E N V I R O N M E N T   P R O T E C T I O N   A U T H O R I T Y

Code of Practice for

Aquifer Storage and Recovery

Government of South Australia

EPA South Australia

WaterCare It's in your hands

Code of Practice for

Aquifer storage and recovery

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Cover photos: ASR pipe (Dept. Water, Land and Biodiversity Conservation)
City of Salisbury greenfields (City of Salisbury)

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DEFINITION OF TERMS

aquifer	a rock or sediment in a geological formation, group of formations or part of a formation which is capable of being permeated permanently or intermittently and can thereby transmit water
aquitard	a layer in the geological profile which separates two aquifers and restricts the flow between them
artesian	an aquifer in which the water surface is bounded by an impervious rock formation—the water is held under sufficient hydrostatic pressure that it rises to the surface in any well or borehole which penetrates the overlying confining layer
aquifer storage and recovery (ASR)	the process of recharging water into an aquifer for the purpose of storage and subsequent withdrawal
artificial recharge	the process of artificially diverting water from the surface to an aquifer
contamination	the condition of land or water where any chemical substance or waste has been added at above background level and represents, or potentially represents, an adverse health or environmental impact
coliform	several types of aqueous bacteria; a characteristic of faecal pollution from warm-blooded animals; can indicate sewage pollution of waters
confining layer	a rock unit impervious to water, which forms the upper bound of a confined aquifer; a body of impermeable material adjacent to an aquifer
disinfection	elimination of pathogenic organisms from water, usually achieved by chlorination, UV exposure, etc.
environmental values	particular values or uses of the environment that are conducive to a healthy ecosystem and also provide public benefit, welfare, safety and health, e.g. aquatic ecosystem, drinking water, recreation and aesthetics, agriculture, aquaculture and industrial—often called 'beneficial uses'
filtration	numerous methods of filtering a water sample or supply to remove suspended sediment and the larger animal and plant life
groundwater (also underground water)	water occurring naturally, or stored, below ground level
injection well	artificial recharge well through which water is pumped or gravity fed into the ground
pathogens	disease-causing micro-organisms, many of which are aquatic
pollutant	any solid, liquid or gas (or combination thereof) including waste, smoke, dust, fumes and odour, heat or anything declared by regulation to be a pollutant (see Schedule 4, Water Quality Policy)
pretreatment	any treatment (e.g. detention, filtration) to alter the quality of water prior to recharge

screen	the part of a well consisting of a slotted well casing or wire-wound tubular frame which permits the flow of groundwater to the well whilst maintaining the integrity of the well
stormwater	rain or melted precipitation that runs off land or structures on land

1 PURPOSE OF THIS CODE OF PRACTICE

The *Code of Practice for Aquifer Storage and Recovery* (ASR Code) is for aquifer storage and recovery (ASR) only and is not intended for the disposal of stormwater without pre-treatment, monitoring and recovery.

ASR is the storage of water in a well during times when water is available, and recovery of the same water from a well during times when it is needed.

The ASR Code outlines the requirements of the Environment Protection Authority (EPA) for the storage and recovery of waters in aquifers. By following these requirements, the operator should be able to comply with the *Environment Protection Act 1993* (the Act) and the *Environment Protection (Water Quality) Policy 2003* (Water Quality Policy).

The Act, the Water Quality Policy and this Code are primarily concerned with the protection of the environment, rather than the technical issues concerning ASR or any requirements under other legislation. Regulation of ASR under both the Environment Protection Act and the *Water Resources Act 1997*, including conditions of licence, are not considered in this Code.

The requirements outlined in this document aim to:

- protect or improve groundwater quality where ASR is practiced
- ensure that the quality of recovered water is fit for its intended use
- protect the aquifer and aquitard from being damaged by depletion or over-pressurisation
- prevent problems such as clogging and excessive recovery of aquifer material
- ensure that the impacts on surface waters downstream are acceptable and are taken into account in catchment water management.

Disposal of all waters underground must comply with the Water Quality Policy.

The ASR Code does not apply to injection of wastewater—for example, water from a municipal wastewater treatment plant such as a sewage treatment works or a septic tank effluent disposal (STED) system.

The Code is intended for use by proponents of artificial recharge schemes, consultants, catchment water management boards and councils. It covers a complex subject; although it is intended to be a practical guide, it cannot cover all the situations that may need to be considered at a specific site, and proponents are encouraged to seek professional advice.

Throughout the ASR Code, the use of the words 'must' or 'must not' indicates requirements that need to be followed in order to comply with the Act and the Water Quality Policy. Failure to comply may result in prosecution. Use of the words 'should' or 'should not' indicates advisory information. If followed, this advice ought to lead to a satisfactory outcome, but there may be other ways which have not been specified that would be just as acceptable in achieving the required outcome.

The ASR Code is aimed at protecting the quality of groundwater and associated environmental values, including dependent ecosystems. The broader environmental, social and economic benefits of an ASR scheme are not covered but will be taken into account during the licence application process. The EPA recognises that ASR has significant environmental outcomes in terms of relieving pressure on other water sources (e.g. the River Murray) and sensitive receiving waters. Further, ASR provides South Australia with economic and social benefits.

2 LEGISLATION

The operation of an ASR scheme is subject to the Environment Protection Act, which is concerned with the quality of water stored and recovered. Section 25 of the Act imposes the general environmental duty on all persons undertaking an activity that pollutes to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

In the city of Mount Gambier and in the Adelaide metropolitan area, ASR is a prescribed activity of environmental significance (Schedule 1, 4(2) of the Act) for discharge of stormwater from areas greater than 1 ha to aquifers, and requires licensing by the EPA.

Mt Gambier

In the City of Mount Gambier, the discharge of stormwater by a well or other direct means to the underground aquifer is licensed for a catchment area exceeding 1 ha in size where the stormwater drains to the aquifer from:

- land or premises in the City of Mount Gambier or the Western Industrial Zone of the area of the District Council of Mount Gambier (as defined by the relevant development plan under the *Development Act 1993)*, being land on which a business is conducted; or
- a stormwater drainage system in the City of Mount Gambier or the Western Industrial Zone in the area of the District Council of Mount Gambier (as defined in the relevant development plan under the Development Act).

Licences are issued to discharge stormwater to the aquifer; there is no provision in these licences to extract the water. The prescribed activity is only the discharge of stormwater, not ASR.

The EPA may issue an authorisation in the form of a licence to operate an ASR scheme once development approval has been granted from the local planning authority. Under section 47(2) of the Environment Protection Act, the EPA must grant an authorisation if development approval has been given. Under the referral system in the Development Act, the EPA may direct that the development be refused if it is not satisfied with the environmental impact. To be granted a licence the proponent will need to demonstrate effective ASR operational skills and that the ASR proposal will not cause environmental harm. When the EPA is satisfied that the proposal will allow compliance with the Act, it may grant a licence, to which will be attached operational and reporting conditions.

Operators of an ASR scheme would also need to comply with the mandatory requirements of the Water Quality Policy and the *Water Resources Act 1997*.

Many ASR schemes will not need a licence. To obtain an EPA licence for this activity, the proponent must also obtain a well construction permit from the Department of Water, Land and Biodiversity Conservation (DWLBC) for any proposed wells that will intersect the water table. If groundwater is to be extracted from the aquifer, the proponent must also obtain a licence from DWLBC to extract water. Further information on obtaining these licences/permits should be sought from the DWLBC Water Permit Officer (tel. 8463 6854).

DWLBC licenses the discharge of stormwater to underground aquifers wherever an EPA licence is NOT required under the Act.

3 AVAILABILITY OF SUITABLE SURFACE WATER

The proponent must identify potential pollution sources upstream, and plan risk management strategies, including pollution contingency plans.

Whenever surface water quality is contaminated (such as the first autumn flush in urban catchments) it should be prevented from entering the detention storage.

Comparisons with native groundwater quality and its environmental values will indicate the requirements for treatment of water detained for injection.

3.1 Components of an ASR system

An ASR scheme harvesting stormwater may contain the following structural elements (also see Figure 1):

- a diversion structure from a stream or drain
- a control unit to stop diversion of flow when it is outside the acceptable range of flows or quality
- a wetland, detention pond, dam or tank (which may also be used as a buffer storage during recovery and reuse)
- a spill structure incorporated in wetland or detention storage
- some form of water treatment prior to injection
- well(s) into which the water is injected (may require extraction equipment for periodic purging)—the injection well design may be different from conventional water supply wells, especially in unconsolidated media
- a valve or anti-cavitation device on the injection line
- an equipped well to recover water from the aquifer (injection and recovery may occur in the same well)—a dual purpose injection–recovery well will require the pump to be protected from reverse flows
- a treatment system for recovered water
- systems to monitor the standing water level, and the volumes injected and extracted
- systems to monitor the quality of injectant, groundwater and recovered water
- sampling ports on injection and recovery lines
- a control system to shut down recharge in the event of unfavourable conditions
- provision for the discharge of water purged from the injection well(s).

The area required for ASR project infrastructure will depend on detention storage requirements. Shelter and power will be required for the monitoring units, and if possible these should be located together at a control centre for the operation. Siting should avoid flood-prone land.

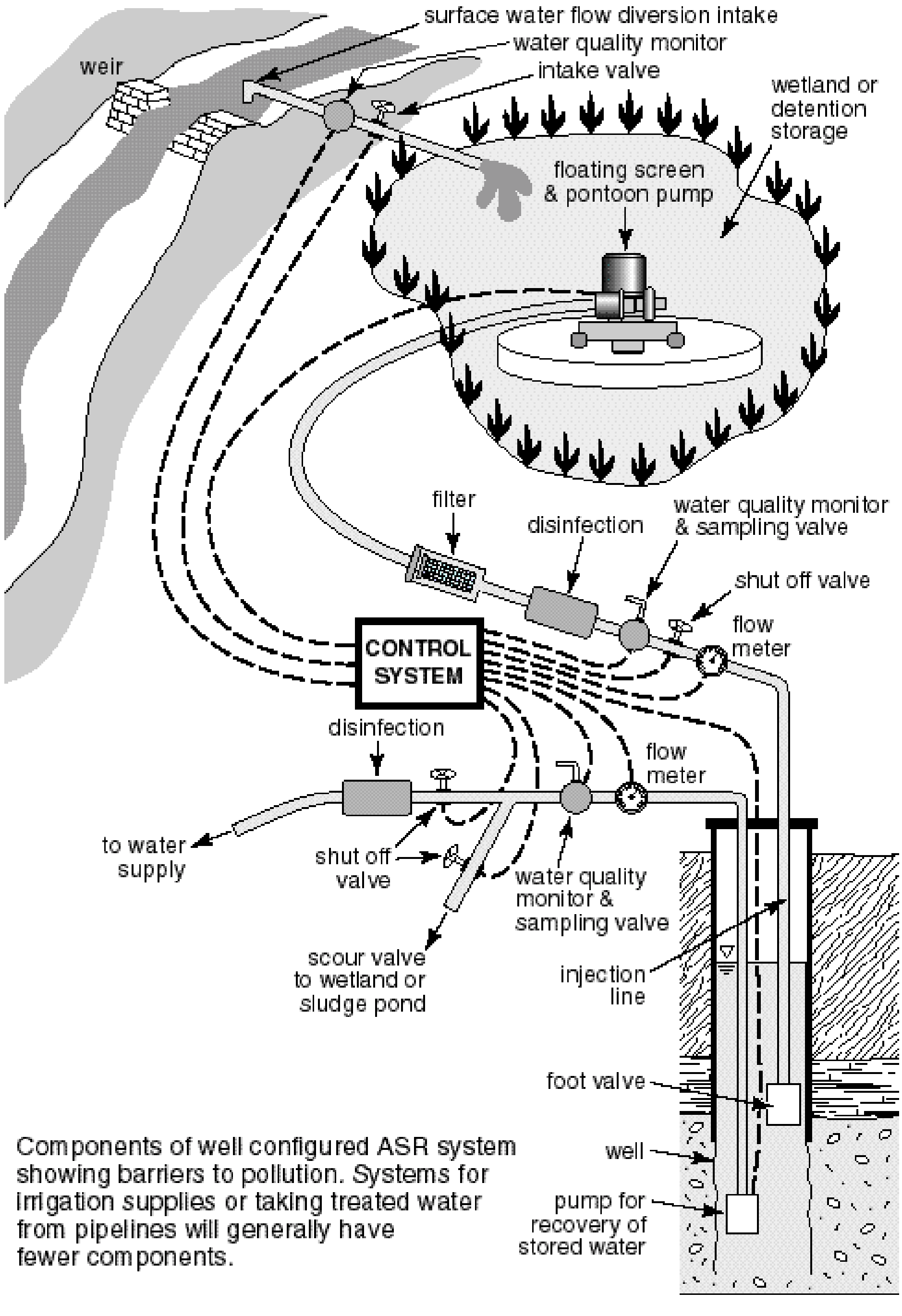

Figure 1 Components of a well-configured ASR system (diagram CSIRO Land & Water)

4 BARRIERS AGAINST POLLUTION AND DAMAGE

Operators of an ASR project must use multiple barriers to reduce the risk of contamination of groundwater supplies (see Figure 2).

Monitoring in itself is not a barrier to pollution and damage, but is an indicator of the success of the barriers described below. It is an essential part of every ASR project. Injectant and recovered water needs to be sampled and analysed according to agreed water quality criteria, and other performance indicators important for the project should be monitored and reported. For example, where passive treatment of pathogens within the aquifer is relied upon, additional monitoring of groundwater may be required.

Increasing the number of barriers incorporated into an ASR scheme increases confidence that the aquifer is protected and that the extracted water is suitable for the intended use. Best management practice should be demonstrated, with all feasible and relevant barriers used to assure groundwater protection is achieved. Use of these barriers has the added benefit of reducing the risk of 'clogging' the ASR injection well.

A well operated and managed system must have many, if not all, barriers described below.

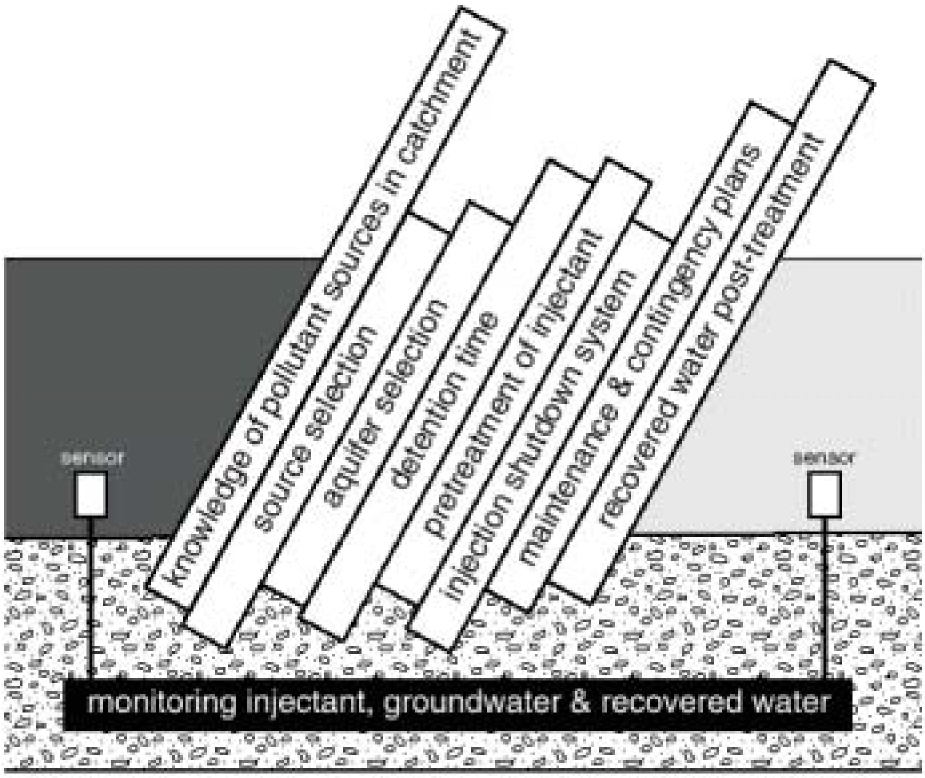

Figure 2 Multiple barriers to protect groundwater and recovered water at ASR projects (diagram CSIRO Land & Water)

4.1 Knowledge of pollutant sources in the catchment upstream

An evaluation of the pollutants that may be present within the injectant water needs to be carried out on a catchment basis. The potential pollutants will vary according to whether the catchment drains urban residential, urban industrial, rural or a combination of any of these catchment types.

The 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. Knowledge of the potential pollutants helps to define water quality sampling and analysis costs when determining the viability of the ASR project.

4.2 Source selection

If artificial recharge is proposed to augment drinking water supplies, it should be possible to divert runoff from polluted surfaces away from the project, or to collect runoff only from roofs in order to obtain the quality of water required for injection.

4.3 Aquifer selection

The Water Quality Policy requires that the quality of water to be injected must be no worse than the quality of water already in the aquifer, and better if possible. This may exclude the use of aquifers containing high quality groundwater for ASR schemes. Other users of the aquifer need to be considered in aquifer selection.

4.4 Passive treatment

A detention pond reduces variability in water quality and therefore mitigates the effects of isolated pollution events in the catchment. Detention storage also allows time to shut down injection if pollution of the surface water source occurs before the diversion to the pond can be closed.

4.5 Management or release of unwanted water

Plans also should be considered for the management or release of unwanted water in the detention storage.

If water is received directly from a pipeline or main, it is preferable not to involve a detention storage as this simply allows opportunities for algal and bacterial contamination.

4.6 Other pretreatments

Screens should be used to sieve out leaf litter, gross pollutants and aquatic life, and prevent these reaching the filter or the injection well. Generally these will be floating screens that also exclude any surface scums from the intake (e.g. from hydrocarbons and pollens) reaching the injection well.

Swimming pool filters, such as recirculating sand filters with backwash facilities, cartridge filters, and diatomaceous earth filters, are relatively cheap and can help reduce concentrations of suspended sediments in injectant water. While these filters will not affect dissolved solutes, they may reduce the frequency of back-flushing of the injection well to economic advantage, especially for turbid source waters and fine-grained aquifers. Simple disinfection systems are also available, including ultraviolet and electrode chlorination systems, which can reduce pathogenic bacteria in injectant water and may reduce the growth of bacterial slimes within the injection well. However, no free chlorine or disinfection products containing chlorine are to be recharged or introduced to the aquifer.

4.7 Injection shutdown system

Controllers should be incorporated to shut down the 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, and other pollutants likely to be present in injectant water that can be monitored in real time.

Use of this technology demonstrates best management practice. The cost of remedial activities for a single pollution event may significantly exceed the cost of control equipment.

4.8 Maintenance and contingency plans

Protection of the surface water pond from contamination will be necessary. This includes constructing the pond away from flood-prone land, taking care with or avoiding the use of herbicides and pesticides, planting non-deciduous vegetation, and preventing mosquitoes and other pests breeding in the detention pond.

Monitoring equipment should be recalibrated at manufacturer-specified intervals. Pumps and pretreatment equipment need to be maintained, e.g. by replacing filter media at manufacturer-specified intervals or volumes. Keeping records of maintenance is part of good management practice.

Contingency plans are required in the event of contaminated water being inadvertently injected. This would include consideration of how to determine the duration of recovery pumping, what sampling intervals are needed and what to do with recovered water.

4.9 Recovered water post-treatment

For drinking water supplies, recovered water may need to be treated, e.g. using ultraviolet disinfection. For some other forms of supply, such as irrigation via drippers, it may be necessary to insert a cartridge filter. Commissioning tests on the operation will indicate if these are necessary.

4.10 Discharge of well development/redevelopment water

This water must not be disposed of to a water body or a watercourse unless it is of suitable quality. It may be used on site, possibly for irrigation, discharged to the sewer (with the approval of the relevant authority), or returned to the wetland.

4.11 Pond sediments

Ponds should be properly constructed and maintained to prevent leaching of pollutants to groundwater—refer to the EPA Guideline *Wastewater Lagoon Construction*. It is an offence under the Water Quality Policy to allow polluted water to intercept the underlying water table. Pond banks should be vegetated to reduce re-suspension of colloids due to wave action. The active storage range should be restricted to reduce the opportunity for cracking of clay liners and to help maintain vegetation cover.

Detention time allows uptake of nutrients by algae, and settling of the larger suspended sediments and any attached heavy metals. Heavy metal reductions of more than 70% are commonly recorded in typical urban wetlands. The figure depends on detention time, sediment sizes and the degree to which the banks of the pond are protected (by reeds) from wave action and re-suspension of clays. Design guidelines for stormwater pollution control ponds and wetlands are available (Lawrence & Breen 1998).

5 QUALITY OF WATER FOR INJECTION AND RECOVERY

The selection of a storage aquifer and the quality of water that can be injected into it will be determined by the Water Quality Policy.

Designated environmental values of the recovered water, such as raw water for drinking, stock water, irrigation, ecosystem support and groundwater ecology are determined from:

- ambient groundwater quality, with reference to the National Water Quality Management Strategy (Australian Drinking Water Guidelines 1996, NHMRC & ARMCANZ; Australia & New Zealand Guidelines for Fresh and Marine Water Quality 2000, ANZECC & ARMCANZ), which specify guideline values for water quality parameters for various environmental values, and have been adopted as designated values contained in the Water Quality Policy
- local historical and continuing uses of those aquifers, where these differ from national and state guidelines; these should be taken into account at the catchment level through appropriate public consultation, most likely coordinated by catchment water management boards for aquifers within their stewardship (Guidelines for Groundwater Protection 1995, ARMCANZ & ANZECC).

Artificial recharge should improve or at least maintain groundwater quality.

5.1 Groundwater attenuation zones

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

Attenuation zones can apply in a similar way to that in which mixing zones apply to surface waters. Water quality objectives do not need to be met within the defined attenuation zone but would apply outside the attenuation zone. Clause 15 of the Water Quality Policy places certain restrictions on the EPA when granting an attenuation zone—for example, if the zone’s operation is unsustainable (Clause 15(2)(d)(I)).

5.2 Aquifer selection criteria

Factors to consider when choosing a suitable aquifer include:

- the environmental values of the aquifer
- sufficient permeability of the receiving aquifer
- salinity of aquifer water greater than injection water
- possible damage to confining layers due to pressure increases
- the adverse effects of reduced pressure on other groundwater users
- the higher recovery efficiencies of porous media aquifers
- the benefits of re-pressurisation of over-exploited aquifers
- the impacts on other aquifer users
- aquifer mineral dissolution, if any, and potential for well aquitard collapse.

6 MONITORING NEEDS

Monitoring is necessary to provide assurance that groundwater quality is protected and that the recovered water is fit for its intended use, and to initiate contingency measures if 'failures' occur. Monitoring is also necessary to ensure that the system performs as intended, that volumes of recharge and recovery are known and that the injection pressures are acceptable. The effort needed for water quality monitoring will depend on the consequences and risks of contamination, which will depend on the barriers that have been established. Signals from equipment monitoring the quality of surface water both upstream of the intake to the detention storage and in the injection pipe can be used to shut down and prevent access of contaminated water into the pond and well. However, the range of parameters which can be monitored in real time is still only small (e.g. electrical conductivity (salinity), turbidity, temperature, pH and dissolved oxygen, as well as pressure and flow).

For other pollutants, e.g. pesticides, pathogenic organisms or metals, it may be several weeks before laboratory analyses are available. This information can nevertheless be of value in demonstrating that the existing barriers are adequate, or determining whether further barriers such as additional pre-treatment are needed. The nature of those pollutants and their concentrations will determine whether some form of recovery or remedial action is required. If the time (or volume) interval between samples is sufficiently small, occasional high readings may be tolerated, as there may be sufficient information to limit the unknown mass of introduced pollutant to values smaller than those which would require aquifer decontamination procedures (e.g. pump and treat).

In accordance with best management practice, regular monitoring will be the responsibility of the proponent. As a guide, it is recommended that proponents of all projects which recharge more than 20 ML/year should install at least one continuous monitoring device (which controls a cutoff valve) for any variable which can be correlated with pollutant sources. For example, in harnessing urban stormwater the monitored variable may be turbidity, which has been found to be strongly correlated with metal and nutrient concentrations. In some rural catchments where surface flows can reach high salinities (which may be unacceptable for recharge), proponents should also monitor salinity as a control variable.

The EPA may grant an exemption from water quality criteria for the discharge of waste into underground waters (Clause 15 of Water Quality Policy) if monitoring can show that the concentration of pollutants is reduced by physico-chemical and microbiological processes (an 'attenuation zone').

It is strongly recommended that a monitoring program be designed and interpreted by a suitably qualified professional hydrogeologist, with the goal of protecting the environment.

7 ECONOMIC FACTORS

It is important that privately owned ASR operations be economically viable so that the proponent has an ongoing commitment to maintaining the protective barriers and monitoring their effectiveness, and to maximising the overall performance of the project. Routine maintenance is needed to avoid the potentially large costs of bore clogging, equipment failure or recovery of polluted water. 'Trading off' treatment costs against the possibly higher costs of well redevelopment or pollution invariably favours higher treatment options.

The following diagram represents the decisions that need to be made to improve injectant water quality, and which impact on the economic feasibility of ASR.

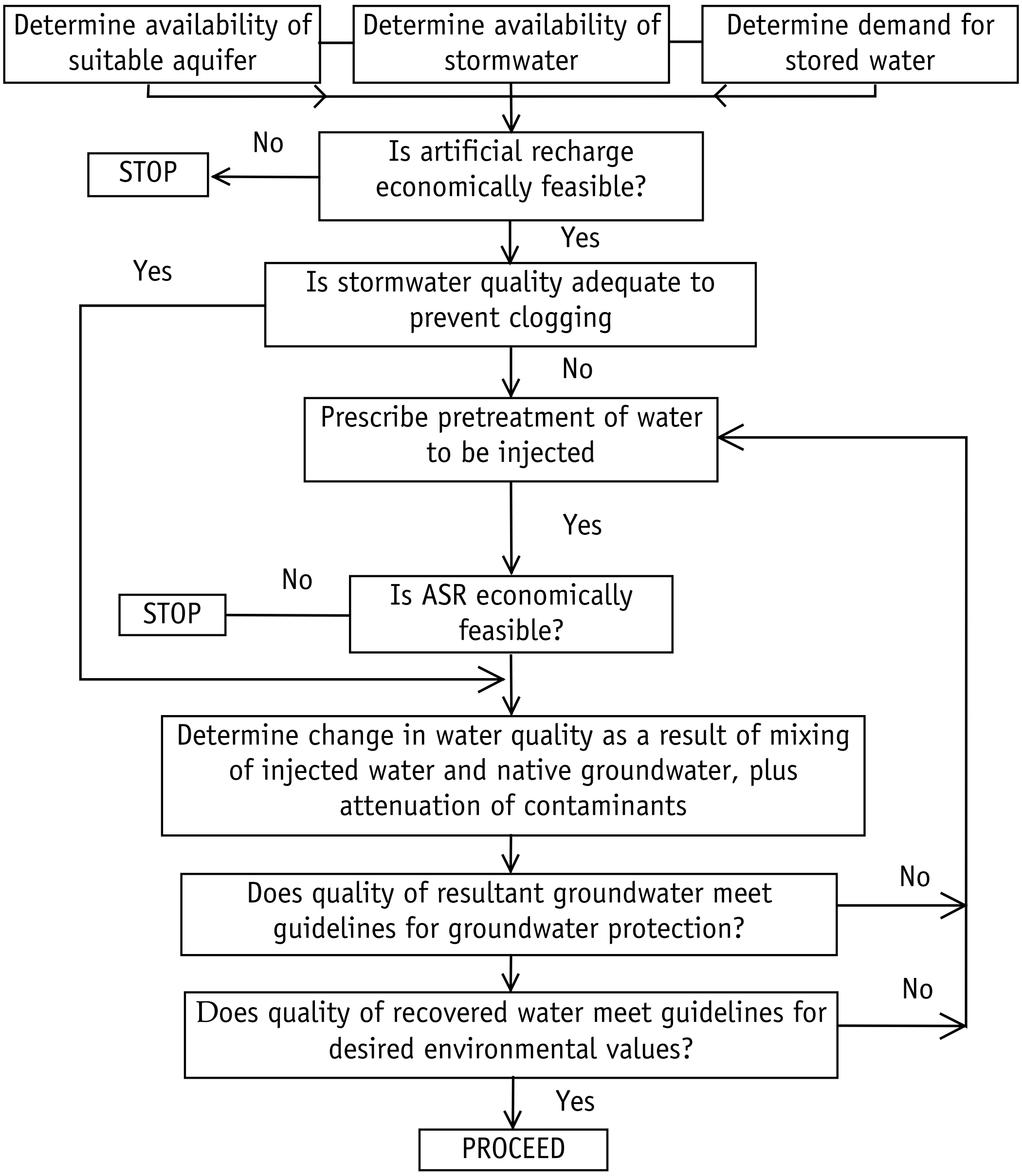

Figure 3 Economics of ASR in relation to sustainability (from Dillon & Pavelic 1996)

8 DOMESTIC SCALE ASR

Domestic scale ASR schemes are subject to the same obligations to comply with the Water Quality Policy as commercial schemes. These include the obligation to protect the environmental values of our groundwater as outlined in the Water Quality Policy; non-compliance could result in the issuing of a fine or an Environment Protection Order.

Rising groundwater levels could cause: flooding of cellars; increased saline groundwater ingress to sewers; salt damp; differential movement of footings and cracking of houses; dryland salinity and death of salt- and water-sensitive vegetation; damage to pavements and roads; and submergence of underground utility services. Conversely, declining water levels due to an imbalance between recharge and extraction could affect differential settlement of footings, reduce or stop baseflows in urban streams, reduce yields of wells and, in coastal areas, induce salinisation. Furthermore, ASR increases opportunities for pollution of the shallow aquifer and the potential for human contact with polluted groundwater.

Given that there are limitations on the investment in failsafe control systems to prevent these potentially significant problems, it is necessary to have a guide for ASR in shallow systems that is practical and robust. Good design can reduce the amount of management ASR well owners will need to exert, but good management cannot be eliminated entirely, and all proponents of ASR wells should be aware of their ongoing responsibilities if ASR is to produce benefits with no adverse side effects.

The EPA does not support single dwelling ASR.

8.1 Principles and practices that will lead to sustainable operations

It is recommended that domestic scale ASR in shallow aquifers not be undertaken in locations where water tables are already shallow (less than 5 m) or in areas where:

- 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.

The 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 leaves, pine needles and other gross pollutants into the well.

Runoff from paved areas must not be admitted, unless this has first passed through a sand filter. (This will also help to avert clogging of the well.) If cars or motorbikes or other machinery containing petrol, diesel, oil or other hydrocarbons are parked on a paved area which is part of the well's catchment, an oil-grease trap must be used in addition to a sand filter.

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

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

At least the uppermost 2 m on the outside of the well casing must be cement grouted to prevent upward leakage outside the casing and waterlogging in the vicinity of the well.

The ASR scheme should record water entering the well and water extracted from the well, with a view to keeping these approximately in balance. Ideally, two water meters should be used, and annual records of recharge and discharge maintained.

In areas where groundwater levels are deep or declining, there may be a requirement to ensure that groundwater recharge exceeds extraction over a given period of several years.

Where native groundwater is saline, care will be needed that the salinity of recovered water is acceptable for irrigating salt-tolerant species, especially towards the end of summer. During the first few years of operation, withdrawal should be less than recharge to improve the salinity of subsequently recovered water.

The well should have provision for groundwater level measurements, such as a tube within the well through which a water level monitoring probe can pass. The owner should have access to a water level monitoring probe and an electrical conductivity meter, and hands-on training in how to use these.

Water level and salinity should be recorded at least every six months, at the end of the wet and dry seasons. Without water injection and extraction flow meters, there should be at least an additional two water level measurements recorded, in December/January and June/July annually.

If water tables rise or fall by more than 2 m at the same time of year over a course of five years (when neither recharge nor discharge is occurring), meters should be installed, and bore owners should aim to increase either net discharge or net recharge so as to re-establish a local groundwater balance.

The well needs to have a permanently equipped pump which can be activated intermittently in winter to purge suspended solids that accumulate in the well during injection. This water should be discharged to lawns or gardens and may be allowed to enter the stormwater system (the Water Quality Policy will apply).

When a property containing an ASR well is sold, the new owner should be alerted to the management requirements. If they are unwilling to adopt these requirements, the well should be locked or backfilled with bentonite pellets or concrete by an appropriately qualified contractor, the State Government's well-licensing group notified, and stormwater diverted.

When several neighbours combine to establish a single ASR well, a legal agreement needs to set out the obligations for each of the parties, covering the costs of maintenance of the well, supply of stormwater and maintenance of the well catchment, ownership of recovered water, keeping of records and the consequences of changes in ownership of any of the properties.

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Aquifer Storage Recovery
www.asrforum.com

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

CSIRO water reclamation project in Australia
www.clw.csiro.au/research/catchment/reclamation/

Environment Protection and Heritage Council (EPHC)
www.ephc.gov.au/index.html

Environment Protection Authority
www.epa.sa.gov.au/

Department of Water, Land and Biodiversity Conservation
www.dwlbc.sa.gov.au