheme that harvests stormwater typically contains the following structural elements:

- a diversion structure from a stream or drain
- a control unit to stop diversions when flows are outside an acceptable range of flows or quality
- some form of treatment for stormwater prior to injection

- a constructed wetland, detention pond, dam or tank, part or all of which acts as a temporary storage measure (and which may also be used as a buffer storage during recovery and reuse)
- a spillway or overflow structure incorporated into the wetland or detention storage for flows to bypass the injection system
- well(s) into which water is injected into an aquifer (may require extraction equipment for periodic purging (with scour valve))
- an equipped well to recover water from the aquifer (injection and recovery may occur in the same well)
- a treatment system for recovered water (depending on its intended use)
- systems to monitor water levels and volumes of water injected and extracted
- systems to monitor the quality of injected water, groundwater and recovered water
- water quality sampling points on injection and recovery lines
- a control system to shut down injection in the event of unfavourable conditions.

Figure 9-1 presents a schematic of the major elements of an ASR scheme.

9.3 Aquifer Selection

Factors to consider when choosing a suitable aquifer include:

- environmental values of an aquifer (e.g. high quality groundwater may exclude the use of an aquifer for ASR)
- an aquifer may already be providing beneficial uses to others and the quality and flow requirements of these users must not be compromised
- sufficient permeability of a receiving aquifer
- if the salinity of aquifer water is greater than injection water, then the salinity concentration will influence the viability of recovering water from the aquifer
- possible damage to confining layers due to pressure increases
- adverse effects of reduced pressure on other groundwater users
- aquifer mineral dissolution, if any, and potential for well aquitard collapse.

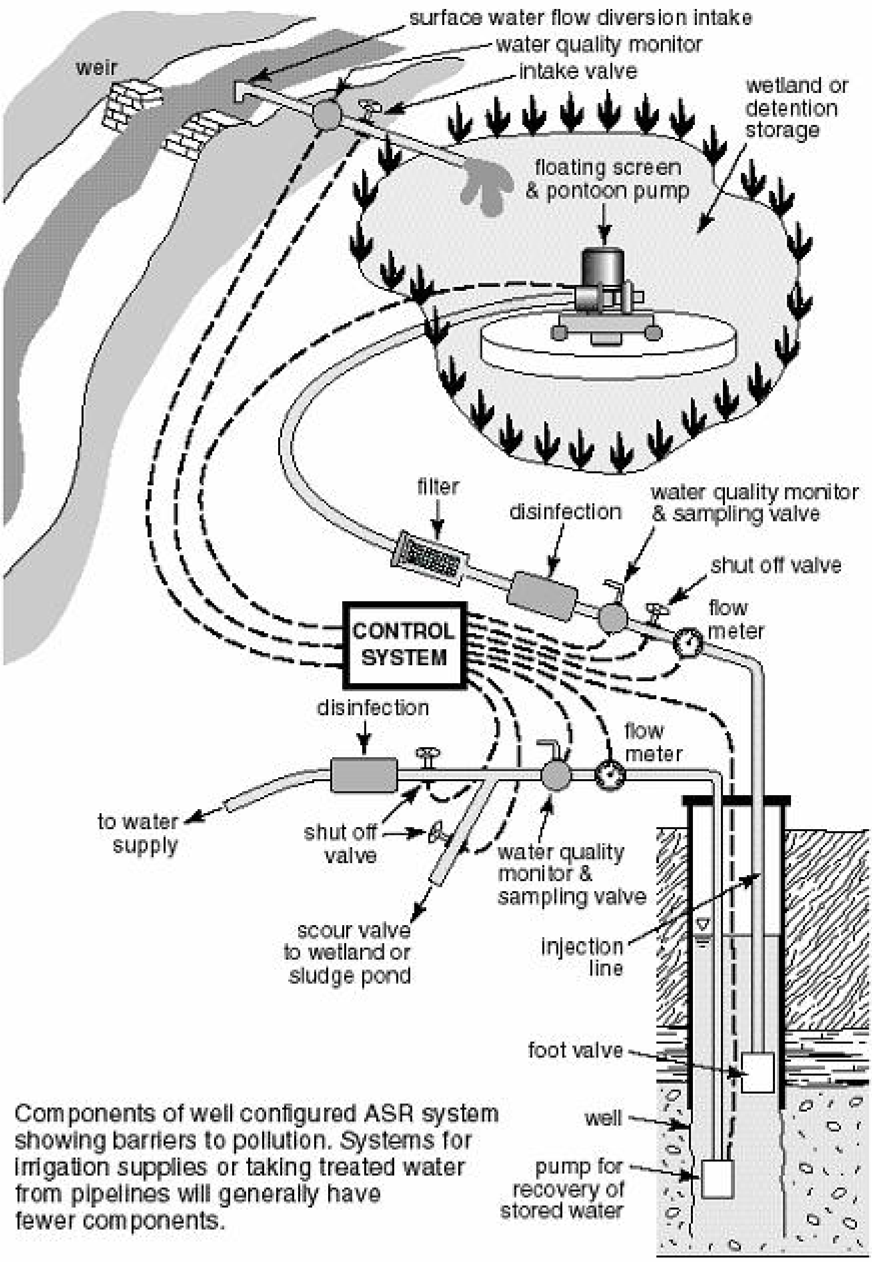

Figure 9-1: Components of a Well Configured ASR System

(Source: Dillon et al 2000 in DWLBC 2002)

9.4 Treatment and Pollution Control

For stormwater ASR systems, water quality treatment will be required prior to injection into groundwater. The level of treatment depends on the existing quality of the groundwater and the beneficial uses associated with the groundwater. In accordance with the *Environmental Protection (Water) Policy 1997*, the primary considerations when introducing stormwater to an aquifer include:

- environmental values of the aquifer for other users
- existing water quality
- cumulative effect of the proposal with other known releases to the aquifer.

The following subsections provide a brief description of the issues to be considered when assessing the treatment and pollution control requirements of a stormwater ASR scheme.

9.4.1 Quality of Water for Injection and Recovery

The quality of water that can be injected into an aquifer should be determined through assessment of designated environmental values and beneficial uses of an aquifer, and subsequent discussion with Townsville City Council and relevant referral agencies (e.g. EPA and DNRM).

Designated environmental values of aquifer water, such as raw water for drinking, non-potable use, stock water, irrigation, ecosystem support and groundwater ecology, can be determined from:

- ambient groundwater quality, with reference to the National Water Quality Management Strategy (*Australian Drinking Water Guidelines* (NHMRC & NRMMC 2004)*; Australia & New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000))
- local historical and continuing uses of those aquifers.

Once environmental values of the aquifer have been established, stormwater quality treatment requirements can be derived through discussion with the relevant local authority and relevant referral agencies (i.e. EPA and DNRM). These are intended to preserve or potentially improve existing groundwater quality.

9.4.2 Knowledge of Pollutant Sources in the Catchment Upstream

Each ASR scheme must identify potential pollution sources within a catchment and plan risk management strategies, including pollution contingency plans. For urban stormwater harvesting, treatment measures described in this manual are considered a minimum requirement.

Comparisons with native groundwater quality and its environmental values will indicate treatment requirements for water detained for injection (see Section 10.4.1). An evaluation of the pollutants that may be present within injected water needs to be carried out on a catchment basis. Pollutants will vary according to whether the catchment drains residential, industrial, rural or a combination of any of these land use types.

Concentrations of pollutants typically have seasonal or within-event patterns, and heavy pollutant loadings can be avoided by being selective in the timing of diversions (e.g. not diverting flow during large floods when treatment systems are often bypassed). Knowledge of the potential pollutant profile helps to define water quality sampling and analysis costs when determining the viability of an ASR project (for example, if there are any specific industrial activities upstream that contribute particular stormwater pollutants such as hydrocarbons).

9.4.3 Pretreatment Prior to Injection

Many of the treatment measures described in earlier chapters of these Guidelines are suitable as pretreatments for stormwater ASR schemes. In general, methods that have long detention times are advantageous to reduce pathogenic microorganisms in addition to other pollutants.

An advantage of using stormwater treatment measures with large storages (e.g. wetlands) is that they offer a dilution effect. Should an isolated pollution event occur, this dilution effect reduces the risk of aquifer contamination.

9.4.4 Injection Shutdown System

Controls need to be incorporated to shut down an injection pump or valve if any of the following exceed the criteria for the environmental values of the aquifer:

- standing water level in the well
- injection pressure
- electrical conductivity (salinity)
- turbidity
- temperature
- pH

- dissolved oxygen concentrations
- volatile organics
- other pollutants likely to be present in injectant water that can be monitored in real time.

9.4.5 Maintenance and Contingency Plans

Protection of treatment and detention systems from contamination is a necessary part of designing an ASR system. This includes constructing treatment systems away from flood prone land, taking care with or avoiding the use of herbicides and pesticides within the surrounding catchment, planting non-deciduous vegetation, and preventing mosquitoes and other pests breeding in storage ponds.

Contingency plans should be developed to cater for the possibility of contaminated water being inadvertently injected into an aquifer. These include how to determine the duration of recovery pumping required (to extract contaminated water), sampling intervals required and how to manage recovered water.

9.4.6 Recovered Water Post-Treatment

Where recovered water is intended for drinking water supplies, further treatment standards (e.g. using ultraviolet disinfection) will be required to meet drinking water standards. For other forms of supply, such as irrigation via drippers, it may be necessary to insert a cartridge filter in the supply line to remove fine suspended solids. The extent of further treatment will depend on the intended end use and a fit-for-purpose approach should be adopted in accordance with EPA Queensland (2004).

9.4.7 Construction of Injection Wells

During and following construction, injection/ extraction wells must be purged for a sufficient period to remove poor quality water that may have been caused by the construction process. This water is usually high in fine sediment and will be unsuitable for disposal to a surface water body or a watercourse. It may potentially be used on site for irrigation, discharged to sewer (with the approval of the relevant authority), or returned to a treatment system.

9.4.8 Groundwater Attenuation Zones

In some cases, the impact of certain ground water pollutants can be diminished over time because of natural processes within an aquifer. Chemical, physical and microbiological processes can occur to ameliorate the harm or potential harm caused by these pollutants.

9.5 Domestic Scale ASR

It is possible to install a stormwater ASR scheme at domestic scale. Generally, they are subject to the same considerations as larger scale design, however being smaller systems, they are likely to be shallower and therefore a number of additional design constraints exist.

Domestic scale ASR in shallow aquifers must not be undertaken in locations where the following apply:

- water tables are shallow (less than 5 m)
- saline groundwater ingress to sewers occurs
- water tables could rise to within 5 m of the soil surface as a result of ASR in areas of expansive clay soils
- other structures such as cellars or basements could be adversely impacted by rising water tables
- dryland salinity is an issue in the local catchment.

Water recharged must be of the highest possible quality, equivalent to roof runoff after first flush bypass, such as overflow from a rainwater tank, and must be filtered to prevent entry of particulate organics (i.e. leaves) and other gross pollutants. Runoff from paved areas must not be admitted unless it has first passed through a treatment measure (as described in previous chapters) to reach the required quality for injection.

An inventory should be made of other potential pollutants in the injection well catchment and strategies devised to ensure these are excluded, or are treated and removed before water enters the well.

Aquifer pressure must at all times be below ground level. To achieve this, injection should be by gravity drainage, rather than by using a pressurised injection system, and there should be an overflow facility (e.g. to a garden area or to a stormwater drainage system) where excess water discharges to.

9.6 Additional Information

This chapter provides a brief introduction into ASR and the considerations required to assess feasibility. Considerably more investigations and consultation are required to determine the functional details of a possible ASR system.

There are some Australian guidelines available for ASR systems (particularly from South Australia where there is considerable experience with these systems). Some relevant guides and websites for further information are listed below.

EPA SA (Environment Protection Authority South Australia) 2004, *Code of Practice for Aquifer Storage and Recovery,* EPA SA, http://www.epa.sa.gov.au/xstd_files/Water/Code%20of%20practice/cop_aquifer.pdf

Dillon PJ & Pavelic P 1996, Guidelines on the quality of stormwater and treated wastewater for injection into aquifers for storage and reuse, Research Report No 109, Urban Water Research Association of Australia.

Aquifer Storage Recovery: http://www.asrforum.com/

International Association of Hydrogeologists — Managing Aquifer Recharge (IAH–MAR): www.iah.org/recharge/

Department of Natural Resources and Mines (regarding water quality, quantity and licensing requirements): www.nrm.qld.gov.au

9.7 References

ANZECC & ARMCANZ (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand) 2000, *Australia & New Zealand Guidelines for Fresh and Marine Water Quality*, ANZECC & ARMCANZ, ACT

DWLBC (Department of Water, Land and Biodiversity Conservation – CSIRO Land and Water) 2002, *Aquifer Storage and Recovery: Future Directions for South Australia*, prepared by Russell Martin (DWLBC) and Peter Dillon (CSIRO) for DWLBC, SA

EPA Qld (Environmental Protection Agency Queensland) 2004, Queensland Guidelines for the Safe Use of Recycled Water - Public Consultation Draft, EPA Qld

EPA SA (South Australia) 2004, *Code of Practice for Aquifer Storage and Recovery*, EPA SA, http://www.epa.sa.gov.au/xstd_files/Water/Code%20of%20practice/cop_aquifer.pdf

Dillon PJ & Pavelic P 1996, Guidelines on the quality of stormwater and treated wastewater for injection into aquifers for storage and reuse, Research Report No 109, Urban Water Research Association of Australia, SA

NHMRC & NRMMC (National Health and Medical Research Council & Natural Resource Management Ministerial Council) 2004, *Australian Drinking Water Guidelines 2004*, NHMRC & NRMMC,