Strategic Advice on Managed Aquifer Recharge using Treated Wastewater on the Swan Coastal Plain

Section 16(e) report and recommendations of the Environmental Protection Authority

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Executive Summary

Introduction

The Environmental Protection Authority (EPA) has been requested by the Minister for the Environment to provide advice under section 16(e) of the *Environmental Protection Act 1986* on managed aquifer recharge (MAR) using treated wastewater on the Swan Coastal Plain.

The EPA released a Discussion Paper on this topic for 12 weeks public comment on 4 April 2005 and held six forums around the Perth metropolitan area. This allowed the EPA to obtain feedback on the issues raised in the Discussion Paper, and to consider public and government agency comments in the formulation of its advice. The EPA subsequently released draft section 16(e) advice in July 2005 for a 4 week public comment period. Following consideration of the contributions arising from this consultation process, this report provides the final section 16(e) advice requested by the Minister.

Advice

MAR is the infiltration or injection of water into an aquifer. This advice considers only MAR using treated wastewater for the Swan Coastal Plain. The EPA notes that MAR is increasingly being used as a means of water management both within Australia, and around the world.

The EPA supports in principle the concept of wastewater reuse, and recognises the potential for MAR using treated wastewater to play an important role in the sustainable management of Western Australia's water resources. This is particularly the case given the reduction in rainfall which has occurred in the south west of the State since the mid 1970s, and the large reliance on groundwater resources. There are a number of potential environmental, health and social issues associated with MAR, and these will need to be addressed prior to the implementation of any significant MAR scheme.

The use of MAR has the potential to provide benefits for water resources and environmental management. These include maintenance of wetlands and caves, reduced salt water intrusion, increased water availability for irrigation use, and augmentation of drinking water supplies. The EPA recognises that it will not be possible to implement MAR using treated wastewater without some degree of risk. These risks should be assessed against the potential environmental and sustainability benefits of MAR schemes, and the risks associated with taking no action. The EPA expects that in a number of situations, the risks associated with MAR can be managed to negligible or low levels to provide, on balance, a number of benefits for water resources and environmental management.

The EPA supports further investigation of MAR on the Swan Coastal Plain, while advocating a precautionary approach to ensure that the environment and public health are protected. A staged approach is recommended, starting with trials and projects of low risk. Given the lack of experience with MAR on the Swan Coastal Plain to date, and the site-specific nature of transport and attenuation of contaminants, the EPA expects that trials will be necessary prior to the implementation of any large scale MAR scheme. Proponents of MAR schemes will be required to undertake a systematic risk assessment of their proposal.

Any MAR proposal that is likely, if implemented, to have a significant effect on the environment must be referred to the EPA under section 38 of the *Environmental Protection Act 1986*. The EPA expects that any large scale MAR 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. In line with Department of Environment and Department of Health advice, the EPA considers that trials should be conducted outside of Public Drinking Water Source Areas before any large scale proposal for use of MAR to augment drinking water supplies is developed. MAR proposals require Department of Health approval under the *Health Act 1911*.

Recommendations

The EPA submits the following recommendations to the Minister for the Environment:

- that the Minister notes that this advice addresses managed aquifer recharge (MAR) using treated wastewater on the Swan Coastal Plain;
- that the Minister considers the report on the relevant factors as set out in Section 4;
- that the Minister notes that the EPA supports in principle the concept of wastewater use and supports the investigation of MAR using treated wastewater as a means of water management on the Swan Coastal Plain. The EPA has provided a strategic framework in which the concept of MAR on the Swan Coastal Plain can be considered further.

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1. Introduction

The Environmental Protection Authority (EPA) has been requested by the Minister for the Environment to provide advice under section 16(e) of the *Environmental Protection Act 1986* regarding managed aquifer recharge (MAR) using treated wastewater on the Swan Coastal Plain. The Minister requested that this advice provide the guiding principles and advice of the EPA in order to provide a strategic framework within which the concept of MAR on the Swan Coastal Plain can be considered further.

As a first stage in providing this advice, the EPA released a Discussion Paper in April 2005 (Environmental Protection Authority 2005) for 12 weeks public comment. This is available from www.epa.wa.gov.au. The EPA also held six public forums around the Perth metropolitan area in May 2005 to provide an opportunity for members of the public to learn about and raise issues related to MAR. The key issues raised in the public consultation phase are discussed in Section 2.4, and further details of the submissions and forum outcomes are provided in Appendices 3 and 5. Following consideration of the issues raised, the EPA released draft section 16(e) advice in July 2005 for a 4 week public comment period. The issues raised in relation to the draft are provided with the EPA's responses in Appendix 7.

This report provides the final advice of the EPA to Government and to future proponents of MAR schemes using treated wastewater on the Swan Coastal Plain. It identifies what the EPA views as the key risks and opportunities associated with MAR, and key knowledge gaps which require further research. This advice also identifies issues that should be addressed in order for the EPA to determine the acceptability of any MAR proposal. The latter part of this report considers a number of potential applications of MAR identified by the Water Corporation, and provides the initial considerations of the Authority regarding these.

2. Background

2.1 Managed Aquifer Recharge

Aquifers are below ground layers of earth or porous rock that are saturated with groundwater. These are an important source of drinking water in Perth, with approximately half of Perth's drinking water sourced from aquifers (Allison et al. 2002). They are also used to provide large quantities of water for horticulture, industrial uses and irrigation of recreation areas and gardens. Additionally, many natural features, such as wetlands, are either directly or indirectly reliant on groundwater.

MAR, also known as artificial recharge, is the infiltration (Figure 1a) or injection (Figure 1b) of water into an aquifer. Infiltration methods include recharge basins, surface spreading, irrigation pits, and trenches. Injection is carried out using a bore (injection well) or series of bores, generally for deeper or confined aquifers. The term MAR encompasses both aquifer recharge without abstraction, and recharge for later abstraction (Figure 1b). Abstraction is the withdrawal of groundwater.

MAR has been used for centuries throughout the world, particularly in arid and desert areas where natural recharge is intermittent (Pyne 1995). MAR may be used as a means of storing water underground in times of surplus to meet need in times of demand. The water recovered may be used for purposes including the prevention of salt water intrusion in coastal areas, horticultural irrigation, environmental benefits, or to increase drinking water supplies. MAR is described in detail in *Management of Aquifer Recharge for Sustainability* (Dillon 2000).

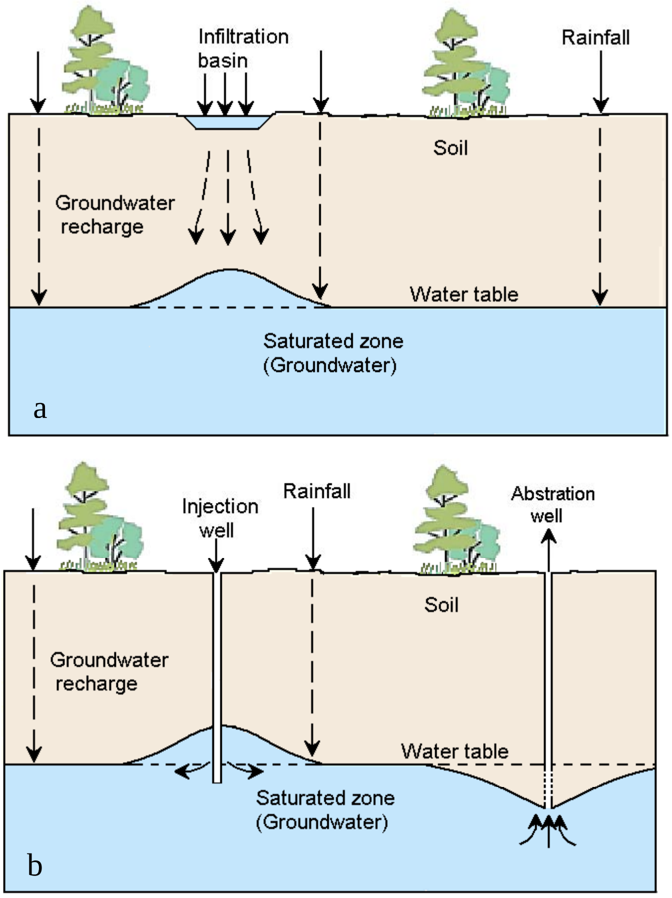

Figure 1: (a) MAR by infiltration, (b) MAR by injection with well abstraction

2.2 Water Recycling and Wastewater Treatment

Drinking water is scheme water that is supplied to residential areas and is suitable for drinking and domestic uses, such as cooking, showers, baths and garden reticulation.

Wastewater (or sewage) is the spent or used water from a community. It comes from domestic, commercial and industrial sources, and includes toilet water. Treated wastewater is wastewater that has undergone treatment in a wastewater treatment plant, as shown schematically in Figure 2. Wastewater treatment may comprise up to three stages, described below. The major wastewater treatment plants in the Perth area are shown in Figure 3. More details of wastewater treatment processes can be found in *Wastewater Engineering: Treatment, Disposal and Reuse* (Tchobanoglous and Burton 1991).

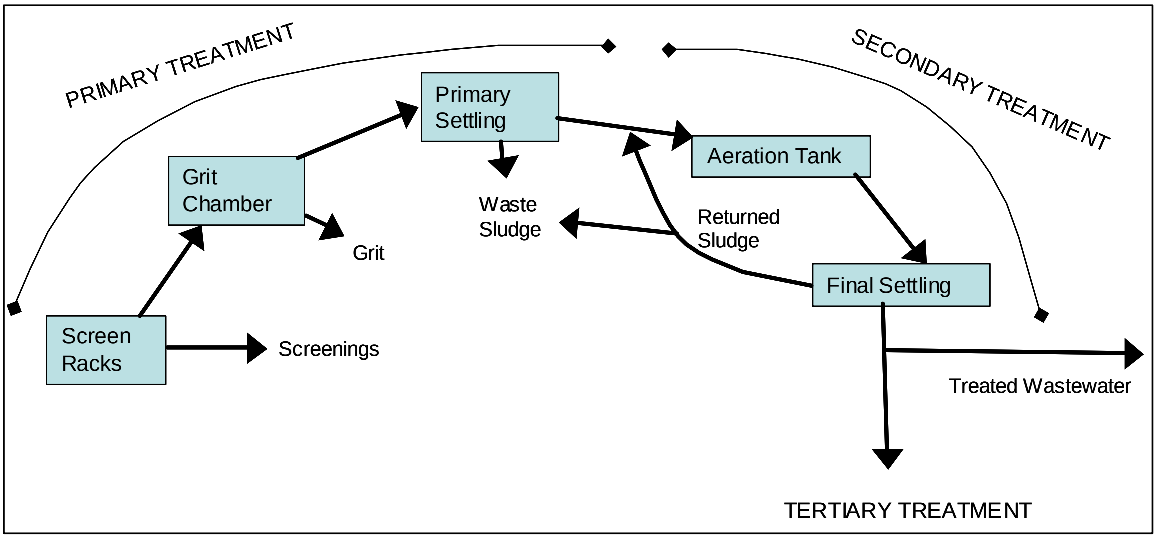

Figure 2: A common wastewater treatment process used to obtain secondary treated wastewater in Perth. (Tertiary treatment can involve many different processes and is not represented in detail here)

Primary treatment is the initial stage of wastewater treatment and involves removing solid particles from the wastewater. Heavy particles sink to the bottom and are removed.

Secondary treatment follows primary treatment. The wastewater flows into tanks where bacteria are used to treat it, often with addition of oxygen. The wastewater then flows into settling tanks where more particles settle to the bottom for removal and any floating scum is also removed. This treatment helps to remove dissolved and suspended organic and inorganic solids.

Tertiary treatment further removes inorganic compounds, and substances such as compounds of nitrogen and phosphorus. Tertiary treatment can involve a range of different processes depending on the required end water quality. It commonly involves filtration, either through a medium such as sand, or through a membrane (or multiple membranes for very high water quality) and may include disinfection with chlorine, ozone or ultra-violet radiation.

Recycled (or reclaimed) water is water which, as a result of treatment of waste, is suitable for direct beneficial use or a controlled use that would not otherwise occur. In Australia, recycled water is classified by water quality parameters and subsequent safe uses, however there is some variation in definitions between the states. As used in this paper, the five classes of recycled water are:

Class A+

Class A+ water is made by the process used to produce Class A water, with the addition of an advanced treatment stage. Advanced treatment processes include chemical clarification, carbon adsorption, reverse osmosis and other membrane processes, air stripping, ultrafiltration, and ion exchange. There is the potential for this class of water to be used to provide drinking water by MAR.

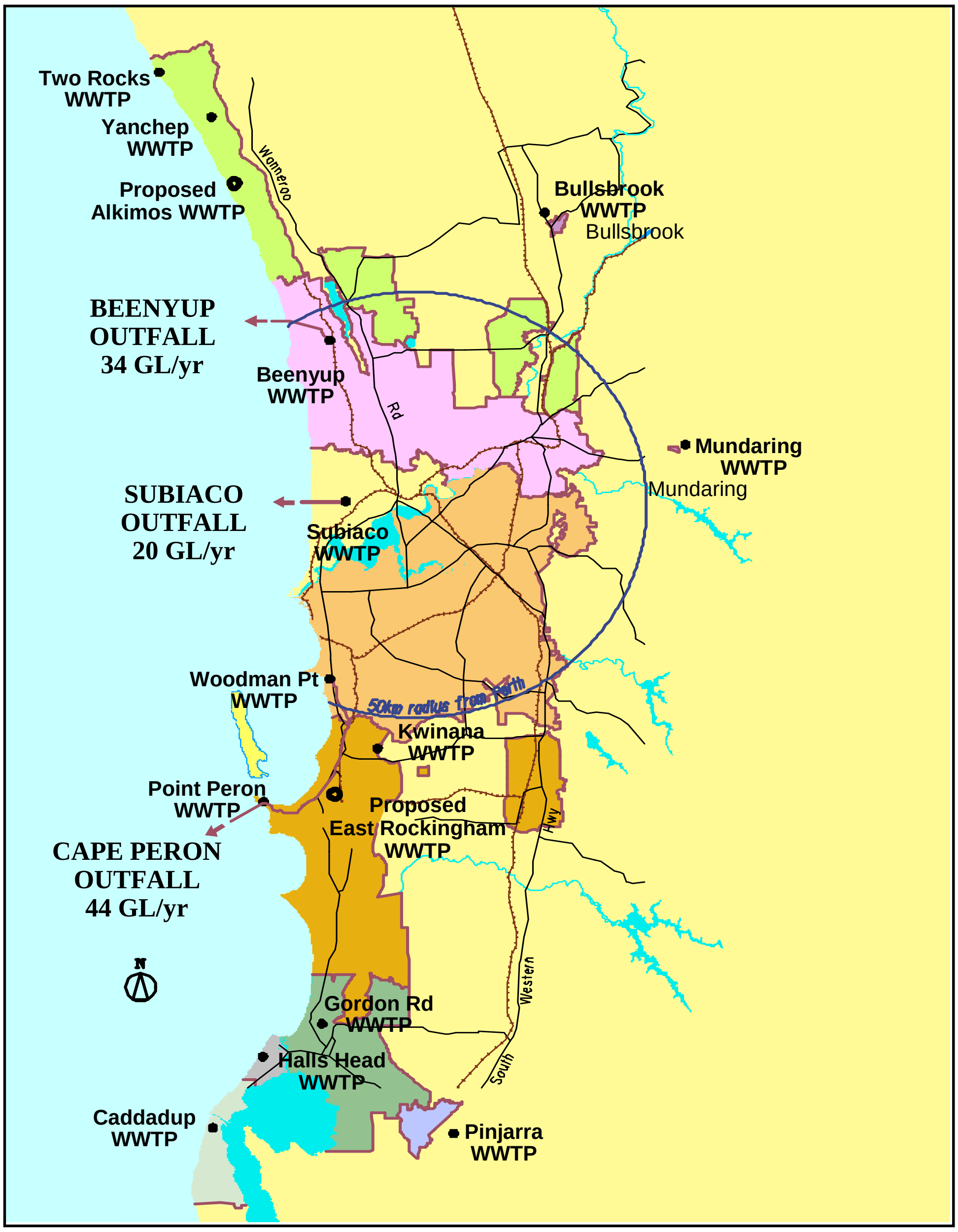

Figure 3: Major wastewater treatment plants in the Perth region. (Water Corporation)

Class A

Class A water is produced by tertiary treatment process with pathogen removal. Both Class A and A+ water require disinfection (the destruction, inactivation or removal of pathogenic micro-organisms). Class A water may be used for:

- urban non-drinking water use with uncontrolled public access;
- agricultural production, e.g. food crops which are consumed raw; and
- industrial applications with the potential for worker exposure.

The Kwinana Water Reclamation Plant produces Class A recycled water using wastewater from the Woodman Point Wastewater Treatment Plant. This is used for industrial purposes such as process and cooling water in the Kwinana Industrial Area.

Class B
Class B water is produced by secondary treatment with some pathogen reduction. This water may be used for:

- agricultural application such as cattle grazing; and
- industrial applications such as washdown water.

Class C
Class C water is produced by secondary treatment with minor pathogen removal. With strict management processes Class C water can be used for:

- urban non-drinking water applications with controlled access;
- food crop production where produce is cooked or washed; and
- industrial systems with no potential for worker exposure.

Class C water is used in Western Australia to irrigate bluegum (*Eucalyptus globulus*) plantations in places such as Manjimup, Margaret River, Nannup and Albany. With strict management processes Class C water is also used to irrigate ovals and golf courses in places such as Broome, Manjimup, Karratha and Northam.

Class D
Class D water is produced by a secondary treatment process. Class D water may be used for:

- non-food crops such as woodlots, turf growing and flowers.

Class D water is infiltrated to shallow aquifers in Halls Head and Geraldton, and extracted downstream as a higher quality product for use in irrigation.

The California Code of Regulations *Title 22* is also referred to in this document, and is used as the basis for wastewater quality requirements in other States of Australia. This sets bacteriological water quality standards on the basis of the expected degree of public contact with the recycled water. For applications with a high potential for the public to come in contact with the recycled water, *Title 22* requires disinfected tertiary treatment. For applications with a lower potential for public contact, *Title 22* requires three levels of secondary treatment, basically differing by the amount of disinfection required. In addition to establishing recycled water quality standards, Title 22 specifies the reliability and redundancy for each recycled water treatment and use operation.

The EPA notes that the Department of Health is the responsible agency for approving the health aspects of water recycling schemes in Western Australia. Water quality requirements, such as turbidity, chlorine residual and bacterial requirements, for each class of water are provided in the Department of Health Draft Guidelines (Appendix 2). The classes are summarised in Table 1.

Table 1. Summary of recycled water class quality and uses

Class	Pathogen target	Uses
Class A+ [1]	7 log reductions[2]	Drinking water by MAR
Class A	7 log reductions	Unrestricted urban non-drinking water use. Food crops for raw human consumption. Third pipe systems.
Class B	<100 E. coli	Agricultural, e.g. dairy grazing. Industrial systems with potential worker exposure
Class C	<1000 E. coli	Controlled access urban use. Food crops for cooked or processed human consumption. Industrial systems with no potential worker exposure.
Class D	<10 000 E. coli	Agricultural non-food crops, such as turf, woodlots and flowers

[1] Class A+ water must also meet the Department of Health chemical guidelines for recycled water (currently under development).

[2] A measure of effectiveness of a process to remove certain viruses or bacteria. Each log reduction reduces the number of infectious units (e.g. viruses or bacteria) by a factor of 10. For example, one log reduction reduces the original level by 90%, two log reductions reduces the original level by 99%, three by 99.9%, etc. The log reduction targets are based on recycled blackwater, the worst case scenario, and would be less for greywater or stormwater systems.

2.3 Risk Assessment Framework

Exposure to risk is recognised as a normal aspect of everyday life. People accept a certain level of risk as necessary to achieve certain benefits. For example, driving a car is a risk which most people take daily. It is generally not practical to seek zero risk; instead risks must be balanced against potential benefits.

In evaluating the concept of MAR, risk benefit analysis provides a tool for the comparison of the risks to its related benefits. Risk is defined as a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence (Warner 1992). A hazard is the potential for adverse consequences of some primary event, sequence of events or combination of circumstances (Warner 1992). Principle 1 of the *Environmental Protection Act 1986* (The precautionary principle) requires assessment of the risk-weighted consequences of options in decision-making.

Around the world there are a large number of standards and guidelines for the use of recycled water. These reflect the difference in attitudes to risk management, in addition to resource availability (Anderson et al. 2001). In Australia, National Guidelines on Water Recycling are being developed by the Joint Steering Committee for Environmental Protection and Heritage Council and National Resource Management Ministerial Council. A critical part of this is the development of an environmental risk assessment process for the use of treated wastewater.

With regard to public health, the Australian Drinking Water Guidelines (National Health and Medical Research Council and Natural Resources Management Ministerial Council 2004) provides guidance on the monitoring and management of drinking water systems, and information on potential contaminants. The guidelines recommend a multi-barrier risk based framework for the protection of drinking water quality. Potential hazards to the water supply are identified and assessed in terms of the level of risk each poses. The World Health Organization (Aertgeerts and Andelakis 2003) also use a risk management framework for the consideration of MAR.

2.4 Consultation

As described earlier, in order to invite comment on MAR using treated wastewater on the Swan Coastal Plain and to provide an opportunity for members of the public and government agencies to raise issues relating to MAR, the EPA released a Discussion Paper and held six public forums. The Discussion Paper was released on 4 April 2005 for 12 weeks public comment. This is available from www.epa.wa.gov.au.

Forums were held in Mosman Park, Hillarys, Riverton, Wanneroo, Bibra Lake and Midland during May 2005. Attendees came from three categories: those self-selected in response to newspaper advertisements, by invitation as a member of an interest group, and those invited following random selection from the electoral roll. At the forums, representatives from the key Government agencies, the Department of Environment; Water Corporation; and Department of Health, presented the key issues associated with MAR, and its potential applications on the Swan Coastal Plain. The PowerPoint slides shown at the forums are available from www.epa.wa.gov.au.

The key issues identified in submissions to the EPA and the key outcomes from each forum are provided in Appendix 3. A list of submitters is also provided in Appendix 4, and Appendix 5 provides the response of the EPA to the submissions.

The forum attendees were generally aware of the current water issues facing Perth, and supportive of the concept of wastewater recycling. There was generally a high level of support for MAR using treated wastewater on the Swan Coastal Plain, particularly for non-drinking water applications. The potential for drinking water reuse raised the greatest number of concerns, however the majority of attendees, supported the concept of MAR using treated wastewater to provide drinking water. Members of the public were of the view that it is the responsibility of the Departments of Health and Environment to set and enforce appropriate health and environmental standards respectively.

Following consideration of the issues arising from the Discussion Paper, the EPA released draft section 16(e) advice in July 2005 for a 4 week public comment period. A list of submitters is also provided in Appendix 7, and Appendix 7 provides a summary of the issues raised in relation to the draft, along with the EPA's responses.

3. Context

3.1 International Context

Around the world, demand for freshwater is increasing rapidly. An investigation by the World Resources Institute found that while many regions of the world have ample freshwater supplies, four in 10 people currently live in regions experiencing water scarcity (Revenga et al. 2000). By 2025, at least 3.5 billion people, nearly half of the world's population, will face water scarcity. Water shortages are a result of factors including increasing population, unsustainable water abstraction, contamination of water sources, and changing climatic and precipitation patterns. The EPA notes that a number of international guidelines related to MAR exist, including the World Health Organization (Aertgeerts and Angelakis 2003), and the *International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management* (United Nations Environment Programme 2000).

In many areas of the world, inadvertent water recycling occurs through the discharge of wastewater into rivers and lakes, with subsequent use downstream. This occurs in Europe and North America in areas where populations live along inland river systems (Prime Minister's Science, Engineering and Innovation Council 2003). For example, along the Thames, the Rhine and the Ohio Rivers, wastewater from upstream cities is treated and returned to the river. The mix of river water and treated wastewater is re-treated and used to provide drinking water downstream.

Planned wastewater reuse, both direct and indirect, is also common around the world. Uses include:

- horticulture;
- industry;
- environmental benefits; and
- drinking water.

Direct reuse of wastewater is considered to provide context, however this section 16(e) advice does not consider the direct reuse of wastewater. Direct reuse is the direct transfer of wastewater to the user, without intermediate storage in the environment.

Horticulture

In many cities, wastewater is discharged directly to land or water without any treatment. For example, untreated wastewater from the Mexico City basin has been used for decades to irrigate cropland in the Mezquital Valley, State of Hidalgo, Mexico (Pescod 1992). This may present a health risk in cases where there is direct human contact with the wastewater.

In Monterey Bay, California, tertiary treated wastewater is used by vegetable growers for crop irrigation. This project was initiated in the 1980's due to seawater intrusion in the Salinas Valley impacting on the quality of groundwater. Currently 24 GL[1] per year of recycled water meeting the *Title 22* California Code of Regulations is supplied to approximately 4900 ha of farmland in the northern Salinas Valley for agricultural and irrigation uses (Pescod 1992).

In Israel, MAR is used in combination with direct wastewater reuse to provide irrigation water. Between 65 and 70% of urban and industrial wastewater is reused in agriculture following secondary treatment (Icekson-Tal et al. 2003). The Dan Region Reclamation Plant is the largest wastewater treatment and reuse project in Israel, producing over 130 GL of recycled water per year. It has been in operation for 25 years. Wastewater from the Dan Region is conveyed to four recharge basins covering

[1] 1 gigalitre = 10^9 L = 1000 000 000 L. One gigalitre is the approximate volume of 450 Olympic swimming pools.

an area of 80 ha, with infiltration by alternate flooding and drying (Icekson-Tal et al. 2003). Abstraction wells are located 300 to 1500 m from the recharge basins.

Industry

Direct reuse of wastewater for industrial purposes is common around the world and generally well-supported by communities due to the low level of human contact with the recycled water. Industrial reuse schemes exists in many countries, for example in Singapore treated wastewater produced by the NEWater plant (tertiary treated with microfiltration, reverse osmosis, and disinfection) is used in wafer fabrication plants (http://www.pub.gov.sg/NEWater).

MAR is uncommon for the supply of recycled water to industry. Heavy industries generally use water at a relatively constant rate year round, and therefore can be supplied directly with recycled water, which is also produced at a relatively constant rate throughout the year.

Environmental benefits

A number of examples of MAR projects for environmental benefits exist around the world, often overlapping with horticultural and drinking water use. For example, Water Factory 21 in Orange County, California prevents sea water intrusion by injecting treated wastewater into the aquifer. This project has been in operation since 1976. It has provided significant data on the capability and reliability of advanced wastewater treatment processes to remove microbiological and chemical constituents, and data on groundwater quality and monitoring techniques.

In the West Basin Municipal Water District, California, secondary treated wastewater is injected into the coastal South Bay aquifers, following microfiltration and reverse osmosis, to prevent salt water from entering the aquifer (Australian Academy of Technological Sciences and Engineering 2004). Initially a combination of 50% imported water and 50% of recycled water were injected. In 2000 an expert review panel and the California Department of Health Services gave approval for 100% recycled water to be injected.

Drinking water

Direct reuse of treated wastewater for drinking is relatively uncommon. In Windhoek, Namibia, treated wastewater from the Gammams wastewater treatment plant supplies half of the water into the Windhoek drinking water network, with the other half obtained from a surface reservoir. The capacity of the plant is currently being upgraded to 7.67 GL per year. Since 1968, recycled water has contributed 4% of the total water supply in Windhoek, though this has reached up to 31% during droughts (Anderson 2003).

In Singapore the NEWater demonstration water recycling plant was commissioned to produce treated wastewater for drinking. Wastewater is tertiary treated with advanced dual-membrane (microfiltration and reverse osmosis) and ultraviolet technologies. A review by an expert panel concluded in 2002 that the plant has demonstrated that drinking water can be produced consistently and reliably on a large scale. This water is indirectly used to supply drinking water, with approximately 12.4 GL per annum of NEWater, around 1% of daily supply, blended into the raw water reservoir (http://www.pub.gov.sg/NEWater).

MAR to increase public drinking water supplies is used in a number locations in the United States and around the world. For example, the Hueco Bolson Recharge Project in Texas treats wastewater to drinking water quality, which is then injected directly into the primary drinking water source for the city of El Paso. At this site approximately 14 GL per year of treated wastewater is injected, of which half (7 GL) may enter drinking water supplies (Southwest Consortium for Environmental Policy and Research 1999).

At Water Factory 21 in California, mentioned earlier in relation to preventing salt water intrusion, approximately 21 GL of secondary treated wastewater is further treated by microfiltration and reverse osmosis for injection into four coastal aquifers. Up to 5% (1 GL per year) of this water may return to the drinking water supply. To date there has been no evidence of any significant health risks from this practice (Australian Academy of Technological Sciences and Engineering 2004).

The largest scale MAR project to provide drinking water in Europe is in the Veurne-Ambacht region of Belgium. Approximately 2.5 GL per year of tertiary treated wastewater is infitrated into dunes following microfiltration and reverse osmosis. This water takes approximately 40 days to reach the aquifer, and is extracted at a minimum distance of 40 m from the edges of the infitration pond. This supplies an additional 2.5 GL of drinking water, constituting 40-50% of the regional drinking water demand (Johan Verbauwhede, IWVA, Intercommunale Waterleidingsmaats-chappij van Veurne-Ambacht, personal communication).

3.2 National Context

At a national level, water availability and management is a critical issue. Australian domestic water use per person is second highest in the world, following the United States of America (Australian Academy of Technological Sciences and Engineering 2004). The Australian Water Services Association found that the country is facing a 275 GL shortage of drinking water in the next 10 years unless drastic conservation measures and new treatment methods are put into place. On 17 June 2005 it was reported in the Australian Newspaper that dam levels in eastern Australia were at record lows (The Australian, p 14, Cities have outgrown their dams). Sydney and Canberra have less than two years water supply left without further substantial rain, and Melbourne has only slightly more.

Given this context, the Australian Academy of Technological Sciences and Engineering (2004) review of current trends in water recycling in Australia concluded that governments should recognise wastewater, stormwater and rainwater as additional water resources rather than disposal problems. It recommended that wider use of recycled water should be undertaken for applications where drinking water quality is not required. Increased water recycling is also supported by *The Value of Water: Inquiry into Australia's Management of Urban Water* (Allison et al. 2002) and *Recycling Water for Our Cities* (Prime Minister's Science, Engineering and Innovation Council 2003).

A range of wastewater reuse projects are operational in Australia, both direct and indirect, with water sourced from both stormwater and treated wastewater. For example, in South Australia 20 GL per year of Class A water from the Bolivar Wastewater Treatment Plant is directly used in horticultural irrigation on the North Adelaide Plains. At Werribee in Victoria, the largest water reuse project in Melbourne, up to 8.5 GL of Class A water will be supplied to vegetable growers and the surrounding environment per year. This will increase the reliability of water supply for local growers and provide significant environment benefits to the area.

At present, 22 MAR schemes are operational in the Adelaide region, injecting approximately 2 GL per year of rural and urban stormwater runoff into aquifers (Department of Water, Land and Biodiversity Conservation South Australia 2005). There are also a number of operational MAR schemes in Queensland. For example, at Bribie Island, up to 1.8 GL per year of secondary treated wastewater is discharged into three shallow ponds. This water forms a groundwater mound between the ocean and water supply trenches in order to prevent salt water intrusion into the scheme water supply (Resource Sciences and Knowledge 2000).

While most MAR to date in Australia has been for applications with lower human contact, a MAR trial at the Greenfields Railway Station site in South Australia has recently commenced to examine the potential for recovering pre-treated stormwater to provide public drinking water supplies (Department of Water, Land and Biodiversity Conservation South Australia, 2005).

In June 2005 the Goulburn Mulwaree Council made a submission to the Federal Government through its Water Smart Australia Program for funding of the Goulburn Mulwaree Council Sustainable Cities Project. This $32 million project aims to increase the secure yield of Goulburn's water supply by reclaiming wastewater and returning it to the Sooley Dam catchment. The project includes:

- construction of a new wastewater plant;
- construction of an advanced water reclamation plant to produce drinking quality water for transfer to Bumana Creek watercourse and into Sooley Dam via a chain-of-ponds wetland;
- rehabilitation of the chain-of-ponds wetland system in Bumana Creek to polish the water before the final indirect recharge of the existing storage at Lake Sooley; and
- the provision of off takes from the transfer pipeline to allow urban reuse, including the Racetrack and sporting field irrigation

(Parsons Brinckerhoff 2005).

The Toowoomba City Council has also requested funding through the Water Smart Australia Program for the $68 million Toowoomba – Water Futures project. This includes:

- purifying 5000 ML per year of wastewater to a standard higher than drinking water and pumping this into Cooby Dam to supplement drinking water supplies;
- supplying the reject stream from the advanced water treatment plant to a coal mine after the reject stream has been mixed with a slightly higher quality water from the water reclamation plant;
- supplying 1000 ML per year of water from the advanced water treatment plant to a horticultural area;

- supplying 500 ML per year of reclaimed water to urban areas for non drinking uses; and
- supplying reclaimed water to meet future needs of a planned industrial estate.

(Toowoomba City Council 2005).

The Victoria Environmental Protection Authority 'Use of Reclaimed Water – Guidelines for Environmental Management' (2003) states that there is currently insufficient information available to develop generic guidelines, therefore proposals will be assessed on a case by case basis. In Queensland, guidelines are being developed which include indirect drinking water reuse of wastewater (Queensland Environmental Protection Agency 2004).

3.3 State Context

The climate of Perth is drying, with a significant reduction in rainfall measured in the south-west of Western Australia since the mid 1970s (Berti et al. 2004). Over the past 28 years, there has been a 10-20% reduction in rainfall in the south-west of the State, with a subsequent 40-50% reduction in runoff to dams, and reduced recharge of groundwater (Government of Western Australia 2003a). It is expected that climate change due to greenhouse gas emissions will continue to dry the climate in future (Water and Rivers Commission 2000).

At the same time, the population of the Swan Coastal Plain, and therefore demand for water, is increasing. From 1985 to 2000, water use in Western Australia approximately doubled, to nearly 1800 GL per year, and groundwater use increased threefold (Water and Rivers Commission 2000). In Western Australia between 1999 and 2000, irrigated agriculture was the largest water user in the state, constituting 40% of the total state-wide demand. This was followed by the mining industry (24%), then household use (13%) (Water and Rivers Commission 2002), however not all of this is of drinking water quality. The total annual demand for water in the Perth metropolitan area is currently estimated at almost 600 GL, with approximately half of this being self-supply for irrigation and half for public scheme water (Government of Western Australia 2003a).

A management strategy has been in place since 1994 to reduce demand for drinking water (Water and Rivers Commission 2002). This includes public awareness campaigns and water restrictions, such as two day per week sprinkler use. Demand management has succeeded in reducing summer demand for water, however the Australian Academy of Technological Sciences and Engineering (2004) considered that the success of demand management has 'hardened' water consumption, making it more difficult to achieve future savings either through efficiency gains or water restrictions. The *Western Australia Water Assessment* (2000) predicted that water use will double over the next 20 years (Water and Rivers Commission 2000). This is expected as a result of increasing population, along with increasing water use in the mining, industry and service sectors, and the estimate that irrigated agricultural use will more than double over this period (Government of Western Australia 2003a).

Increasing demand for water, coupled with decreasing rainfall, has significant implications for water resource management, in particular the determination of sustainable yields and the allocation of water resources. Currently drinking water supplies in Perth are sourced from both protected surface and groundwater catchments, with approximately half from each source (Allison et al. 2002). The *Western Australia Water Assessment* (Water and Rivers Commission 2000) found that approximately one third of the State's water resource systems are at a high or fully allocated level, with some areas being over-allocated. For the Perth groundwater division, it was reported that water use is at or near the sustainable limits, including the Gnangara and Jandakot superficial aquifers, and the Leederville and Yarragadee confined aquifers (Water and Rivers Commission 2000). In a number of groundwater sub-areas on the Coastal Plain there is no further groundwater currently available for allocation. Should the drying climate trend continue, it is likely that the current sustainable limits will be reduced. Figure 4 shows the decline in the Gnangara Mound, the largest and most important shallow groundwater resource in the Perth area, since 1979.

In response to these issues and the need for a long term plan for water resource management, the State Water Strategy for Western Australia (Government of Western Australia 2003a) was developed. In this strategy, Government set a target of recycling 20% of wastewater by 2012. Recycling wastewater may allow for new water supply source developments to be postponed, wastewater disposal to the marine environment to be reduced, and high quality treated water to be retained for high value uses. Currently in the Perth region 3.3% (3.4 GL per year) of wastewater is recycled (Water Corporation 2002), with approximately 100 GL per year discharged to the marine environment (Government of Western Australia 2003a). This is predicted to grow to 160 GL by 2025, and exceed 200 GL by 2040 (Water Corporation 2005).

The State Water Strategy identifies large-scale, scheme-based reuse options as a priority above reuse at a household scale in view of environmental, economic and health considerations. The Strategy highlights the potential for recycling to provide water 'fit for purpose' for irrigated horticulture, green space irrigation and industry, as well as the potential for MAR to increase water availability in groundwater systems, and to maintain environmental values.

The major wastewater reuse project in Western Australia at present is the Kwinana Water Reclamation Plant, which came online in November 2004. The reclamation plant will reduce industry demand for scheme water by up to 6 GL per year. The plant takes wastewater from the Woodman Point Wastewater Treatment Plant, and treats it to Class A quality by filtration and reverse osmosis, producing water of a quality suitable for major Kwinana industrial customers.

A form of MAR, using stormwater rather than wastewater, currently occurs in Perth with the infiltration of stormwater from residential roofs into soakwells and from roads into stormwater sumps. This accounts for approximately 80% of the stormwater in Perth, with the remaining 20% (120-130 GL per year) drained to rivers and the ocean outfalls (CSIRO submission 17 June 2005).

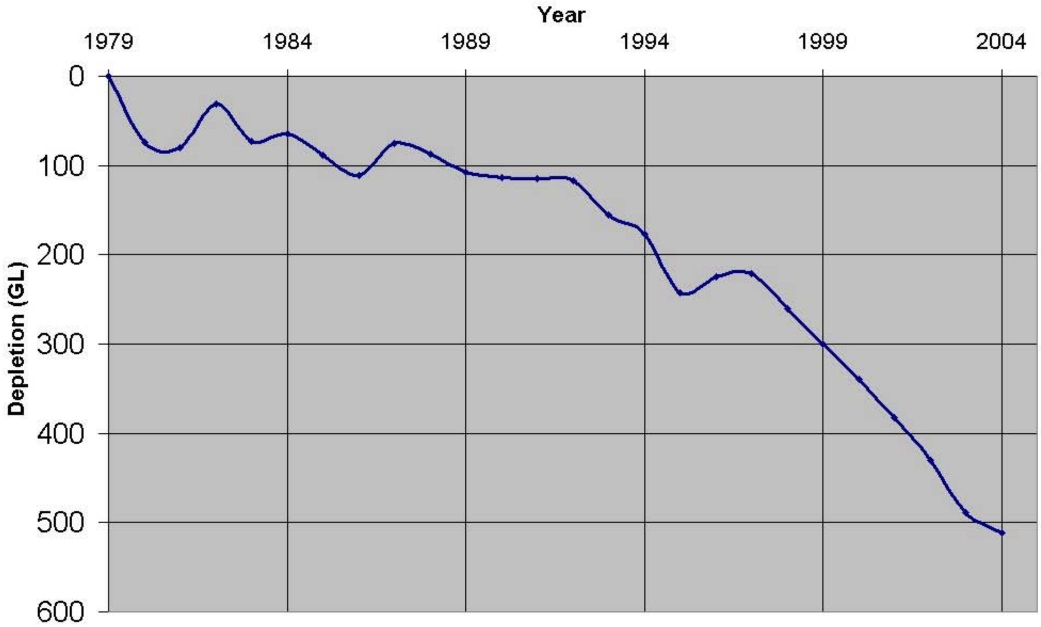

Figure 4. Depletion of the Gnangara Mound since 1979 (Vogwill 2004)

Several small-scale Water Corporation MAR projects using treated wastewater are currently operational, and a number of feasibility and pilot studies have been conducted. At the Kwinana, Geraldton and Halls Head Wastewater Treatment Plants, secondary treated wastewater is infiltrated and later withdrawn for use in irrigation. Also in Kwinana, Alcoa use groundwater supplemented by treated wastewater from the Kwinana Wastewater Treatment Plant (Water Corporation submission 28 June 2005). MAR trials have been conducted at Canning Vale (Edmonds et al. 1987), and feasibility studies undertaken at the Broome Wastewater Treatment Plant and on the Mosman Peninsula (SKM 1996, Australian Groundwater Technologies 2004).

The Halls Head Indirect Reuse Scheme is a currently-operational MAR research and development plant (Toze et al. 2002, 2004). Treated wastewater is infiltrated into the shallow aquifer using infiltration basins. For a 24 month period, groundwater was monitored for potential environmental and health risks from major contaminants, particularly microbial pathogens, and for the influence of MAR on the local groundwater system (Toze et al. 2002). The CSIRO concluded that at this site the recovered MAR water is of suitable quality for irrigation purposes and has negligible health and/or environmental risks.

3.4 Principles of the *Environmental Protection Act 1986*

Any MAR proposal should have regard for the principles of the *Environmental Protection Act 1986*, as set out below. MAR is considered in the context of these principles in this section 16(e) advice.

The precautionary principle

Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, decisions should be guided by -

(a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and
(b) an assessment of the risk-weighted consequences of the various options.

The principle of intergenerational equity

The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

The principle of the conservation of biological diversity and ecological integrity

Conservation of biological diversity and ecological integrity should be a fundamental consideration.

Principles relating to improved valuation, pricing and incentive mechanisms

1. Environmental factors should be included in the valuation of assets and services.
2. The polluter pays principle – those who generate pollution and waste should bear the cost of containment, avoidance or abatement.
3. The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and the assets and the ultimate disposal of any wastes.
4. Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.

The principle of waste minimisation

All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.

4. Factors

4.1 Sustainability

To be sustainable, development must meet the needs of current and future generations through an integration of environmental, social and economic goals (Government of Western Australia 2003b). Sustainability requires that the precautionary principle be employed where there is the risk of serious or irreversible environmental damage, and that intergenerational equity apply to ensure that the health, diversity and productivity of the environment be maintained or enhanced for the benefit of future generations.

Increasing demand for water has traditionally been met by the development of new sources, such as the construction of dams. The environmental, social and economic costs of such approaches may be high, and in some cases these costs are seen as unacceptable (Allison et al. 2002). MAR should not be considered in isolation, but evaluated against the range of alternative water supply options, as required by the Precautionary Principle. This involves consideration of energy intensity, including requirements for water treatment and pumping, and other infrastructure. MAR should be considered as part of an integrated system.

The EPA notes that MAR is consistent with the principle of waste minimisation. MAR is supported by the waste hierarchy defined in EPA Position Statement 7 'Principles of Environmental Protection' (Environmental Protection Authority 2004), which places reuse and recycling above disposal.

The *Western Australian State Sustainability Strategy* sets out several objectives with regard to the protection of drinking water and aquatic ecosystems. These objectives include:

- protect all drinking water catchments and all aquatic systems of high environmental/conservation, scenic and heritage significance;
- ensure that the abstraction of water does not exceed the water requirements of aquatic ecosystems; and
- provide for the protection of water-dependent ecosystems, while allowing for management and development of water resources to meet the needs of current and future users

(Government of Western Australia 2003b).

With regard to these objectives, MAR has the potential to increase the sustainable yields of aquifers by allowing recharge water to be used following a residence time in the aquifer, or by increasing water pressure in a confined aquifer and thus making other water available. The use of recycled water in this way has the potential to maintain groundwater dependent ecosystems, such as wetlands and caves, which are currently being impacted by declining groundwater levels. However, these potential benefits must be balanced against the risks, such as the potential for decreased water quality to adversely affect the environment. As part of the risk assessment for any MAR proposal, both the current and future beneficial uses of the environment should be considered.

A balance should also be sought between the economic costs of treating water and the environmental costs associated with that water quality. Should the water quality requirement be so high that the project does not proceed, there is a risk that a potential environmental benefit may be lost.

The EPA considers that increased wastewater recycling provides an opportunity to better and more sustainably manage water resources in Western Australia. However, the EPA notes that there is also a risk that, if not applied and implemented judiciously, there is the potential for MAR to be contrary to the principles of sustainability. As an example of this, MAR may provide the best means of maintaining groundwater dependent ecosystems on the Gnangara Mound for future generations. However, given the range of environmental issues associated with MAR, the implementation of schemes in areas of high environmental value may be incompatible with the precautionary principle. A high level of understanding of the potential impacts of MAR schemes would be required before considering any large scale proposals in such areas. Any MAR proposal referred to the EPA should address sustainability.

4.2 Environment

4.2.1 Environmental Risks

There are a number of environmental risks associated with MAR. Key risks relate to:

- groundwater contamination;
- surface and marine water contamination; and
- ecosystem degradation.

Groundwater Contamination

MAR has the potential to affect groundwater quality and flow. The recharge and abstraction of water may cause changes in groundwater levels, and may affect yield by changing the hydraulic parameters of the aquifer. The integrity of aquifer composition under conditions of long-term injection of wastewater has been identified by Scatena and Williamson (1999) as requiring further investigation.

Treated wastewater may contain nutrients, such as nitrogen and phosphorus, at levels higher than in the native groundwater. It may also contain pathogens, heavy metals and chemicals. The concentrations of these contaminants will be dependent on the level of wastewater treatment prior to recharge. Some studies have also reported the potential for trihalomethanes to be formed when residual chlorine present in the recharge water continues to react with organic matter in the aquifer (Fram et al. 2003, Pavelic et al. 2005). This requires investigation with particular focus on the Swan Coastal Plain.

The introduction of wastewater into an aquifer may induce geochemical reactions such as mineral precipitation, dissolution, cation exchange and redox reactions (Toze et al. 2001). These reactions have the potential to affect the adsorption or attenuation of metal or inorganic contaminants. For example, Appleyard et al. (submitted) postulate that MAR in the Gwelup area using wastewater with a high biochemical oxygen demand (BOD) could change groundwater chemistry, with the potential to cause acidification and the release of heavy metals from aquifer sediments. However, the CSIRO submit that the use of high BOD water would be impractical, causing microbial growth in the vicinity of the recharge site which would lead to clogging and therefore decrease recharge (CSIRO submission 17 June 2005). The EPA considers that this will be resolved in the development of specific proposals and through MAR trials.

The potential for pathogens to survive and multiply in aquifers has been identified (Resource Sciences and Knowledge 2000), however it is expected that this is quite rare (CSIRO submission 17 June 2005). It has been reported that the number of organisms surviving in an aquifer declines at an exponential rate, depending upon a range of chemical, physical and biological processes, indigenous groundwater micro-organisms and water chemistry (Toze et al. 2001). Site-specific data on pathogen survival will be necessary for the EPA to evaluate any large-scale MAR proposal for Class B and C schemes, particularly in cases when MAR is reliant on the aquifer to improve environmental water quality. For MAR schemes of Class A or above, the Department of Health require the absence of pathogens to be demonstrated.

Changes in groundwater quality may affect subterranean fauna such as stygofauna and troglofauna. Stygofauna are aquatic subterranean animals, found in a variety of groundwater systems, while troglofauna occur in air chambers in underground caves or voids (Environmental Protection Authority 2003). The coastal karst system of the Swan Coastal Plain is known to contain a rich subterranean community. Changes as a result of MAR may be adverse, however there is also the potential that MAR using treated wasterwater may benefit stygofauna (CSIRO submission 17 June 2005). Stygofauna predominantly rely on the presence of bacteria and dissolved organic carbon for growth, therefore MAR may provide an environment suited to their growth. This requires further research.

Surface and Marine Water Contamination

MAR using treated wastewater may influence surface water quality as the recharge water moves into surface water bodies, with the potential for nutrient enrichment (eutrophication). For inland waters, the presence of phosphorus at certain concentrations has the potential to cause algal blooms in wetlands and streams.

It is generally accepted that groundwater on the Swan Coastal Plain eventually discharges to the marine environment through surface flows and direct groundwater discharge. Appropriate management of MAR is therefore necessary to ensure that marine environmental values[2] are protected.

The outflow of nitrogen rich water into coastal marine waters may cause eutrophication (Government of Western Australia 2003c). Eutrophication of the marine environment in Western Australia has been documented in Cockburn Sound (DEP 1996) and Albany Harbours (EPA 1990), where proliferation of algae in the water column (i.e. phytoplankton) and on the leaves of seagrass (i.e. epiphytes) was attributed to excessive inputs of nutrients from industry and the catchment. In both locations, excessive growth of phytoplankton and epiphytes reduced light reaching seagrass leaves, ultimately leading to dramatic loss of seagrass and changes to fundamental ecological processes.

Having a sound understanding of the mechanisms of groundwater flow to the marine environment is important for MAR. For example it is possible that where karstic limestone occurs as part of the nearshore geology, solution pipes could potentially provide preferential groundwater flow direct to the marine environment. While it is possible that, depending on water treatment prior to MAR, nitrogen loads to the marine environment may be reduced by discharging treated wastewater to groundwater for MAR, the potential for impacts from other contaminants (e.g. toxicants), where concentration rather than load affects marine biota, may be increased because there is no dilution through a diffuser. This requires consideration in planning any MAR scheme.

The EPA also recognises that the level of wastewater treatment prior to MAR may have implications for the marine environment. Reverse osmosis of wastewater is one high-level treatment option being explored by the Water Corporation to minimise

[2] Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health which require protection from the effects of pollution, waste discharges and deposits (NWQMS: ARMCANZ /ANZECC 1994).

potential for contaminants to enter aquifers. A by-product of the reverse osmosis process is a concentrated waste stream which will require disposal. If a decision were to be taken to discharge reverse osmosis waste products directly to the marine environment, it should be recognised that while the total load of contaminants is unchanged, as compared with traditional ocean disposal of wastewater, the concentrations of contaminants in the waste stream will increase and the mixing and dispersion characteristics of the more concentrated effluent may be altered.

The environmental significance of the issues outlined above will be dependent on factors including the method and level of wastewater treatment prior to MAR, biogeochemical processes acting on treated wastewater in the aquifer, the mode and rate of discharge, and the characteristics of the receiving environment.

Ecosystem Degradation

MAR using treated wastewater has the potential to affect ecosystem values in groundwater and other systems, such as wetlands. One of the key concerns is the introduction of chemicals. Chemicals of concern include endocrine disruptors, pharmaceutically active products and personal care products (such as sunscreen and soaps).

Endocrine disruptors are exogenous substances that interfere with the structure and function of the endocrine system, causing effects largely through interaction with hormone receptors of the affected organism (Toze et al. 2001). These have been associated with developmental, reproductive and other health problems in wildlife and laboratory animals. Chemicals in wastewater may survive in waterways for several years, and in some cases may interact with other chemicals in the environment to form new compounds (Allison et al. 2002). The *Inquiry into Australia's Management of Urban Water* (Allison et al. 2002) found that the extent to which pharmaceutically active chemicals constitute a problem in Australia is difficult to ascertain.

Ecosystem protection values for chemicals require separate consideration to values for the protection of human health, as these are not necessarily sufficient to protect environmental values. The *CRC for Water Quality and Treatment, Occasional Paper 7, Review Of Endocrine Disruptors In The Context Of Australian Drinking Water* (Falconer et al. 2003) states that concentrations of endocrine disruptors in domestic wastewater may cause changes in aquatic fauna. The levels involved are orders of magnitude less than the concentrations likely to cause detectable health effects in humans if this water is a component of drinking water. The potential for endocrine disruptors and pharmaceutical products to cause aquatic environmental damage has only recently been recognised, and information on their effects is relatively scarce. This is currently an active area of research.

The EPA notes that the concentrations of chemicals are related to the level of wastewater treatment. A variety of advanced treatment technologies have been shown to significantly increase the quality of treated wastewater (e.g. Chapman 2003), thereby decreasing the number of chemicals of environmental concern in the water. However further research in this area is needed, particularly with regard to environmental and ecotoxicological impacts. The Department of Fisheries advise that the potential for these chemicals to cause aquatic damage has only relatively recently become recognised and information on their effects is scarce and often of poor quality (Department of Fisheries, letter 22 November 2004).

With regard to ecosystem values, the EPA notes that the Department of Environment encourages research on potential contaminants in treated wastewater (DoE submission 9 September 2005). This includes methods to accurately estimate their presence and quantities, and the establishment of an environmental risk assessment framework to assess any contaminants that are likely to be detected and interact in groundwater dependent ecosystems.

A further environmental issue associated with MAR using treated wastewater is the potential for heavy metals to accumulate in soils. Heavy metals are easily and efficiently removed from wastewater during common treatment processes, however in some cases, such as wastewater from an industrial source, there is the potential that they may become bioavailable. This requires further research.

4.2.2 Environmental Benefits

MAR projects may be proposed for two key environmental purposes:

- improvement in water quality; and
- environmental water allocation.

Improvement in water quality

Infiltration or injection of treated wastewater into a groundwater aquifer may improve the quality of the recharge wastewater by physical, chemical and biological processes in the aquifer. For example, the soil may act as a filter, removing suspended solids, biodegradable materials and micro-organisms. Residence time in the aquifer may also allow for the die-off of microbial pathogens and their removal by indigenous native groundwater micro-organisms, and the attenuation of chemicals such as organics.

When the injected water is of a higher quality than the native groundwater, this may produce a net improvement in water quality through dilution or the promotion of favourable geochemical reactions (Centre for Groundwater Studies 1999). For example, in South Australia saline and brackish aquifers have been freshened by MAR with seasonally available fresh water. This water is then suitable for use in irrigation during the dry months (Pyne 1995).

Another potential application of MAR is to prevent salt water intrusion in coastal aquifers. Salt water intrusion can occur when fresh groundwater is withdrawn at a greater rate than it is replenished, allowing salt water from the ocean to intrude into the fresh water aquifer. This may lead to the aquifer becoming salty and unsuitable as a source of drinking or irrigation water. MAR may be applied in such areas to create a hydraulic barrier to the salt water. This excludes salt water from the aquifer as the recharge water moves towards the coast.

Environmental water allocation

MAR using treated wastewater may be used to restore groundwater levels in areas where these have been lowered, with the potential to restore the environmental values of systems such as wetlands or caves. MAR may also free up allocations of water to allow rivers, wetlands or vegetation to be maintained or restored.

Treated wastewater may be used in irrigated horticulture, having the potential to significantly decrease horticultural water requirements from other sources and provide public drinking water or groundwater benefits. In cases where recycled wastewater is used for horticultural applications, the nutrients in recycled water may lessen the requirement for commercial fertilisers.

Given the drying climate of the south-west, MAR may present a means of protecting groundwater dependent ecosystems and preventing acidification due to the drying of acid sulphate soils.

4.3 Public Health

Health risks include both microbiological and chemical risks. The major microbiological risk is infection from viruses, bacteria, protozoa and helminths. The risk associated with chemicals is adverse health effects following prolonged human exposure (ARMCANZ/ANZECC 2000a).

In order to manage these risks, the Western Australia Department of Health (DoH) has developed draft *Recycled Water – Groundwater Recharge Guidelines* (2005) which will apply to any MAR scheme using treated wastewater. These Guidelines are attached in Appendix 2.

The general principles underpinning MAR schemes will need to be met irrespective of the end use proposed. The extent of compliance with monitoring and drinking water quality guidelines required for individual schemes will be proportional to the human exposure and subsequent public health risk.

The DoH Guidelines are based on the following principles:

A number of principles underpin the derivation of health guidelines for aquifer recharge settings and these must be addressed in any proposal. They are:

1. All schemes must be individually approved although new users may be added to a scheme if the proposed new use is of an equivalent or lesser human exposure level.

2. All schemes must adopt a risk management framework.

3. All schemes are approved on a "fit for purpose" basis. The allocation of any proposed scheme to a "fit for purpose" category is based on the extent of human exposure and the subsequent modelled risk. For example, all aquifer recharge schemes involving indirect potable use are assumed to have an ingestion exposure of two litres per day for 70 years.

4. Requirements will include both quality and process components

5. All schemes require three types of monitoring.

   5.1. Validation (will it work): this may include chemical and pathogen testing to demonstrate effectiveness of removal processes however surrogates can be used to demonstrate this (eg MS2 phage)[3]. Validation testing is based on obtaining a sufficient database to provide convincing evidence that a process or method will work.

5.2. Operational Testing (is it working): this will include a series of measurements and observations to confirm performance of preventative measures. Operational monitoring is based on the need to allow timely intervention and can be both continuous (disinfection, filtered water turbidity) or six monthly (inspection of structures).

5.3. Verification (did it work): this may include testing for chemicals and micro-organisms. The frequency of required monitoring is based on an assessment of need, and is based on notional ideas about the variability of water quality characteristics system complexity and other perceptions.

6. The water extracted from the aquifer after the recharge process must be of a required quality without extra treatment being necessitated.

7. While a risk management approach is required for all aquifer recharge proposals, for those involving indirect potable reuse, the best available technology is also mandated and must include a reverse osmosis component.

8. The major health issues of concern are chemicals and pathogens, including viruses, bacteria, helminths, and parasites. Overseas work has demonstrated the relative unimportance of heavy metals and radiation although local validation of this will be required. Chemicals are only a concern for indirect drinking water schemes.

9. Separation times will be required between recharge and extraction for all proposals involving indirect potable re-use. Minimum times based on the mode of recharge will be identified. These will be shorter for infiltration compared to injection but, in all cases, the longer the time between recharge and extraction, the greater the margin of safety. Minimum separation distances between infiltration or injection and extraction will also be required. Separation times will also be required for class A schemes such as horticulture, if these have been approved without a requirement for full treatment prior to spreading.

In setting health guidelines for MAR, the Department of Health has taken account of the current development of national guidelines for wastewater reuse and guidelines in place in MAR schemes elsewhere in the world. The Department of Health believes that wherever possible local guidelines should reflect best practice described in national and international policies. The Department of Health does however recognise that in this instance, pressures in Western Australia for consideration of MAR for source development put the local health debate well ahead of national processes. In addition, pressures on source development in international communities may lead to the guidelines that are deemed inadequately protective in a Western Australian setting.

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[3] MS2 phage is a bacteriophage or a virus that infects bacteria. These bacteriophages are easier to grow and propagate than viruses which infect man and are used to test how other viruses would act when these viruses can't be examined directly. MS2 phage, a single stranded RNA virus, has been used in many water reuse schemes to monitor how, more difficult to assess, human viruses of concern would be affected.

4.4 Regulatory Requirements and Guidelines

The Commonwealth is involved in water management in Australia through the *National Environmental Protection Council Act 1994*, and the *Environment Protection and Biodiversity Conservation Act 1999*. Constitutional responsibility for recycled water rests with the States and Territories (Australian Academy of Technological Sciences and Engineering 2004).

The *National Water Quality Management Strategy* provides a series of national guidelines for water quality management at a federal level. This is supported in Western Australia by the State Water Quality Management Strategy, 2001 (Government of Western Australian 2003c). The National strategy is comprises 21 guideline documents for water quality management, including the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ARMCANZ/ANZECC 2000c). Two Guidelines are directly relevant to MAR: *Australian Guidelines for Sewerage Systems – Effluent Management* (ARMCANZ/ANZECC 1997) and *Australian Guidelines for Sewerage Systems – Reclaimed Water* (ARMCANZ/ANZECC 2000a).

The National Resource Management Ministerial Council is currently developing *National Guidelines For Water Recycling*, expected to be released for public comment in late 2005. These will consist of a suite of documents including a *Framework for Management of Recycled Water Quality and Use* and documents which provide specific criteria and guidance for health and environmental parameters relating to identified priority uses. Additionally, the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC/ARMCANZ 2000b) are relevant to MAR as they provide methodologies for setting quality objectives for surface and groundwater.

In 1982 the Australian Water Resources Council published guidelines on the use of reclaimed water for aquifer recharge. These guidelines were updated in the 1996 *Guidelines on the Quality of Stormwater and Treated Wastewater for Injection into Aquifers for Storage and Reuse* (Dillon and Pavelic 1996). These guidelines recommend that the level of groundwater protection should be dependent on the potential beneficial uses of the native groundwater, and therefore on current groundwater quality. The EPA notes that such a differential protection policy is unlike policies in many other parts of the world, as it does not assume drinking water quality as an essential objective. This takes into account that much groundwater in Australia is too saline for drinking water supplies, and also that the allowable concentrations of some contaminants, such as phosphorus, are lower for ecosystem protection than for drinking water supplies (Dillon and Pavelic 1998).

In Western Australia, water resources are managed by the Water and Rivers Commission (Department of Environment). Under the *Rights in Water and Irrigation Act 1914*, the right to use, flow and control groundwater is vested in the Crown. This Act requires the licensing of all wells abstracting from aquifers in proclaimed Groundwater Areas, and all artesian wells. Public Drinking Water Source Areas (PDWSAs) are proclaimed and protected from contamination risks through the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* and *Country Areas Water Supply Act 1947*, administered by the Water and Rivers Commission. PDWSA is the collective description for Underground Water Pollution Control Areas, Water Reserves, and Catchment Areas declared under the above Acts. PDWSAs are classified into three groups: Priority 1 areas are managed in accordance with the principle of risk avoidance to ensure no degradation of the drinking water source; Priority 2 areas are defined to ensure that there is no increased risk of pollution to the water source, and Priority 3 areas are where it is practical to manage the risk of pollution to the water source.

By-laws under the above Acts enable the management and control of specified potentially polluting activities and land uses. Accordingly, the Department of Environment will be a decision maker through its legislative responsibilities for MAR proposals. The extent of its decision making powers is still to be determined for MAR and it may vary depending on the proposal. The Department of Environment is also developing a management policy for MAR in the 2005-06 financial year. It is expected that options for trading and/or cost recovery of MAR schemes would form part of the policy (Department of Environment submission 27 June 2005).

MAR proposals will be considered under the provisions of the *Environmental Protection Act 1986*. Under Part III of the *Environmental Protection Act 1986*, the *Environmental Protection (Gnangara Mound Crown Land) Policy 1992* applies on the Gnangara Mound. The policy aims to protect the level and quality of groundwater, native vegetation and wetlands in this area by controlling activities that cause the quality of groundwater to be decreased. The discharge of contaminants in the policy area is only permitted if done so under authorisation of the *Environmental Protection Act 1986*. This includes authorisation following assessment of a proposal by the EPA, or the decision of the EPA not to assess. This policy is due to be updated.

Part IV of the *Environmental Protection Act 1986* provides for the assessment of proposals considered likely to have a significant environmental impact. This is discussed further in Section 5. MAR proposals may also be subject to Part V of the Act. This part of the Act regulates discharge through works approvals and licences.
The Government policy context underpinning the evaluation of the potential impacts of MAR on the marine environment is provided in the *State Water Quality Management Strategy (SWQMS) Document No 6* (Government of WA, 2004), which is based on, and consistent with, the *National Water Quality Management Strategy* documents. The framework described in the SWQMS No. 6 involves identifying Environmental Values and Environmental Quality Objectives and clearly setting out where they do and do not apply through consultation with the community. Environmental Quality Criteria are the numerical and/or narrative benchmarks which are used in combination with results of environmental monitoring to gauge whether management strategies are effective in protecting the Environmental Values. The EPA is implementing the environmental quality management framework described in SWQMS No. 6 in the marine environment through its policy formulation (e.g *State Environmental (Cockburn Sound) Policy, 2005*) and environmental impact assessment roles under the Act.

Consistent with the SWQMS, the EPA, through consultation with the community, has established a set of EVs and spatially defined boundaries for the Environmental Quality Objectives in the State marine waters between Mandurah and Yanchep.

Proposals with the potential to either positively or negatively impact on coastal waters will be considered by the EPA in the context of the Environmental Values and Environmental Quality Objectives set out in *Perth's Coastal Waters Environmental Values and Objectives* (Environmental Protection Authority 2000). Potential impacts on the Swan or Canning rivers should be assessed against the management targets set out in the Swan Canning Cleanup Program (Swan River Trust 1999).

State and Local Government planning processes exist to protect water sources through the Western Australian Planning Commission's Statement of Planning Policies (for example, Statement of Planning Policy No. 2: Environment and Natural Resources Policy, and Statement of Planning Policy No. 2.7: Public Drinking Water Source Policy). These policies are prepared under provisions in the *Town Planning and Development Act 1928*. Amendments may also require approval under the relevant Metropolitan Regional Scheme and/or Local Government Town Planning Scheme. The EPA also notes that Planning (or Development) Approval may be required for any development works which may be involved with MAR proposals.

The *Health Act 1991* includes provisions to protect public health in relation to the consumption of drinking water. Approval by the Department of Health is required for any water recycling in Western Australia under sections 97, 107 2 (b) and 129 of the *Health Act 1911*. Under this Act, it is an offence for any person to pollute any water supply or water catchment containing water intended for human consumption.

The Economic Regulation Authority (ERA) is responsible for the licensing of water service providers to ensure the delivery of safe water. The Water Division of the Economic Regulation Authority is responsible for the functions outlined in section 4 of the *Water Services Licensing Act 1995*. These functions consist of licensing water service providers and monitoring the performance of water industry service providers. In addition, the Minister may refer to the ERA an inquiry on water issues. The Water Division would be responsible for managing this inquiry. The ERA licenses water service providers in Western Australia, setting out the conditions by which water and wastewater services operate. The ERA also benchmarks water providers to evaluate business performances and to encourage water providers to gain efficiencies and improve performance.The Commonwealth Department of Environment and Heritage may be involved in MAR proposals under the *Environment Protection and Biodiversity Conservation Act 1999.*

4.5 Aboriginal Heritage

The Western Australia Department of Indigenous Affairs (DIA) provided advice (DIA, letter 26 April 2005) that MAR proposals may impact on Aboriginal sites. DIA recommend that a comprehensive Aboriginal heritage study of any MAR area be undertaken, including desktop studies to identify any previously registered Aboriginal heritage sites within MAR areas. DIA also advised that an archaeological and ethnographic survey should be undertaken in consultation with the Aboriginal community. It is DIA's preference that Aboriginal sites are avoided. Where this is not possible, the proponent may seek the consent of the Minister for Indigenous Affairs to use the land under section 18 of the *Aboriginal Heritage Act 1972*.

4.6 Community Involvement

There is a high level of support for the concept of water recycling, with unfavourable attitudes generally found to be more likely with a higher level of human contact or proximity to the application (ARMCANZ/ANZECC 2000a). Community involvement from the initial planning stages will be important to allow any concerns to be identified and addressed.

The Water for a Healthy Country National Research Flagship recently released a report 'Predicting Community Behaviour in Relation to Wastewater Reuse – What Drives Decisions to Accept or Reject?' (Po et al. 2005). This reports on a three year investigation which attempted to develop a measure of community intended behaviour in relation to wastewater reuse. It includes the results of a case study of providing drinking water using MAR in Perth, in which 400 people were surveyed regarding their intended behaviours. The EPA recommends proponents of MAR schemes consider the findings of this report prior to the design of a community involvement plan.

Any MAR proposal subject to environmental impact assessment under section 38 of the *Environmental Protection Act 1986* will require a high level of community consultation. The EPA notes that it may be preferable in some cases that consultation and/or peer review of proposed schemes is carried out by an independent third party.

5. EPA Advice

5.1 Overarching advice

The EPA is of the view that MAR using treated wastewater has the potential to play an important role in the sustainable management of Western Australia's water resources. This is particularly the case given the reduction in rainfall which has occurred in the south west of the State since the mid 1970s, and the large reliance on groundwater resources. There are a number of potential environmental, health and social issues associated with MAR, and these will need to be addressed prior to the implementation of any significant MAR scheme.

The use of MAR has the potential to provide benefits for water resources and environmental management. These include maintenance of wetlands and caves, reduced salt water intrusion, increased water availability for irrigation use, and augmentation of drinking water supplies. The EPA recognises that it will not be possible to implement MAR using treated wastewater without some degree of risk. These risks should be assessed against the potential environmental and sustainability benefits of MAR schemes, and the risks associated with taking no action. The EPA expects that in a number of situations, the risks associated with MAR can be managed to negligible or low levels to provide, on balance, a number of benefits for water resources and environmental management.

The specific environmental risks associated with MAR are highly dependent on the proposal characteristics. These include the proposed wastewater treatment process, the intended final use of the recharged water, the environment likely to be impacted, aquifer characteristics, and the proposed management system. Proponents of MAR schemes will be required to perform a systematic risk assessment of their proposals. The EPA understands that the *National Guidelines on Water Recycling* (National Resource Management Ministerial Council), to be released for public comment in late 2005, will also support a risk management framework.

The EPA recommends a staged approach to MAR, starting with trials and projects of lower risk. Given the limited experience with MAR on the Swan Coastal Plain to date, and the site-specific nature of transport and attenuation of contaminants, the EPA expects that trials will be necessary prior to the implementation of any large scale MAR using treated wastewater.

The EPA supports the principles of the *National Water Quality Management Strategy* (ARMCANZ/ANZECC 1997, 2000a, 2000b), and has been given the task by Government of coordinating the implementation, and reporting on the success, of the framework for protecting the State's water resources which is set out in the *State Water Quality Management Strategy Document No. 6* (Government of Western Australia 2004), which provides a national framework for the protection of groundwater resources.

The goal of groundwater protection is to ensure that groundwater resources can support their beneficial uses in an environmentally, economically and socially sustainable and acceptable manner. Beneficial uses include abstraction for irrigation and stock, and maintenance of ecosystems, both in environment receiving groundwater discharge and within the aquifer itself. The EPA will not support MAR where it is considered likely, on the basis of risk assessment, to unacceptably affect the beneficial uses of groundwater or any other identified beneficial uses.

The EPA expects proponents of MAR schemes using treated wastewater to demonstrate that the recharge water is chemically and microbiologically compatible with the native groundwater. At the point of withdrawal or movement into marine or terrestrial water bodies supporting defined EVs, the recharge water should meet the relevant environmental water quality guidelines for protecting the designated Environmental Values of the water. In cases where MAR is reliant on the treatment of water by natural processes in the aquifer, EPA support will be dependent upon whether risk assessment provides assurance that the scheme will not cause unacceptable degradation of the aquifer or the marine environment, or detrimentally affect the beneficial use of the resource.

While there is currently no specific environmental legislation relating to MAR, it is the view of the EPA that Part V of the *Environmental Protection Act 1986* provides a suitable regulatory mechanism for managing the daily operation of MAR schemes. Any MAR proposal that is likely, if implemented, to have a significant effect on the environment should be referred to the EPA under section 38 of the *Environmental Protection Act 1986* for environmental impact assessment. At this time the EPA considers that any large-scale MAR using treated wastewater, or proposals for MAR or trials in areas of high environmental value, are likely to require formal assessment. The EPA expects that its assessment of such proposals would be informed by the results of scientifically sound studies to predict mixing and dispersion of discharges of MAR water and wastes, as well as the ecological and health-related consequences of these discharges. The EPA will apply the framework described in the *State Water*

Quality Management Strategy No. 6 when evaluating the potential marine environment impacts of MAR proposals.

The EPA may also develop an environmental management framework for the protection of groundwater and maintenance or enhancement of groundwater resources as the results of further research and trials become available. This would involve identification of Environmental Values and the development of Environmental Quality Objectives (management goals) to protect these values. Such a system would allow for the management of cumulative effects, as done for Perth's Coastal Waters (Environmental Protection Authority 2000).

MAR proposals require Department of Health approval under the *Health Act 1911*, in addition to planning approvals.

5.2 Potential Applications on the Swan Coastal Plain

There are a number of potential applications of MAR using treated wastewater on the Swan Coastal Plain that may prove to be technically feasible. A brief description of five key applications was included in the EPA's Discussion Paper for public comment (Environmental Protection Authority 2005), and is provided here along with the EPA's initial considerations due to the lack of details on these applications at this time. A summary of the potential applications, their risks and benefits and the key regulatory standards and processes, is provided in Table 2.

The EPA notes that the technology exists to provide engineering solutions to a large number of the water quality issues associated with MAR. However, for many MAR applications it may be cost prohibitive to treat wastewater to a high level. The issues of concern to the EPA will be dependent on a number of factors, including the proposed level of wastewater treatment and characteristics of the recycled water proposed to be used in MAR.

MAR for Improvement of Groundwater Quality

MAR to improve groundwater quality and prevent salt water intrusion may have application on the Mosman-Cottesloe Peninsula, containing the suburbs of Mosman Park, Cottesloe and Peppermint Grove. This area is underlain by a thin fresh groundwater lens overlying salt water.

The Peninsula is subject to salt water intrusion as a result of abstraction of groundwater by a number of large water users, including golf courses, park and recreation reserves and private schools. Appleyard (2003) estimates that the amount of freshwater beneath the Cottesloe peninsula has been reduced by about 40% due to groundwater abstraction. In 2003, groundwater salt levels reached a record high. The average salinity reached 1460 parts per million (ppm) in January, and peaked at 2600 ppm, the highest since monitoring began in 1996 (Post Newspaper 2004). Salinity of 1200 ppm was reported as being likely to kill many garden plants, while Norfolk Island pines can tolerate salinity of approximately 1100 ppm.

Table 2. Summary of key issues and requirements related to potential MAR applications

				REGULATORY STANDARDS/PROCESS				
				HEALTH		ENVIRONMENT		
	MAR Application	Key Risks	Key Benefits	Criteria	Legislative role	Criteria	Legislative role	EPA role and comments
1	Improvement of groundwater quality	- Environmental impacts e.g. eutrophication, Fish Habitat Protection Area - Chemicals of concern	- Reduce salinity in freshwater aquifer - Reduce salt water intrusion	Likely Class A	- *Health Act 1911* - Potential for human exposure, uncontrolled access	NWQMS TBD	- Part III and V *EP Act* - Swan Canning EPP - Coastal Zone SEP (in prep)	Likely to require assessment
	e.g. Mosman Peninsula	Potentially low attenuation of contaminants due to karstic limestone subsurface	- Increased water availability - Reduce use of drinking water for irrigation					
2	Irrigated horticulture	- Environmental impacts - Chemicals of concern - Impacts on other beneficial uses	-Manage declining water tables - Reduce risk of acid sulphate soils	Class A	- *Health Act 1911* - Potential for human exposure, uncontrolled access	NWQMS TBD	- Part III and V *EP Act* - Lakes EPP - Gnangara EPP - Clearing Regs - Swan Canning EPP	Large-scale proposals require referral to the EPA
	e.g. Carabooda	Priority 3 PDWSA to west	Increased opportunity for horticulture in Gnangara				Approval under MWSSD Act if in PDSWA	Likely to require assessment
	e.g. small scale horticulture with single or several users			Potentially Class B	Controlled access			EPA assessment dependent on potential environmental impacts
3	Multiple benefits		- Maintain or improve environmental features currently impacted by lowered water tables - Increase sustainability of horticulture - Reduce risk of acid sulphate soils	Class A	- *Health Act 1911* - Potential for human exposure, uncontrolled access	NWQMS TBD	- Part III and V *EP Act* - Lakes EPP - Clearing regs - Gnangara EPP - Swan Canning EPP - Lakes EPP	Large-scale proposals require referral to the EPA
	e.g. Gnangara Mound							
4	Integrated water management in new residential areas	- Environmental impacts, e.g. groundwater dep	- Reduce consumption of higher quality water for low quality requirement activities	Class A	- *Health Act 1911* - Potential for human exposure,	NWQMS TBD	- Part III and V EP Act - Lakes EPP - Clearing regs	EPA assessment dependent on potential environmental impacts

	MAR Application	Key Risks	Key Benefits	REGULATORY STANDARDS/PROCESS HEALTH Criteria	Legislative role	ENVIRONMENT Criteria	Legislative role	EPA role and comments
		ecosystems - Impacts on other beneficial uses	(e.g. irrigation) - Reduce risk of acid sulphate soils		uncontrolled access		- Gnangara EPP - Coastal Zone SEP - Swan Canning EPP	
	e.g. Alkimos	Priority 1 and 3 PDWSA in proximity to MAR sites						
5	Increase drinking water supplies	- Environmental impacts - Impacts on beneficial uses - Protection of drinking water source - acceptability to community	- Increase public drinking water supplies - Maintain or improve environmental features currently impacted by lowered water tables - Reduce risk of acid sulphate soils	Class A+	- *Health Act 1911* - Augmentation of drinking water supplies following MAR. - Health biological and chemical guidelines	- NWQMS - ADWG - TBD	- Part III and V EP Act - Approval under MWSSD Act (if in PDSWA) - Lakes EPP - Clearing regs - Gnangara EPP - Swan Canning EPP	Further information and studies of MAR on the SCP is necessary before EPA would support MAR in a PDWSA
	e.g. Pinjar borefield	Existing Priority 1 PDWSA – priority value of area for drinking water						Formally assess

Note this table presents only the key requirements related to each of these scenarios. For the complete list of legislative requirements refer to Section 4. Only additional factors are listed for each specific application example.

ADWG	Australian Drinking Water Guidelines
EP Act	*Environmental Protection Act 1986*
EPP	Environmental Protection Policy
MWSSD Act	*Metropolitan Water Supply, Sewerage and Drainage Act 1909*
NWQMS	National Water Quality Management Strategy
PDWSA	Public Drinking Water Source Area
SEP	State Environmental Policy
TBD	Further criteria To Be Determined by the Department of Environment

In order to reduce salinity and increase the availability of groundwater suitable for irrigation, tertiary treated wastewater from the Subiaco Wastewater Treatment Plant could be used to recharge the superficial aquifer underlying the Mosman Peninsula by subsurface infiltration. The Water Corporation estimates that 0.5 GL of recharge per annum would be used by private irrigators from backyard bores, and 2.5 GL per annum for large greenspace irrigators, such as golf courses.

One of the key environmental risks associated with such a proposal is the potential for eutrophication of groundwater or surface water ecosystems, in particular the Swan River and the near-shore ocean. The importance of this issue would be dependent upon the characteristics of the wastewater prior to recharge. It is possible that MAR into a fractured limestone subsurface may provide little attenuation in contaminant concentrations due to preferential flow. The EPA also notes the complexity of predicting solute transport in fractured media.

MAR on the Mosman-Cottesloe Peninsula may have implications for the Cottesloe Reef Fish Habitat Protection Area, which was established to protect the biodiversity of this ecologically significant area. Groundwater discharge from coastal seepage faces and offshore springs may have an important role in sustaining biological diversity on wave-cut platforms that fringe part of the coastline of the area (Appleyard, personal communication). The Water Corporation however submit that Western Australian waters are so nutrient poor that additional nutrients would be likely to enhance primary production and benefit fisheries (Water Corporation submission 28 June 2005). Further investigation of this would be required in order for the EPA to assess this proposal.

The Department of Health advises that the level of treatment required for groundwater quality improvement will be dependent on the likelihood of extraction for backyard bores or other forms of human contact. If there is no possibility of human exposure, MAR for the improvement of groundwater quality does not need to meet any Department of Health guidelines.

In the case of this application, the public could access the aquifer via private bores, and plausibly use this water for vegetable growing or filling swimming pools. Also children playing in yards may drink it. Therefore all pathogen guidelines must be met. It is assumed that exposure in this setting will remain limited and casual, so there is no technical requirement to meet chemical guidelines for human water consumption. A demonstration of a seven log reduction[4] in pathogens is required if wastewater is the source of recycled water. An equivalent log reduction would be required for recycled water sourced from greywater or stormwater. The Department of Health will permit the required log reductions to be demonstrated in the unsaturated zone for infiltration recharge schemes. The number of log reductions required may be reduced if local data are developed demonstrating consistent microbiological reduction activity in local aquifers.

[4] A measure of effectiveness of a process to remove certain viruses or bacteria. Each log reduction reduces the number of infectious units (e.g. viruses or bacteria) by a factor of 10. For example, one log reduction reduces the original level by 90%, two log reductions reduces the original level by 99%, three by 99.9%, etc.

The EPA notes that the Water Corporation submission (22 August 2005) states that based on current knowledge and advice from Department of Environment, the Water Corporation has made the decision not to investigate MAR on Mosman Peninsula further at this time, as it does not consider it possible to provide the level of certainty required to get approval for this scheme.

The EPA notes that the Water Corporation submission (22 August 2005) states that based on current knowledge and advice from Department of Environment, the Water Corporation has made the decision not to investigate MAR on Mosman Peninsula using treated wastewater further at this time, as it does not consider it possible to provide the level of certainty required to get approval for this scheme. Supply of excess drainage water, however, is likely to be more viable, and Water Corporation will continue investigations regarding the potential for supply from Herdsman Main Drain to address water needs for the Mosman Peninsula via MAR.

Conclusion: The EPA supports in principle the concept of MAR to improve groundwater quality, but considers that further research would be required in order to evaluate any specific MAR proposal for this purpose due to the potential for environmental impacts.

MAR for Irrigated Horticulture

The Carabooda area, located on the Gnangara Mound north of Wanneroo, is the major market gardening region north of Perth. As a result of climate change, water use by nearby pine plantations, and a large amount of abstraction, groundwater levels have declined by up to 5 metres over the last 25 years. This has impacted remnant bushland areas and a number of important groundwater dependent ecosystems including the Yanchep caves root mat communities, Loch McNess, Lake Wilgarup, Lake Yonderup, Lake Nowergup and Coogee Springs.

MAR using treated wastewater could be implemented to manage declining water levels and provide water for sustainable irrigation in horticultural areas. This has the added advantage that wastewater contains elevated levels of nutrients, and thus may decrease fertiliser requirements.

Conceptually, treated wastewater could be piped from either Beenyup or proposed Alkimos Wastewater Treatment Plant to the eastern (upgradient) side of the horticultural precinct to be recharged into the unconfined superficial groundwater aquifer. Horticulturalists would be able to extract the recharge water from the superficial aquifer using existing private bores. Currently approximately 10 GL per year of superficial groundwater is allocated to horticulture in Carabooda. There is the potential for MAR to supply up to 20 GL per annum of treated wastewater, including some environmental allocation.

In considering this potential application, the EPA notes that irrigated horticulture using wastewater is relatively common around the world. For example, in the Northern Adelaide Plains of South Australia over 20 GL per year of wastewater from Bolivar Wastewater Treatment Plant is used directly in irrigated horticulture. The wastewater is treated to be suitable for unrestricted horticultural use, including spray irrigation of salad crops (Australian Academy of Technological Sciences and Engineering 2004). Produce grown with recycled water in South Australia, Victoria, New South Wales and Queensland are sold in markets both nationally and internationally (Jim Kelly, personal communication).

The use of MAR, as opposed to direct piping of treated wastewater, allows for water quality improvement in the aquifer during storage, for example pathogen die-off, and provides a means of storing the recycled water to meet seasonal demand. However, there is greater potential for environmental impacts. The EPA considers that the key environmental issues requiring further investigation prior to implementation of a large-scale MAR scheme for horticulture are:

- water quality improvements during MAR, if improvement is required during storage in the aquifer;
- pathogen survival;
- impacts on the aquifer, for example, as a result of changes in the aquifer chemistry;
- impacts on wetlands and ecosystem values, including stygofauna, particularly due to chemicals; and
- the potential for bioaccumulation of heavy metals.

The EPA also notes that there is a need for consideration of water use efficiency in the horticultural industry. MAR should not be viewed as a panacea to water shortages or an opportunity to increase abstraction, placing pressure on other environmental values.

The Department of Health advise that the level of treatment for horticultural areas is dependent on the type of horticulture and the extent of possible human exposure. For ready to eat produce, without a further disinfection or processing step, e.g. lettuces, an assumption is made that human exposures of 10-100 mL are possible and demonstration of log reductions to Class A standard is required. For produce with a protective peel, e.g. oranges, or produce not directly ingested without cooking, a lower standard of pathogen reduction will be acceptable. However, horticultural areas are usually mixed in nature, and it is unlikely that schemes would be viable without full Class A treatment processes. Data does not exist to suggest horticultural reuse schemes lead to a concentration of chemicals in produce. Therefore, in the absence of an indirect drinking water component to the scheme, there is no requirement to meet Department of Health chemical criteria for human consumption. For public acceptance and transparency, it is likely that chemical monitoring will be necessary to reassure the public of produce safety.

Conclusion: The EPA supports in principle MAR to provide water for irrigated horticulture. Trials may be appropriate in some circumstances to demonstrate that water quality improvements would be achieved to meet Department of Health requirements, and that MAR will not result in unacceptable environmental impacts. MAR should not be viewed as a panacea to water shortages or an opportunity to increase abstraction, placing pressure on other environmental values.

MAR for Multiple Benefits

There are multiple demands for groundwater at the western edge of the Gnangara Mound. These include horticultural irrigation, pine tree plantations, environmental needs, in the form of groundwater dependent ecosystems including wetlands and caves, and public water supply needs drawn by the Water Corporation. It is likely that a MAR scheme could be devised that would have multiple benefits including maintenance of environmental needs. Groundwater modelling is currently in progress to determine the volume and location of recharge. It is likely that locations for recharge would be largely in the Carabooda or Pinjar regions, similar to those for horticultural irrigation and drinking water supplies, but would be able to provide benefits for the whole Gnangara groundwater resource.

The EPA considers that the key environmental issues requiring further investigation prior to implementation of large-scale MAR scheme for multiple benefits are as cited for Irrigated Horticulture.

Conclusion: As for MAR for irrigated horticulture, the EPA supports MAR for multiple benefits in principle. Trials may be appropriate in some circumstances to demonstrate that MAR will not result in unacceptable environmental impacts

MAR for Integrated Water Management in New Residential Areas

MAR may be implemented in new residential areas as part of an integrated water management scheme. For example, around the proposed Alkimos and East Rockingham Wastewater Treatment Plants there is the potential to use MAR to recharge the aquifer with treated wastewater, which could be abstracted for backyard garden use or irrigation of public open spaces and golf courses. This is currently done in Salisbury, Adelaide at the Mawson Lakes development. The $16m recycling scheme treats a mixture of treated wastewater from the Bolivar Wastewater Treatment Plant and stormwater harvested in Salisbury to Class A standard. The treated wastewater is stored and extracted from deep saline aquifers (Gardner 2003). This is used in combination with a third pipe system (see Section 6), with the extracted water used for all outdoor purposes and toilet flushing.

The Department of Health advise that the critical component of integrated schemes is the presence or absence of "in-house use". All schemes connected to each residential property, even if for toilet flushing or bathroom use alone, must be treated to a Class A standard. The majority of previous reuse schemes involving in-house usage have at some stage been associated with cross-connection issues. Accordingly, when this possibility is factored in, quantitative microbial risk assessment modelling requires Class A pathogen log reductions. As the schemes described above for new residential areas do not include a component of drinking water reuse, the Department of Health do not require chemical monitoring. Schemes involving reuse for drinking water are covered below. Schemes which only involve open space irrigation or other external use may have lesser quality pathogen standards.

Conclusion: The EPA supports in principle MAR using treated wastewater as a component of integrated water management in new residential areas. The consideration of any specific proposal will require detailed information if any significant environmental impacts are likely. The EPA also recommends consideration of third pipe systems, as discussed in Section 6.

MAR to Increase Drinking Water Supplies

As discussed in Section 3.1, MAR schemes to augment drinking water supplies currently exist in a number of locations around the world. The potential for MAR to increase drinking water supplies is also being investigated in further areas, including Pima County Arizona (Arizona Daily Star, 19 June 2005), and Toowoomba in Queensland (ABC News Online, 13 July 2005).

The primary issue for use of MAR to increase drinking water supplies is protection of public health. Use of MAR for drinking water reuse raised the greatest number of concerns in public submissions and by attendees at the public forums, however, the majority of submitters/attendees, supported the concept of MAR for drinking water reuse. Extensive community consultation should occur before developing and implementing any such scheme.

The Gnangara Mound is Perth's primary source of groundwater for drinking water supplies. A reduction in rainfall for Perth since the mid 1970s has resulted in reduced natural recharge and declining water levels on the mound. MAR therefore provides a significant opportunity for offsetting the reduction in natural recharge to maintain or increase drinking water supplies from the Mound.

The Water Corporation conceptually propose that treated wastewater from the Beenyup Wastewater Treatment Plant, following advanced tertiary treatement (with micro-filtration and reverse osmosis), could be used for MAR on Gnangara Mound. The wastewater could be recharged either by piping inland either for infiltration to the superficial aquifer, or by injection into the Leederville confined aquifer.

Such a scheme would allow increased upstream abstraction of native groundwater, and the potential for later abstraction of the recharged water for public drinking water supplies. The recharge and abstraction points would be separated by several kilometres, and would therefore meet the Department of Health *Recycled Water – Groundwater Recharge Guidelines* requirement of, respectively, at least six or nine months retention time in the aquifer, following infiltration or injection. It is expected that the sequential purification provided by advanced tertiary treatment, the natural capacity of the aquifers to purify the water, along with dilution due to mixing with the native groundwater, would be signficant.

With current flows from Beenyup WTW, up to 27 GL per year of tertiary treated effluent could be recharged, with an estimated 7 GL per year of secondary treated and RO reject wastewater discharged to the ocean through the existing ocean outfall.

The Water Corporation Draft Position Statement '*Public Drinking Water Source Areas and Aquifer Replenishment with Recycled Water*' states that any MAR proposal in a Public Drinking Water Source Area (PDWSA) would need to demonstrate no increase in risk to water quality (equating to the DoE management strategy for Priority 2 areas).

Any MAR project in a Public Drinking Water Source Area (PDWSA) would require the Department of Environment approval. The provisions of the Gnangara Mound Crown Land Environmental Protection Policy also apply. The Department of Environment has confirmed that detailed scientific studies, trials and assessment of the social acceptability of indirect drinking water reuse of treated wastewater should be carried out to demonstrate its viability, prior to any large scale scheme. The trials should preferably be undertaken outside of operational PDWSAs. Depending on the site chosen for MAR, there may also be surface and underground ecosystems that would require protection.

All MAR schemes which involve a component of indirect drinking water reuse would be required to comply with the full spectrum of Health Department Guidelines (Appendix 2) or subsequent revisions thereof. The Health Department also considers that trials should be undertaken outside of PDWSAs, particularly on the fate of chemicals, before any trial in a PDWSA.

Conclusions: The EPA supports further investigation of MAR to increase drinking water supplies. In line with Department of Environment and Health Department advice, the EPA considers appropriate studies and trials should be undertaken outside PDWSAs. Any future proposal in a PDWSA would be assessed on its merits, including an assessment of risk, and be subject to full public review.

The EPA supports the *National Water Quality Management Strategy* view (Government of Western Australia 2003c, 2004) that indirect drinking water reuse may in some cases be the best planning option for the management of the water cycle, where fresh water resources are limited.

6. Other advice

The EPA recommends further investigation of third pipe systems for specific applications, particularly new developments. These are centralised schemes based on recycled water (obtained either from wastewater or stormwater) supplied to households. The schemes are known as third pipe, as scheme drinking water is supplied in the first pipe, wastewater leaves the house in the second pipe and recycled water is supplied through the third pipe connected to the residence. In some schemes the third pipe provides water only for outdoor use, while in other schemes this water is also used for toilet flushing.

It is recognised that third pipe systems are expensive to install in already built urban areas. However the EPA considers that third pipe schemes using wastewater warrant consideration in new urban areas, particularly near proposed new wastewater treatment plants, such as East Rockingham and Alkimos.

A number of third pipe systems exist in residential areas around Australia. These include Rouse Hill in New South Wales, New Haven in Adelaide and Springfield in Queensland. At Rouse Hill, for example, 4.4 ML/day of wastewater from the Rouse Hill wastewater treatment plant is treated for reuse by ozonation, microfiltration and superchlorination. This provides water to 12 000 homes using purple pipes (Australian Academy of Technological Sciences and Engineering 2004). The major issue associated with this scheme to date has been the number of plumbing errors in connecting Sydney Water mains to house fittings, leading to cross connections (Australian Academy of Technological Sciences and Engineering 2004).

One of the key projects in Australia is the Pimpama Coomera WaterFuture Project in Queensland. This is a pilot study for exploring new methods of water management. This includes supply of water to houses from rainwater for bathrooms and laundries, recycled water for toilet flushing and external uses, and scheme drinking water for use in the kitchen. The project aims to reduce drinking water consumption by 84%, and use 86% of recycled water used from the new Pimpama Wastewater Treatment Plant (Gold Coast City Council 2004). The council also intends to investigate MAR as a means of water storage for times of low demand.

The Department of Health advise that Class A water would be required for any third pipe system, along with stringent governance regarding the management and ongoing maintenance of any such proposals.

7. Future Work

MAR is a developing technology in Australia (Scatena and Williamson 1999). It is the view of the EPA that further research, including trials, is required before any large scale MAR using treated wastewater can operate on the Swan Coastal Plain.

It is considered that there is a reasonable level of knowledge of the health risks associated with MAR, and how gaps in this knowledge can be addressed (see Department of Health Draft Recycled Water – Groundwater Recharge Guidelines). With respect to environmental risks, the EPA recommends that the Department of Environment develop a strategy to address quantification of the environmental risks associated with MAR, and how any knowledge gaps can be addressed.

Key issues identified by the EPA for further consideration include:

- the potential sustainability benefits of MAR;
- environmental risks and risks associated with chemicals in treated wastewater, such as endocrine disruptors, heavy metals, pharmaceuticals and nutrients. This should include modelling to predict environmental concentrations for assessment against predicted no effect concentrations.
- the behaviour of disinfection by-products, and potential for trihalomethanes to be formed;
- impacts of recharge water on chemical and microbiological characteristics of the native groundwater;
- the potential for chemicals in wastewater to bioaccumulate in the food chain (Department of Fisheries, 22 November 2004);
- the fate and survival of introduced micro-organisms in groundwater;
- the chemistry of MAR on the Swan Coastal Plain and the potential for the release of arsenic;
- aquifer composition under conditions of long-term recharge of wastewater, and
- social studies regarding community knowledge and acceptance of MAR.

The EPA considers that it would be valuable to consolidate and consider together the results of all MAR trials to date. There is also the potential to gain data from existing operations, such as the Kwinana Wastewater Treatment Plant, regarding parameters such as pathogen die-off.

Trials were identified by members of the public as an important stage in the public acceptance of MAR, and the EPA concurs with this view. The EPA also expects that trials would be valuable in the study of chemical and biological processes in the subsurface, and as a test of predictive transport modelling.

The EPA notes that a collaborative research project (including the Department of Environment, Department of Health and Water Corporation) is proposed under the Premier's Collaborative Research Program. This is planned as a three year project aimed at characterising treated wastewater for drinking, following reverse osmosis treatment. Wastewater would be characterised for its microbial and chemical constituents, and to understand any seasonal and catchment differences in trace contaminants of concern in relation to human and environmental health. One of the major project aims would be to determine the key chemicals of concern in Perth's treated wastewater which need to be monitored and managed, and the effectiveness of best available high technology treatment processes to remove them.

The Water Corporation has also begun a project with Oceanica and input from the Department of Environment, to assess the environmental risks of MAR using treated wastewater on the Gnangara Mound. The project is a first stage in characterising the risks associated with MAR on the Swan Coastal Plain and determining the level of wastewater quality improvement required to ensure an acceptable environmental outcome, as required by the Water Reuse Steering Committee. The environmental risk assessment work will define the process needed to address the environmental risks and impacts associated with the use of treated wastewater for groundwater recharge, and determine the process to address any information gaps that currently prevent risks from being quantified.

The Department of Environment is developing a policy on MAR in the 2005-06 financial year. It is expected that this will address options for trading and/or cost recovery of MAR schemes. The Department of Environment are also developing a Water Quality Protection Note 'Artificial Recharge of Groundwater'. This will provide the current views of the Department on MAR, and provide guidance on the issues of environmental concern. It is expected that this will be released in late 2005.

8. Conclusions

The EPA submits the following recommendations to the Minister for the Environment:

1. That the Minister notes that this strategic advice is for managed aquifer recharge using treated wastewater on the Swan Coastal Plain;
2. That the Minister considers the report on the relevant factors as set out in Section 4;
3. That the Minister notes that the EPA supports in principle the concept of wastewater use and supports the investigation of MAR using treated wastewater as a means of water management on the Swan Coastal Plain. The EPA has provided a strategic framework in which the concept of MAR on the Swan Coastal Plain can be considered further.

Appendix 1

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Appendix 2

Draft Department of Health Guidelines

Recycled Water

Groundwater Recharge Guidelines

Department of Health
Government of Western Australia

Recycled Water
Groundwater Recharge Guidelines

Table of Contents 2

Principles Underpinning Health Guidelines

A number of principles underpin the derivation of health guidelines for aquifer recharge settings and these must be addressed in any proposal. They are:

1. All schemes must be individually approved although new users may be added to a scheme if the proposed new use is of an equivalent or lesser human exposure level..

2. All schemes must adopt a risk management framework.

3. All schemes are approved on a “fit for purpose” basis. The allocation of any proposed scheme to a “fit for purpose” category is based on the extent of human exposure and the subsequent modeled risk. For example, all aquifer recharge schemes involving indirect potable use are assumed to have an ingestion exposure of two litres per day for 70 years.

4. Requirements will include both quality and process components

5. All schemes require three types of monitoring.

    5.1. Validation (will it work): this may include chemical and pathogen testing to demonstrate effectiveness of removal processes however surrogates can be used to demonstrate this (eg MS2 phage)[1]. Validation testing is based on obtaining a sufficient database to provide convincing evidence that a process or method will work.
    5.2. Operational Testing (is it working): this will include a series of measurements and observations to confirm performance of preventative measures. Operational monitoring is based on the need to allow timely intervention and can be both continuous (disinfection, filtered water turbidity) or six monthly (inspection of structures).
    5.3. Verification (did it work): this may include testing for chemicals and micro-organisms. The frequency of required monitoring is based on an assessment of need, and is based on notional ideas about the variability of water quality characteristics system complexity and other perceptions.

6. The water extracted from the aquifer after the recharge process must be of a required quality without extra treatment being necessitated.

7. While a risk management approach is required for all aquifer recharge proposals, for those involving indirect potable reuse, the best available technology is also mandated and must include a reverse osmosis component.

[1] MS2 phage is a bacteriophage or a virus that infects bacteria. These bacteriophages are easier to grow and propagate than viruses which infect man and are used to test how other viruses would act when these viruses can’t be examined directly. MS2 phage, a single stranded RNA virus, has been used in many water reuse schemes to monitor how, more difficult to assess, human viruses of concern would be affected.

8. The major health issues of concern are chemicals and pathogens, including viruses, bacteria, helminths, and parasites. Overseas work has demonstrated the relative unimportance of heavy metals and radiation although local validation of this will be required.

9. Separation times will be required between recharge and extraction for all proposals involving indirect potable re-use. Minimum times based on the mode of recharge will be identified. These will be shorter for infiltration compared to injection but, in all cases, the longer the time between recharge and extraction, the greater the margin of safety. Minimum separation distances between infiltration or injection and extraction will also be required. Separation times will also be required for class A schemes such as horticulture, if these have been approved without a requirement for full treatment prior to spreading.

WATER QUALITY OBJECTIVES

Pathogen Improvement Requirements

There has been significant recent debate about the acceptable level of pathogen reduction which should be mandated for water quality. Various models of quantitative microbial risk assessment (QMRA) have been assessed. The most recent consensus approach appears to be to set a health modeling limit of 1×10^{-6} Disability adjusted life years (DALYS) to allow for both the risk of infection and the potential severity of infection as well. The required log removal numbers using this approach equate quite closely to those derived from modeling a 1 in 10^{-3} infection risk.

In the derivation of the required level of disinfection or log removal, the most important factor is the concentration of pathogens in the source material so direct pathogen monitoring of sewerage may be required to undertake the risk assessment. In a DALY model, viruses remain the most important pathogen in terms of probability of exposure as generally they lead to more severe outcomes of infection. To satisfy viral log removal QMRA criteria however would require demonstration of very low concentrations of viruses eg. one per 10,000 litres and this is beyond the capacity of current laboratory processes. In view of this, aquifer recharge proponents will need to demonstrate:

- Validation of their proposed process. For example, class A or indirect potable schemes utilizing treated wastewater will need to demonstrate a 7 log pathogen reduction in influent or demonstrate a 5 log removal after the secondary treatment stage. This validation must cover the full range of pathogens although indicator organisms such as MS2 phage can be substituted for direct viral testing. The required extent of validation processes will be decreased if the process proposed is based on systems with known pathogen removal rates such as a standardised Title 22 system.

- A HACCP type framework with corrective actions for potential problems. This framework should incorporate a scheme specific operational testing regime with parameters such as turbidity, UV light dose, chlorine residual etc relevant to the proposal.

- A verification model based on pathogen testing.

The required standard of microbiological water quality for varying reuse schemes including MAR is shown in Appendix A. (Page 11)

The expected microbiological effectiveness of treatment trains, on site controls and possible suitable uses currently under consideration in the proposed national reuse guidelines are shown in Appendix B. (Page 14)

Heavy Metals

International and interstate data suggest that the combination of source control programs and standard wastewater treatment processes eliminate heavy metals as a health risk in reuse projects. Monitoring of post treatment effluent has invariably identified heavy metal concentrations of 1 to 2 orders of magnitude below current drinking water guidelines. In view of this, proponents will be required to submit a single set of data confirming the absence of heavy metals and no further monitoring will be required.

Chemicals

An extensive assessment of potential chemical impacts is required for indirect potable schemes and the information gleaned from this assessment must be fed into source control programs where relevant.

Proponents will need to undertake a review of the following groups, however much of this is for scheme assessment and not all agents will have action levels or required responses:

- Chemicals with known maximum contaminant levels as identified in the current drinking water guidelines.

- Chemicals without known MCLs but for whom an action level exists.

- Priority toxic pollutants as determined by the Department of Health.

- Endocrine disrupting chemicals, pharmaceutically active compounds and other chemicals. In this group required assessments will include:

    - some synthetic and natural hormones such as ethinyl oestradiol, 17-B oestradiol and oestrone;
    - a range of industrial endocrine disruptors including bisphenolA, nonylphenol and nonylphenol polyethoxylate, octylphenol and octylphenol polyethoxylate, and polybrominated diphenylethers;

Phthalates are not on the list of required monitoring chemicals as epidemiological evidence suggests it is unnecessary.

While EDC monitoring will be required, it is as much for public transparency as for any health risk assessment. Recent Queensland work using mosquito fish (*Gambusia)* demonstrated no intersex or shortening of the male fin in recycled water. Additionally, concentrations of endocrine disruptors required to affect fish were higher than those found naturally in the wetlands post secondary treatments from wastewater treatment plants. In addition, toxicological effects were possible at levels lower than those required to cause endocrine effects. Other non reuse sources of endocrine disrupting compounds are ubiquitous and the relative risk for human health from recycled water remains negligible.

Research is continuing and will be monitored however, at this point of time, endocrine disrupting compounds are regarded not as a health issue but are an environmental and public perception issue.

- Other priority pharmaceuticals which are not endocrine disruptors will also need to be measured.

- Tentatively identified or “yet to be imagined” Chemicals. Considerable debate has occurred regarding the public perception requirement to demonstrate the absence of any possible harm from currently identified compounds at levels below detection or compounds outside the range of normal review. Some overseas regulators have managed this process by requiring mass spectrographic reviews of wastewater looking for tentatively identified compounds which would then require further investigation, and also by setting a total organic carbon (TOC) limit on individual schemes to ensure that oxidative removal processes were sufficient to deal with all organics. These overseas guidelines currently include a requirement to reduce TOC to a level of 1mg/L litre. With spreading schemes it is allowable for the required TOC levels to be achieved in mound monitoring in the vadose zone and not to be required in the spreading water itself. These strict TOC requirements also only apply to intentional ground water recharge for reuse municipal water supplies and are not required in a number of other recharge settings. In Western Australia a program to look for tentatively identified compounds may not be a requirement for operational reuse schemes but the possible benefit of this program will be assessed in aquifer recharge trials over the next few years. Similarly a decision on the benefits of such tight TOC requirements will be made after recharge trials.

  Overseas schemes have also set limits on total nitrogen levels at 5mg/L. These levels were set due to concerns over potential increases in total nitrogen fixation in the aquifer and concerns that subsequent nitrite/nitrate levels in drinking water may exceed guidelines. Data are not however available to support the concerns that fixation is occurring. In addition recent reviews of the real health importance of nitrates in drinking water have tended to the view that only met-haemaglobinaemia is important and that even the importance of this as a neonatal concern has been greatly overstated leading to overly restrictive nitrate guidelines. These recent data will be considered when a final decision is made on total nitrogen in reuse schemes.

- At this point in time, public health guidelines are focused on protection via mandated process trains, and the collection of further information during recharge trials in Western Australia. Data from monitoring wells in trials will heavily influence final decisions.

The list of chemicals required to be monitored in Western Australia for any indirect potable scheme associated with MAR is attached in Appendix C. (Page 17) This overly-exhaustive list forms the basis of discussions for reuse monitoring during reuse and MAR trials. The Department of Health anticipates reducing the list after demonstration of effective chemical reduction processes during upcoming trials.

A number of lists exist to set investigation and intervention levels for chemicals of concern. These include the Californian wastewater reuse guidelines, the Australian Drinking Water Guidelines and the European Union predicted no effect levels (PNEC). This information, along with the results of chemical testing during reuse trials, will be used to set levels for action (divert scheme water), levels for notification (look at what is happening), and levels of interest (collect information until we understand more) in the final WA Health indirect potable guideline.

Radiation

Current Western Australian drinking water guidelines for testing radiation reflect significant background levels in some sources and testing difficulties. Rather than the full suite of ADWG testing water authorities are only required to test for radium sources and not for total alpha or beta levels. Reuse schemes will require a source control program which may identify industrial sources and the need for extra testing. Overseas work however, suggests that generic potential sources of radiation, such as the excretion of sources in the urine post radiation therapy, are unimportant due to the small number of affected individuals, the associated dilution and the short half life of isotopes involved.

Reuse schemes will only be required to meet current radium testing guidelines applicable to drinking water. However the issue has been referred to the West Australian Radiological Council and guidelines may be altered if the councils' deliberations require this, or if source control reviews identify concerns.

Minimum Treatment Processes

The required minimum treatment processes include validating systems to comply with the requirements of pathogen log reduction and to comply with requirements for chemical removal described previously.

Current consensus is that some aquifers provide minimal control over chemical removal so all Western Australian aquifer recharge schemes involving indirect potable reuse will require a reverse osmosis step within the treatment process. Reverse osmosis is a proven technology for chemical removal and while some data exist that nano-filtration technology may be a viable option, nano-filtration is a less well proven technology and is not deemed acceptable at this point of time.

Monitoring Requirements including testing wells

The requirement for validation, operational monitoring and verification were outlined in the principles underpinning scheme approvals.

Validation for aquifer recharge schemes will include weekly demonstration of pathogen reduction in all 4 pathogen groups for at least 2 months prior to commissioning of schemes. This pre-commissioning phase may be increased if expected log reductions are not met or 'innovative technology' is used to achieve the pathogen reductions.

Validation will also include continuous monitoring of key operational conditions relevant to the plant construction eg turbidity, conductivity, chlorine residual … These parameters will form the basis of operational monitoring subsequently. In addition precommisioning will also involve quarterly review of chemical levels for the priority list as determined by the Department of Health, an assessment of TOC levels and some mass spectrographic analysis.

Interim monitoring wells will be required for all schemes. These wells will be used to:

- Confirm retention times between spreading / injection and extraction zones via tracer studies
- Monitor changes in chemical levels with time in the aquifer
- Confirm the absence of microbial contamination

A final specific determination of the extent of monitoring required will be made by the Department of Health in consultation with proponents after assessent of each individual scheme and the risks to human health.

Source Control Program

A source control program must be implemented and should include:

1. An assessment of the fate of the specified contaminant compounds through the wastewater and recycled water treatment systems.
2. A source investigation and monitoring program focused on the specified contaminants.
3. An outreach program to industrial, commercial and residential communities within the sewage collection agency's service area to manage and minimize the discharge of compounds of concern at the source.
4. A program for maintaining an inventory of compounds discharged into the wastewater collection system so that the new compounds of concern can be evaluated rapidly.

Overseas studies have shown that these source control programs can aid community input to and acceptance of reuse schemes.

Recharge methods, retention times and distance to extraction

Proposals should include an overview of the proposed recharge methods whether injection or via spreading grounds and an estimate of the retention time and an outline of distance to extraction point. Precommisioning monitoring will be required to confirm estimates.

As a general rule spreading systems will require retention times in the aquifer of at least six months and a notional separation of 150m between spreading and extraction with the retention time critical. Injection proposals will require retention times in the aquifer of at least nine months and a notional separation of 600m between injection and extraction

Engineering Report

All proponents shall submit an engineering report that includes an operations plan to the Department of Health. This report shall be prepared by an engineer experienced in the fields of wastewater treatment and public water supply, in conjunction with a geologist experienced in hydrogeology.

Recycled water shall not be spread or injected until a complete engineering report is submitted and the Department of Health has issued an approval for precommisioning work to begin.

The engineering report shall consist of a comprehensive investigation and evaluation of the project, impacts on the existing and potential uses of the impacted groundwater basin, and the proposed means for achieving compliance with the water quality criteria.

The engineering report shall include, but not be limited to, the following:

- A description of the proposal;
- An engineering plan of the recycling plant, transmission facilities, spreading basins/subsurface injection bores, and monitoring bores;
- A hydrogeologic study on the impacted groundwater basin that addresses the following:
    - Impact of the proposal on domestic groundwater sources;
    - Description of any other existing or proposed projects that could impact the groundwater basin, and an estimate of the cumulative impact on water quantity and quality with and without the proposed project;
    - Sources of groundwater basin recharge water, areas of surface spreading or subsurface injection, groundwater quantity, quality, and flow patterns for all aquifers in all impacted groundwater basins;
    - For new projects, a description of the pre-project groundwater quality in the impacted groundwater basin;
    - For all bores that will be impacted by the proposed project:

        - ♦ Use of each;
        - ♦ The estimated or measured shortest recycled water retention time underground and horizontal separation, along with the methods for obtaining these;
    - Quantitative descriptions of the aquifer transmissivity, groundwater movement, historic depth-to-groundwater, safe yield of the basin, influence of localized pumping, and usable storage capacity of the groundwater basin; and
    - Description of any existing or anticipated flows into, or recharges of, the basin that could affect the quality of water in the monitoring bores or drinking water bores downgradient of the project.
- Identification of the agency responsible for preventing the use of groundwater for drinking water within certain areas, and the mechanism that will be used;
- A contingency plan for diversion of recycled water when required;
- A plan for monitoring groundwater flow and water quality in the impacted groundwater basin, including a map of the locations of monitoring bores in the spreading basin and groundwater basin, details on their construction, and a rationale for their siting;
- A water quality monitoring plan for the recycled water, diluent water, water in the vadose zone as necessary, water in the mound as necessary and monitoring bores;

Operations and Maintenance Manual

The operations and maintenance manual shall include, but not be limited to, the following:

- Operational and management personnel job descriptions and required qualifications and associated training programs;
- If RO membrane technology is used, the routine testing procedures for the integrity of the RO membranes and the RO membrane replacement schedule;

- Routine maintenance and performance monitoring for the disinfection system;

- Maintenance and calibration schedules for all monitoring equipment, process alarm set points and response procedures for all alarms;

- Maintenance of injection and monitoring bores, and spreading basins;

- Vector control activities related to the project;

- A description of how the project will measure the retention time to demonstrate compliance with required retention times.

- A list of the pesticides and herbicides used in the spreading facilities; and

- The procedures used for compliance with control of non regulated chemicals .

Appendix A

Fit for Purpose microbiological guidelines for wastewater reuse

Fit for Purpose Guidelines for Recycled Water *

Class	Recycled Water Quality Objectives[1]	Treatment Process[2]	Range of Uses
A+	▪ Turbidity < 2 NTU[6] ▪ < 10 / 5 mg/L BOD / SS ▪ pH 6 – 9 [7] ▪ 1 mg/L Cl2 residual (or equivalent disinfection)[8] ▪ <1 *E.coli* per 100 mL; ▪ <1 helminth per litre; ▪ < 1 protozoa per 50 litres; ▪ < 1 virus per 50 litres. ▪ <2-10mg/L nitrogen ▪ Meet DOH Chemical Guidelines for Recycled Water	▪ Secondary[2] ▪ Filtration[3] ▪ Disinfection[4] ▪ Advanced treatment[5]	Indirect Potable Reuse Aquifer Recharge
A	▪ < 10 *E.coli* org/100 mL ▪ Turbidity < 2 NTU[6] ▪ < 10 / 5 mg/L BOD / SS ▪ pH 6 – 9 [7] ▪ 1 mg/L Cl2 residual (or equivalent disinfection)[8] ▪ <10 *E.coli* per 100 mL; ▪ <1 helminth per litre; ▪ < 1 protozoa per 50 litres; ▪ < 1 virus per 50 litres.	▪ Secondary[2] ▪ Filtration[3] ▪ Disinfection[4]	Urban (non-potable): with uncontrolled public access Agricultural: eg human food crops consumed raw Industrial: open systems with worker exposure potential
B	▪ <100 *E.coli* org/100 mL ▪ pH 6 – 9[7] ▪ < 20 / 30 mg/L BOD / SS[10]	▪ Secondary[2] and pathogen reduction[9]	Agricultural: eg dairy cattle grazing Industrial: eg washdown water
C	▪ <1000 *E.coli* org/100 mL ▪ pH 6 – 9[7] ▪ < 20 / 30 mg/L BOD / SS[10]	▪ Secondary[2] and pathogen reduction[9]	Urban (non-potable): with controlled public access Agricultural: eg human food crops cooked/processed, grazing/fodder for livestock Industrial: systems with no potential worker exposure
D	▪ <10000 *E.coli* org/100 mL ▪ pH 6 – 9[7] ▪ < 20 / 30 mg/L BOD / SS[10]	▪ Secondary[2]	Agricultural: non-food crops including instant turf, woodlots, flowers

* Table adapted from Victorian EPA guidelines

1. Unless otherwise noted, recommended quality limits apply to the recycled water at the point of discharge from the WWTP

2. Secondary Treatment processes include activated sludge processes, trickling filters, rotating biological contractors, and may include stabilization ponds.

3. Filtration means the passing of wastewater through natural undisturbed soils or filter media such as sand and/or anthracite, filter cloth, or the passing of wastewater through micro-filters or other membrane processes.

4. Disinfection means the destruction, inactivation, or removal or pathogenic microorganisms by chemical, physical, or biological means.

5. Advanced wastewater treatment processes include chemical clarification, carbon adsorption, reverse osmosis and other membrane processes, air stripping, ultrafiltration, and ion exchange.

6. Turbidity limit is a 24-hour median value measured pre-disinfection. The maximum value is five NTU.

7. pH range is 90th percentile. A higher upper pH limit for lagoon-based systems with algal growth may be appropriate, provided it will not be detrimental to receiving soils and disinfection efficacy is maintained.

8. Chlorine residual limit of greater than one milligram per litre after 30 minutes (or equivalent pathogen reduction level) is suggested where there is a significant risk of human contact or where recycled water will be within distribution systems for prolonged periods.

9. Helminth reduction is either detention in a pondage system for greater than or equal to 30 days, or by a DOH approved disinfection system (for example, sand or membrane filtration).

10. Where Class C or D is via treatment lagoons, although design limits of 20 milligrams per litre BOD and 30 milligrams per litre SS apply, only BOD is used for ongoing confirmation of plant performance. A correlation between process performance and BOD / filtered BOD should be established and in the event of an algal bloom, the filtered BOD should be less than 20 milligrams per litre.

Appendix B

Microbiological Effectiveness of treatment trains, on site controls and suitable uses

Draft national health reuse guidelines

Typical treatment processes and specific on-site controls for designated uses

Use	Total Log reduction required *prot;virus; bact*	Treatment Process Description	Treatment Process Log reduction *prot virus bact*	On site control/use restrictions Description	On site control/use restrictions Log reduction
Dual reticulation	5; 6; 5	Coagulation[1] Filtration, Disinfection	5; 6; >6		
Municipal irrigation	3.5; 5; 4	Coagulation[2] Filtration, Disinfection	5 5 >6		
Municipal irrigation	3.5; 5; 4	Secondary Disinfection Secondary treatment with lagoons and disinfection	0.5-1 1-3 >6 1-4 2-6 >6	**Combinations of** No public access during irrigation Possible exclusion periods (eg no use until 1-4 hrs after irrigation) 25-30m buffer zones to nearest point of public access Spray drift control: - low throw sprinklers - microsprinklers - part circle sprinkers (180^{O} inward throw) - tree/shrub screens - amemoter switching	 2 log 1 log 1 log 1 log
Municipal irrigation	3.5; 5; 4	Secondary	0.5-1; 0-2; 1-3	No public access during irrigation **and** Possible exclusion periods (eg no use until 1-4 hrs after irrigation) **and** 25-30m buffer zones to nearest point of public access **and** Spray drift control: - low throw sprinklers - microsprinklers - part circle sprinklers (180^{O} inward throw) - tree/shrub screens - amemoter switching	2 log 1 log 1 log 1 log
Landscape irrigation	3.5; 5; 4	Secondary Disinfection Secondary	0.5-1; 1-3; >6 0.5-1; 0-2; 1-3	**Combinations of** Microspray Drip irrigation No public access	 2 log 2 log 2 log

Use	Total Log reduction required	Treatment Process		On site control/use restrictions	
	prot;virus; bact	Description	Log reduction *prot virus bact*	Description	Log reduction
Commercial food crop	5; 6; 5	Coagulation[2] Filtration, Disinfection	5; 5; >6	1.5-2 days between final watering, supply and consumption Ground contact and eaten raw (eg lettuce, celery) or grown below surface and eaten raw (eg carrots) No ground contact and eaten raw (eg tomatoes, capsicums). No ground contact (trees etc) and eaten raw (eg apples, peaches, apricots	1 log (virus)
Commercial food crop	5; 6; 5	Secondary treatment with lagoons and disinfection	1-4; 2-6; >6	<u>Drip irrigation</u> No ground contact and eaten raw (eg tomatoes, capsicums). <u>Spray irrigation</u> Ground contact and skin removed prior to consumption (eg melons)[2] **and** 1.5-2 days between final watering, supply and consumption	3 log 2 log 1 log (virus)
Commercial food crop	5; 6; 5	Secondary treatment and disinfection	0.5-1; 1-3; >6	<u>Spray irrigation</u> No ground contact and skin removed prior to consumption (eg citrus, nuts)[2] **and** 1.5-2 days between final watering, supply and consumption <u>Drip irrigation</u> No ground contact (trees etc) and eaten raw (eg apples, peaches, apricots)[3].	3 log 1 log (virus) 4 log
Commercial food crop	5; 6; 5	Secondary	0.5-1; 0-2; 1-3	Grown below surface and cooked or processed (eg potatoes, beetroot) No ground contact and heavily processed (eg grapes for wine production, cereal crops) <u>Drip irrigation</u> No ground contact and skin removed prior to consumption (eg citrus, nuts)[2].	5 log 5 log 5 log
Commercial crop		Primary plus lagoons or secondary	0.5-1; 0-2; 1-3	Crop/plants not for human consumption (eg treelots, turf)	5-6 log

[1] After secondary treatment, additional Ct set to achieve higher virus removal, [2] After secondary treatment,
[3]Produce not to be wet when harvested and dropped produce not to be harvested,
[4].Dropped produce not to be harvested

Suitable uses associated with typical treatment processes and on-site controls

Treatment	Suitable Uses	On Site Controls	Water quality requirements
Secondary Treatment **Coagulation Filtration, Disinfection**	**Dual reticulation** **Municipal irrigation** **Commercial food crops (raw produce)** **Firefighting** **Industrial uses**		Turbidity ≤ 2 NTU Chlorine residual to achieve minimum Ct (could vary depending on use eg ≥ 60 mg.min/L for dual reticulation but lower for industrial uses) *E.coli* <1 per 100 mL for dual reticulation *E.coli* <10 per 100 mL for other uses BOD <20mg/L (as a measure of effectiveness of secondary treatment
Secondary treatment with lagoons and disinfection	**Commercial food crops** No ground contact and eaten raw (eg tomatoes, capsicums). Ground contact and skin removed prior to consumption (eg melons)[2]	Drip irrigation Minimum 1.5-2 days between final watering, supply and consumption	Chlorine residual to achieve minimum Ct (eg ≥ 15 mg.min/L) *E.coli* <100 per 100 mL Minimum detention in lagoons of 30 days BOD <20mg/L, SS < 30mg/L (as a measure of effectiveness of secondary treatment)
Secondary treatment with disinfection	**Commercial food crops** No ground contact and skin removed prior to consumption (eg citrus, nuts)[2] No ground contact (trees etc) and eaten raw (eg apples, peaches, apricots)[3].	Spray irrigation **and** minimum 1.5-2 days between final watering, supply and consumption Drip irrigation	Chlorine residual to achieve minimum Ct (eg ≥ 15 mg.min/L) *E.coli* <100 per 100 mL BOD <20mg/L, SS < 30mg/L (as a measure of effectiveness of secondary treatment)
Secondary treatment with disinfection	**Municipal irrigation including dust suppression**	**Combinations of** No public access during irrigation Possible exclusion periods (eg no use until 1-4 hrs after irrigation) 25-30m buffer zones to nearest point of public access Spray drift control: - low throw sprinklers - microsprinklers - part circle sprinklers (180^{O} inward throw)	Chlorine residual to achieve minimum Ct (eg ≥ 15 mg.min/L) *E.coli* <100 per 100 mL BOD <20mg/L, SS < 30mg/L (as a measure of effectiveness of secondary treatment)

Treatment	Suitable Uses	On Site Controls	Water quality requirements
		- tree/shrub screens - amemoter switching	
	Landscape irrigation	**Combinations of** Microspray Drip irrigation No public access during irrigation	Chlorine residual to achieve minimum Ct (eg $\geq$ 15 mg.min/L) *E.coli* <100 per 100 mL BOD <20mg/L, SS < 30mg/L (as a measure of effectiveness of secondary treatment)
Secondary treatment without disinfection	**Commercial food crops** Grown below surface and cooked or processed (eg potatoes, beetroot) No ground contact and heavily processed (eg grapes for wine production, cereal crops) No ground contact and skin removed prior to consumption (eg citrus, nuts)[2].	Drip irrigation	*E.coli* <1000 per 100 mL BOD <20mg/L, SS < 30mg/L (as a measure of effectiveness of secondary treatment)
	Landscape irrigation	**Combinations of** Microspray Drip irrigation No public access during irrigation	*E.coli* <1000 per 100 mL BOD <20mg/L, SS < 30mg/L (as a measure of effectiveness of secondary treatment)
Primary treatment with lagoons	Crop/plants not for human consumption (eg treelots, turf)		*E.coli* <10000 per 100 mL

Appendix C

Initial list of priority "Chemicals of concern" for review prior to MAR projects involving indirect potable reuse. *

*** While a finalised list will only apply to schemes involving indirect potable reuse, it is likely that early MAR schemes, not involving a potable outcome, will be required to monitor these to provide baseline data.**

Chemicals of Concern in Recycled Water

VOCs[2]

Benzene
Butyl benzenes
- n-butyl benzene
- sec-butyl benzene
- tert butyl benzene

Carbon tetrachloride
Chlorobenzene
2-Chlorotoluene, 4-Chlorotoluene
Dibromochloropropane
Dichlorobenzenes
- 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene

Dichloroethanes
1,1-dichloroethane, 1,2-dichloroethane
Dichloroethenes (dichloroethylenes)
- 1,1-dichloroethene, 1,2-dichloroethene, cis and trans

Dichloromethane (methylene chloride)
Dichlorodifluoromethane
1,2-Dichloropropane, 1,3-Dichloropropene
Ethylbenzene
Hexachlorobutadiene
Isopropyl benzene
Methyl tertiary butyl ether (MTBE) and related compounds
- Ethyl tertiary butyl ether
- Tertiary amyl methyl ether
- Tertiary butyl alcohol

Methyl isobutyl ketone
n-propyl benzene
Styrene (vinylbenzene)
1,1,2,2-Tetrachloroethane
Tetrachloroethene (tetrachloroethylene, perchloroethylene)
Toluene
1,1,1-Trichloroethane, 1,1,2-Trichloroethane, 1,2,3-Trichloropropane
Trichlorobenzenes (total)
Trichloroethene
Trichlorofluoromethane
1,1,2-Trichloro-1,2,2-trifluoroethane
1,2,4-trimethylbenzene
1,3,5-trimethylbenzene
Vinyl chloride
Xylenes
EDB

[2] During trials a tentatively identified compound screen for VOCs will also be included

Halogenated Disinfection By-products
Haloacetonitriles
- dichloroacetonitrile, trichloroacetonitrile
- dibromoacetonitrile, bromochloroacetonitrile

Cyanogen chloride/bromide
Trichloroacetaldehyde
Trihalomethanes (THMs)
- Chloroform
- Bromodichloromethane
- Chlorodibromomethane
- Bromoform

Haloacetic acids (HAA_5)
- chloroacetic acid
- dichloroacetic acid
- trichloroacetic acid
- bromoacetic acid
- dibromoacetic acid

Nitroso Disinfection By-products
N-Nitrosodimethylamine NDMA
N-nitrosodiethylamine NDEA
N-nitrosopyrrolidine

Semivolatile Organic Compounds
Polycyclic aromatic hydrocarbons (PAHs)
- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo-a-anthracene
- Benzo-a-pyrene
- Benzo-b-fluoranthene
- Benzo-k-fluoranthene
- Benzo-ghi-perylene
- Chrysene
- Dibenzo-ah-anthracene
- Fluoranthene
- Fluorene
- Indenopyrene
- Naphthalene
- Phenanthrene
- Pyrene
- Polybrominated diphenylethers (PBDPEs)
- Bisphenol A
- Caffeine
- Triclosan
- 1,4-Dioxane
- Hexachlorobenzene

Alkyl phenol ethoxylates

Phenols

Chlorophenols

- 2-chlorophenol
- 2,4-dichlorophenol
- 2,4,6-trichlorophenol
- Pentachlorophenol

Alkyl phenols

Polychlorinated biphenyls (PCBs)

Hormones

Ethinyl estradiol
17-B estradiol
Estrone

Metals

Aluminium
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Chromium
Copper
Iron
Lead
Manganese
Mercury
Molybdenum
Nickel
Selenium
Silver
Thallium
Tin
Uranium
Vanadium
Zinc

Pharmaceuticals and other substances

acetaminopen
amoxicillin
azithromycin
carbamazepine
gemfibrozil
ibuprofen
lipitor
methadone

morphine
salicylic acid
perindopril
Iodinated contrast media (Iomeprol; Iohexol; Diatrizoate)

Organotins
dialkyltins
tributyltin oxide

Chelating agents
Ethylenediamine tetraacetic acid (EDTA)
Nitriloacetic acid (NTA)

Other organic compounds
Formaldehyde
Ethylene glycol

2,3,7,8-TCDD

Anions
Fluoride
Chloride
Bromide
Iodide
Cyanide
Nitrate
Nitrite
Perchlorate
Sulfate

Pesticides
<u>OC</u>
- Aldrin
- Chlordane
- pp-DDT
- Dicofol
- Dieldrin
- Endosulfan
- Heptachlor
- Lindane
- Methoxychlor

<u>OP - Non-polar (low levels)</u>
- Chlorpyrifos
- Diazinon
- Dichlorvos
- Ethion
- Fenamiphos
- Parathion methyl
- Pirimiphos-ethyl
- Azinphos-Methyl

Pyrethroid
- Bioresmethrin
- Fenvalerate
- Permethrin

OP - Non-polar
- Carbophenothion
- Profenofos
- Terbufos
- Tetrachlorvinphos
- Disulfoton
- Ethoprophos
- Monocrotophos
- Thiometon

Fungicide - Carboxamide
- Carboxin

Fungicide - General
- chlorothalonil

Herbicide - General
- Trifluralin
- Pentachlorophenol

OP - Non-polar (high levels)
- Dimethoate
- Fenitrothion
- Maldison
- Methidathion
- Parathion
- Pirimiphos-methyl
- Bromophos-ethyl
- Chlorfenvinphos
- Fenchlorphos
- Fensulfothion
- Formothion
- Pyrazophos
- Sulprofos
- Temephos

Insecticide - General
- Piperonyl butoxide

Herbicide - General
- Pendimethalin
- Quintozene
- Diclofop-methyl

General
- Propargite

OP - Polar
- Acephate
- Trichlorfon
- Mevinphos

Herbicide - Chloroacetamide
- Propachlor

Carbamate
- Oxamyl

Carbamate
- Aldicarb
- Carbaryl
- Carbofuran
- Methiocarb
- Methomyl
- Pirimicarb

Herbicide - Chloroacetamide
- Metolachlor

Herbicide - Triazine
- Atrazine
- Simazine
- Terbutryn
- Propazine
- Ametryn

Herbicide - Triazinone
- Hexazinone
- Metribuzin

Fungicide - General
- Fenarimol

Fungicide - Azole
- Propiconazole
- Triadimefon

Herbicide - General
- Diphenamid
- Norflurazon
- Napropamide
- Propanil
- Propyzamide

Fungicide - Benzimidazole
- Benomyl
- Carbendazim
- Thiophanate

Herbicide - General
- Nitralin
- Oryzalin

Carbamate
- Thiobencarb
- Promecarb

Herbicide - Urea
- Chloroxuron
- Chlorsulfuron
- Diuron
- Fluometuron
- Metsulfuron-methyl

Herbicide - Benzothiadiazinone
- Bentazone

Herbicide - Uracil
- Bromacil
- Terbacil

Herbicide - Acidic
- 2,4-D
- Clopyralid
- Dicamba
- DPA
- Fenoprop/Silvex
- Flamprop-methyl
- Picloram
- 2,4,5-T
- Triclopyr
- Endothal

Herbicide - benzonitrile
- Bromoxynil
- Dichlobenil

Quaternary Ammonium
- Difenzoquat
- Diquat
- Paraquat

Thiocarbamate
- EPTC
- Molinate
- Pebulate
- Vernolate

Appendix 3

Summary of MAR Forum Outcomes

Summary of key issues raised at the EPA MAR Forums

	16/5	17/5	18/5	23/5	24/5	25/5
GENERAL ISSUES RELATING TO MAR						
Benefits						
Reduce pressure on environment and water resources	×	×	×	×	×	×
Reduce salt water intrusion	×	×	×			
Meeting moral obligations	×					
Sustainability	×	×				×
Reduce waste, reduce ocean discharge	×			×		
Increase (higher quality) water availability	×		×	×		
Cost; Economics	×		×			×
Diversity of options				×		
Risks or concerns						
Encourages more water use, not conservation	×		×		×	×
Public reaction without education; Public values	×	×	×	×	×	
Not soon enough	×	×		×		×
Impacts on aquifer	×	×		×		×
Impacts on downstream environment, stygofauna	×			×		×
Accidents can happen		×				×
Should be only one component of water management	×		×			
Water efficiency in homes, estates			×	×		×
Health/Chemicals of concern	×			×	×	
Further information required						
Pilot study or trials, long term impacts	×	×	×	×	×	
Further public education; Social issues	×			×		×
Understanding of aquifers, their connections			×	×	×	×
Cost; Cost benefit analysis	×			×		×
Lack of government direction, who initiates?	×					×
Need to demonstrate need for MAR		×				
Locations of infiltration points				×		
MAR FOR ENVIRONMENTAL BENEFITS						
Benefits						
More natural than ocean disposal		×				
Benefits to wetlands			×	×		×
Save higher quality water for drinking				×		
Reduce nutrient runoff from urban development				×		
Preserve biodiversity						×
Risks or concerns						
High levels of nutrients	×					×
Potential to contaminate drinking water		×	×			
Using large areas of land for infiltration		×				
Stygofauna				×		
Infiltration preferable to injection					×	×
Chemical interaction in waste stream					×	

Further information required					
Ongoing research e.g. flora, fauna	×				
Locations for MAR		×			
Cost, optimal MAR project size		×			
Impact on acid sulphate soils			×		×
MAR FOR HORTICULTURAL IRRIGATION					
Benefits					
Benefits for horticulture	×		×		
Provide resource of higher quality, inc quantity	×		×		
Continuation of the industry			×		
Decrease fertiliser use, maintain nutrient levels			×	×	
Increase land available to horticulture			×		
Establish hort precinct, community benefits			×		
Guarantee water quality legislatively			×		
Risks or concerns					
Cost (due to DoH standards), who pays?	×		×		
Free trade agreement implications			×		
Land zoning security			×		
Wont be able to target nutrients over growing season				×	
Implications for people who drink groundwater			×		
Further information required					
Town planning implications			×		
MAR FOR GENERAL USE OR MULTIPLE BENEFITS					
Benefits					
Increase viability of existing bores	×				
Reduce pressure on drinking water supply	×				
Improve health of parks and gardens	×				
Replace water being extracted from Gnangara Mound		×			
Enhance environmental values		×			
Energy consumption benefits		×			
Risks or concerns					
Infiltration preferable to injection		×			
MAR FOR DRINKING WATER					
Benefits					
Climate independent water source			×		
Risks or concerns					
Perception of drinking toilet water	×				
(Perception of) taste difference		×	×		
Delay due to ultra-conservatism within govt agencies			×		

Benefits			
Legislate to make compulsory	×		
Possible use of rainwater	×		
Reduce overall energy consumption	×		
Sustainable living; increased awareness	×		×
Whole of system approach	×		
Smaller pipes, smaller treatment plants		×	
Reduce demand on potable water			×
Risks or concerns			
Legal liability of using the water	×		
Overuse of private bores; Licence these?	×		
Odour		×	
Level of treatment, children could drink		×	
Duplication of retic systems and maintenance		×	
Residents lose control over household system		×	
Contamination of aquifer, especially for drinking			×
Should separate grey and black water			×

Key issues raised at the EPA MAR Forums

16 May 2005 - Mosman Park

Environmental Benefits

Benefits

- Reduce fluctuations – on environmental resources.
- Moral obligation not to waste water.
- MAR – education resource.
- Keep a balance – saltwater intrusion.
- Reduces pressure on current resources and horticulture – protection of amenity.
- Buys time for population policy in place.

Risks or Concerns

- MAR encourages population growth.
- Does not encourage conservation.
- High levels of nitrogen and phosphorus to native vegetation (wetland ecosystems).
- Public education – can be misunderstood.
- Need to be education programs put in place.
- Caves (stygofauna) are good bio-indicators of surface water.
- Not occurring soon enough.

Further Information Required

- How does aquifer recharge occur on this region – pilot study into retro-fitting for recharge/infiltration.
- Education
- Other agencies demand on water e.g. Pine plantation on Gnangara mound.
- Current (and ongoing) environmental research – fauna/flora
- Historical land use and what impacts has this had on ground water.

General Re-use or Multiple Benefits

Benefits

- Avoid waste.
- Reduce demand for bores.
- Bores reduce pressure on potable supply.
- Health/amenity benefit of adequate parks and gardens.
- Maintain viability of bores.
- Injection close to sea “more acceptable” then injection to Gnangara (“yuk” factor avoided).

Further Information Required

- In future, invite senior high school children to attend forums.
- Why are we putting any wastewater (including stormwater) into the sea?

Public Drinking Water Supply

Risks or Concerns

- Perception of drinking toilet water.
- Need for education on:
    - OK to drink.
    - Proper management to ensure health standards are met.

Further Information Required

- Why is it ok to discharge secondary treated water to ocean but not tertiary treated water to aquifer (perception).
- How much is used by each user group? e.g. Industry.
- Impact of "business as usual" is unsustainable.
- Education is key to acceptance.
- Cost? 50-100% more of $2 a litre for bottled water "sounds reasonable".
- Need "whole system" approach.

Additional thoughts

- An education program for the general public on water issues.
- Pharmaceuticals "buy back" scheme.
- Why is it acceptable to throw it in the ocean?
- Public perception – you can do it in the country – education program.
- Get school teachers on side, kids influence parents.

Irrigated Horticulture

Benefits

- Benefits for horticulture (public open spaces considered a form of horticulture)
- Salt water intrusion (reducing)
- Providing a resource of better quality.
- Frees up water for other uses.
- Long term sustainability.
- Economic.

Risks or Concerns

- Effects on existing groundwater/environment
- DoH standards – high costs?
- Lack of scientific data.
- No trials – need:
    - Field trials
    - Scale
    - Chemical reactions
    - Trials at all proposed sites

Further Information Required

- Costs and who pays?
- Cost – benefit analysis.
- Who initiates?
- Lack of commitment to carry out such a scheme.

Other

- State of the water/health (contamination etc)
- Suitable size trials – must be site specific.
- Lack of data when generating EPA/DoE guidelines.

Integrated Water Management in New Residential Areas

Benefits

- Possible cost (financial) benefits.
- May be able to introduce legislation to enforce integrated water management in new residential areas – developers are not going to comply unless they are forced.
- Possible use of rainwater – benefits from being able to plan the necessary infrastructure.
- Increased planning for new designs and technology (eg. Planned public spaces) – keeping potable water and stormwater separate – sustainable living.
- Reducing overall energy consumption.
- Increased awareness and education of new residents which is transferable to other communities as they move. Increased awareness of water value as a resource.
- All aspects of water use can be considered – irrigation/gardens (waterwise)/education.
- Right resource - right use.

Risks or Concerns

- Health:
    - Health risks may outweigh potential environmental benefits.
    - Can we manage the possible health risks of domestic use?
- Unknown chemicals – question of unknown health risks.
- Legal liability of using the water.
- Prohibiting private bores – only licensed private bores.
- MAR and bores need to have integrated management
- Over use by private bores (people need to pay real cost of water, environmental cost) – restrictions for bores.

Further Information Required

- What's possible, what's required?
- How much do these methods cost?
- More diagrams may help – a flow diagram to explain integrated water management.
- More examples of how this would work.
- Other options and alternatives – Water Corp. inject, others withdraw.

Other Issues

- Rain water use in new and exciting residential areas.
- Overall sustainable living – this is just one aspect.
- Banning all watering in Winter months.

Other comments

- Treatment costs should be considered together with transport costs (often treatment is reported alone)
- The energy intensity of various water supply options should be considered - current system is very high. As energy prices increase, this will have implications. Energy costs associated with proposals should be reported.

17 May 2005 - AQWA

Environmental Benefits

Benefits

- A more natural way of disposing of wastewater by allowing it to reach the ocean through the aquifer. Unlike ocean disposal – short circuiting

Risks or Concerns

- Assimilation capacity of the aquifer (risk of choking the aquifer)
- Accidents happen
- Potential to contaminate WA's drinking water
- Using large areas of land for infiltration ponds

Further Information Required

- Look at locations for MAR – where is it best to have MAR? e.g. along the coast to help control the salt water wedge.
- Cost analysis. What is the optimal size for MAR projects? Must be between single-residence and large wastewater treatment plant (which takes 1/3 of Perth wastewater). Collecting large volumes of wastewater and then distributing out for MAR may not be efficient – economies of scale.

Other Issues or Comments

- What evidence is there that septic tanks were an issue? People had septic tanks and some reported to drink bore water. No problems?
- Pine trees increase abstraction on Gnangara Mound.
- Use of alternatives to MAR, e.g. artificial wetlands? Development of other creative solutions.
- Demonstration projects.
- Thought: piping wastewater up gradient of the Swan River and injecting to keep the river flowing? Dilute nutrients.
- Is MAR a bandaid solution? (using ground to clean water). Have other ideas or technologies been considered? Better to put in and leave, rather than use.
- Urgency of recharge before environmental values are lost. Groundwater dependent ecosystems at risk, will be lost in less than 10 years. Shouldn't waste time considering minor issues.
- Asked about the possibility that recharge water may migrate into drinking water sources, the group was quite comfortable with the idea of drinking the treated wastewater given the DoE and DoH safeguards.

General Re-use or Multiple Benefits

Benefits

- Replace water being removed from the Gnangara Mound, including urban wetlands.
- Enhance environmental values e.g. wetlands and caves.
- Direct substitution (not MAR) e.g. for horticulture.
- Prevent salt water intrusion.
- Need to target location of MAR to get benefits.
  - Use soil-aquifer treatment with MAR
  - Save energy with MAR

Risks or Concerns

- Education (public participation) (all wastewater should be kept on land)
- Prefer infiltration to injection, biological processes
- Public perception of taste difference
- Don't risk Gnangara first, need large scale trial (5-10 years) to demonstrate operational/control before transfer to Gnangara. Sites – e.g. urban/ environmental benefits, lakes
- Need to test hydrogeological modelling with trials
- Detailed environmental guideline for environmental benefits

Further information required

- Need evidence that scheme would actually work
  - on Swan Coastal Plain
  - on-going/extended trial
  - biological/chemical reduction in aquifer
- Preferably operate a smaller scheme in metro area for environmental benefits and monitor in detail.
- Need to demonstrate need – that MAR is more effective and efficient than alternatives.
- Demonstrate a suburb on wastewater for garden irrigation (3rd pipe)

Other issues or comments

- Is it worth saving environmental value (e.g. stygofauna)?
- New residential – need integrated water concept planning.
- Relocate water demands (fit for purpose) to near source e.g. industry – planning. Only use MAR as a tool where necessary, don't want long distance transport.

18 May 2005 - Riverton

General (whole group discussion)

Benefits

- More water available, provided implemented properly
- Environmental benefits – wetlands and salt water intrusion
- Cost of water?
- Cheaper than canal and desalination

Risks or Concerns

- Pricing. Water won't be valued if too cheap, and therefore wasted.
- 1/3 of water is used on gardens. Should have more native gardens.
- Continuous education needed to reduce wastage
- Why worry about caves or stygofauna?
- Housing – water features are a waste; Need more water management and conservation.
- Water efficiency
- Move forward carefully with back-track option in case of currently unknown problems.
- This should only be one component of water supply/cycle, and integrated water management

Further Information Required

- Drinking water trials

- More information on Gnangara Mound, potential locations for MAR
- Are aquifers well connected? impact areas known?
- Results of pilot studies
- Climate change issue bigger than Gnangara Mound
- Increase distance between recharge and abstraction?
- Monitoring and toxicology studies from elsewhere?

Other Issues or Comments

- Provided Dept of Health say is ok, is ok
- Desalination and clearing projects weren't fully explained.
- Salt water from the ocean should be more widely used, e.g. for flushing toilets
- Third pipe systems result in cross connections

23 May 2005 - Wanneroo

Integrated Water Management in New Residential Areas

Benefits

- Technology is available to capture MAR water at subdivisional level
- Smaller waste pipes to smaller treatment plants
- Less ocean discharge
- Saving drinking water supplies

Risks or Concerns

- Stormwater mixed or segregated? concern
- Odour
- Level of treatment (quality), e.g. kids drinking from taps
- Cost compared with rainwater collection?
- Duplication of reticulation systems and maintenance
- Residents loss of use of own household system and forced to use Water Corp system?

Further Information Required

- Cost of second reticulation system
- Number of houses per bore
- Cost of MAR vs cost of household recycle systems

Other Issues or Comments

- Would it be more efficient to separate solid and liquid waste before sending to wastewater treatment plant?
- MAR should be integrated with other water capture systems

Public Drinking Water Supplies

Benefits

- new source
    - climate independent
    - sustainable approach to resource
    - recovery from decline, fixing the damage
- prevent waste of resource
- cost effective

Risks or Concerns

- Delay due to ultra-conservatism (within agencies)
- Public perception takes time, need clear drivers
- People drink groundwater at Carabooda, therefore must be high quality water
- Need drinking water quality A+ prior to MAR for Carabooda/Gnangara area
- Water Corporation running it (poor track record and have an interest in the outcome)
- Lack of social acceptance
- Water quality – for downstream groundwater use (local drinking)
- Are Water Corp and Dept of Health talking about same treatment processes?
- Who will pay for horticultural and environmental allocation of water?
- Taste of water
- Equity issue - if water is supplied for MAR upstream of Carabooda, 'substandard' water would be given to Carabooda people (who drink groundwater) to make more 'good' water available for city people

Further information required

- Answers to chemicals of concern trials
- Better understanding of drivers
- Willingness of public to pay, and value of the resource (unit value)
- Understanding allocation and pricing

Other issues or comments

- Demand management
- Behavioural change

Environmental Benefits

Benefits

- Replenishing groundwater
- Stopping nitrate and phosphate runoff from urban development (not necessary to develop around wetlands)
- Diversity of options, compared to the other high risk options
- Mind shift to waste = resource
- Reduced discharge to marine environment
- Allow higher quality water to be used for drinking water
- Taking pressure off other water resources e.g. Gnangara
- Using existing wetlands for infiltration
- Rehabilitating wetlands

Risks or concerns

- Water efficiency – more emphasis required
- Capturing peoples values to water
- Impacts on stygofauna diversity
- Source control – controls on household chemicals
- THMs and active pharmaceutical products
- Complexity of social issues associated with MAR. Need to consider environmental issues with social and economic.
- Impacts to habitats, downgradient impact to surface habitats
- Lack of co-ordination between government departments, e.g. DPI and EPA.
- Changes in the characteristics of water

Further information required

- Long term impacts
- Success of artificial wetlands
- Information on groundwater system – education required and more research (ecological systems, physical processed)
- Relationship between environmental and social issues
- Location of infiltration points
- Advantages of MAR infiltration over natural infiltration
- Impacts on acid sulphate soils

Other issues or comments

- Consider using rainwater
- Consider using artificial wetlands in infiltration process
- New housing estates should use greywater; New development planning needed
- Need for community education
- Need for move higher density housing where water use is less
- Impacts from climate change
- More mini golf and indoor gold courses rather than large courses

Irrigated Horticulture (Group 1)

Benefits

- Continuation of industry
- Decrease fertiliser use, maintenance of nutrient levels
- Increase land availability for horticulture
- Lower cost than desalination
- Potential establishment of horticultural precincts, community benefits
- Guarantee of water quality by legislative means
- Environmental positives

Risks or concerns

- Who pays? Costs?
- Potential for continuation of potable consumption
- Free trade agreement?

Further information required

- Timeframes
- Cost-benefit analysis
- Town planning implications?
- Marketing

Other issues or comments

- Tourism potential?
- Increased demand for residential land?

Irrigated Horticulture (Group 2)

Benefits

- Increase in water availability

- Carabooda area important for horticulture, MAR has potential to maintain this
- General support for MAR
- Potential to increase water quality
- Benefits to wetlands and caves through MAR

Risks or concerns

- Is there a viable horticulture industry to make cost of MAR viable? sustainable?
- The cost of MAR to horticulturalists may affect viability of industry
- Land zoning security and security of water provision to horticulture
- Is MAR water enough? Will it sustain water use requirements in WA, including horticulture?
- Is the proposed 5 years for implementation too late? Is timeframe appropriate for horticulture?

Other issues or comments

- Consideration of horticultural precincts north of Carabooda due to various landuse pressures, including water supply.

24 May 2005 – Bibra Lake

Environmental Benefits

Risks or Concerns

- Flouride
- Endocrine disruptors – how will they be removed?
- Chemical interactions in the waste streams
- Infiltration vs injection. Infiltration preferred.

Further Information Required

- Travel times in aquifer and biodegradation times
- What would be done with more concentrated waste following reverse osmosis
- Impacts on confined aquifers

Irrigated Horticulture

Benefits

- Makes sense to use the nutrients

Other issues or comments

- Hydroponic igloos
- Won’t be able to target nutrients over growing season

Public Drinking Water Supplies

Risks or concerns

- How protect groundwater drinkers when MAR is used for another application?
- Breach of human rights to add fluoride to drinking water. Would MAR water be fluoridated?
- Preferable to drink tap water
- Deal with perception issues, sell it to the community

Other issues or comments

- Information on travel times, dilution ratios
- Education. Target schools for education about the water shortage
- Need more public involvement
- Chlorination

25 May 2005 – Midland

General Reuse or Multiple Benefits

Benefits

- Reusing water rather than discarding (we're not really short of water).
- Consideration of pricing structure
- MAR cheaper once running
- Saving water for future generations
- Proven elsewhere
- Consumers become part of the water cycle
- Future generations won't think twice, will just be accepted as the norm
- Nutrient recycling

Risks or concerns

- Would think twice about drinking it
- Accidents happen
- Water Corp's poor track record
- "shit is always shit"
- Appears safe now, but in time may find wasn't e.g. DDT
- What if vegetables aren't washed properly?
- Emerging/currently unknown diseases
- With MAR, people could become complacent about water use
- Timelines too long – can't wait 10 years
- Is this a political ploy? Will anything really happen?

Further information required

- Temperature effects in the aquifer? Up to 50 degrees
- How deep would water be injected?

Other issues or comments

- Need to educate people on general water use and saving
- Water is too cheap. Increase price so people use more carefully
- Water Corp make it sound easy to get more water, so people are complacent.
- MAR for industrial use?
- MAR with stormwater rather than wastewater?
- Are councils investigating water recycling?
- Re-education is needed
- Need incentives for new industries to reuse water
- All government agencies will need to market water reuse well
- Need to educate people about groundwater flow and age.

Environmental Benefits

Benefits

- Top up and preserve water table
    - preserving vegetation
    - preventing salt-water intrusion
    - maintaining wetlands
    - possible benefits or problems in relation to acid sulphate soils
    - preserving Yanchep caves and stygofauna
    - displacing development of other water source developments, protecting other environments (eg. SW Yaragadee)
    - preserving overall biodiversity (native flora and fauna)

Risks or concerns

- Urgency, not moving quick enough
- False sense of security of supply
    - may not be implementing enough water conservation initiatives
- Using MAR to offset poor management practices of irrigators and bore users
- Injection vs infiltration – injection is more energy intensive, more greenhouse gases and greater cost.
- Intensive monitoring required, environmental and health
- System failure could lead to pollution of subsoil
- Adequate contingencies needed to manage system failures
- Existing contamination of aquifers
- Present or future (currently considered safe) chemicals of concern – don't know everything
- Not paying enough for water, causes wastage
- Not enough demand management
- Nutrient levels in recharge water too high, impacts to ecosystems
- Current water system management – leaking mains not fixed
- Over irrigation by shires
- Possible impact on microbial balance
- Restrict developers water usage in new subdivisions

Further information required

- Irrigation efficiency
- Water Corp more open with problems and willing to discuss with public
- More international examples
- Extent of acid sulphate soil problems on Gnangara Mound
- Impact of recharge to sensitive areas
- Extent to which Gnangara Mound can recover

Other issues or comments

- Rebates for household wastewater reuse schemes
- Sense of urgency to implement measures

Integrated Water Management in New Residential Areas

Benefits

- For stormwater – won't lose through evaporation
- Tradeable resource
- Capture and store excess stormwater
- Integrate with conservation etc

- Better education for source control in new residential areas
- Small residential systems – can ensure not putting industrial chemicals in by MAR
- Lower cost when using locally
- Reducing demand on imported potable water
- Can be done without smell

Risks or concerns

- Spillage into aquifer, especially for drinking
- Who pays? On-selling allocation of resource? Provide return to operator
- Who is responsible for on-going management and monitoring? Water Corp or local government?
- Impact on groundwater dependent ecosystems
    - needs to be site specific
    - consider natural groundwater system
- Should separate blackwater and some greywater for treatment and use in specific uses (industrial and agriculture). Remaining grey and storm water could be used for MAR
- Managing in areas where already superficial domestic bores

Further information required

- Cost-benefit analysis, including on-selling of resource
- Research into groundwater dependent ecosystems
- Management processes identified – who takes responsibility? Need capacity building and financial assistance for instigator
- Education – through developers
- Need to not only preach to the converted

Other issues or comments

- Tiered water pricing based on garden type?
- Develop alternative disposal/treatment options for chemical disposal (education on source control doesn't work unless made really simple)
- Need incentives or regulation for developers to do it
- Should be closer management of superficial aquifer in residential areas – but not policemen. Better education.
- Regulate or guidelines for waterwise gardens in new areas – convenants? house and garden packages?
- Much better water resource monitoring. A great resource for better management.

Appendix 4

List of submitters
(Discussion Paper)

Organisations:

Australian Water Association – W.A. Branch
Blackwell and Associates
Chamber of Commerce and Industry
Conservation Council of Western Australia
Conservation of Rockingham Environment (CORE)
City of Swan
City of Wanneroo
City of Armadale
CSIRO 'Water for a Healthy Country' Flagship
Department of Environment
Peel-Harvey Catchment Council
North Metro Catchment Group Inc.
Town of Mosman Park
Water Corporation
Wildflower Society of Western Australia (Inc.)

Individuals:

David Buay
Dr Troy W. Harley
Bernie Masters
Miro Riha
Dr Mark Whitten
Stanley Yowke

Appendix 5

Summary of submissions and response
(Discussion Paper)

Key comments and issues raised in submissions

	COMMENT OR ISSUE RAISED	EPA RESPONSE
1	**GENERAL**	
1.1	**MAR context**	
	MAR should be part of a broader water management strategy.	Agree.
	The concept of wastewater recycling and MAR is supported in principle.	Agree.
	MAR should be environmentally responsible, socially equitable and economically viable.	Agree.
	There should be a co-ordinated, whole of government approach to MAR.	Agree.
	A risk management framework should be applied.	Agree.
	MAR should be integrated with long term planning.	Agree.
	A more realistic price should be charged for drinking water.	Noted.
	The technology exists to produce treated wastewater of a quality that poses no unacceptable risks to the environment or health, provided it is managed appropriately.	Noted.
	MAR provides the justification for metering and paying for groundwater by all bore operators so that all water use is more carefully justified.	Noted.
	Given the potential growth of MAR proposals, the legislative options for MAR assessment, approval and ongoing management may need to be considered more fully.	Noted.
	Is Government prepared to risk peoples health and lives to save money?	Noted.
1.2	**Further information**	
	There is insufficient knowledge and understanding to risk implementing MAR at this time.	The EPA advocates a precautionary approach to MAR, but does not consider that the risks preclude further investigation of MAR.
	A cautious approach may result in MAR not being taken up sufficiently to provide major environmental benefits; The potential risks associated with MAR are overstressed in the Discussion Paper.	Noting the risks associated with MAR, the EPA advocates a precautionary approach. The EPA does not consider the risks have been overstated.
	The City of Swan requests that the EPA investigate and consider proposals other than those specifically outlined in the Discussion Paper, particularly in the Swan Valley.	Early advice has been provided on the potential applications identified by the Water Corporation, however this does not limit the applications which can be considered in future.
	Further scientific evaluation of MAR is required, institutional design (rules for water suppliers, users and other stakeholders) should follow.	Agree.
	Cost is not given sufficient consideration in the Discussion Paper.	Noted, however cost is not a key consideration for the EPA.
	There is a need to consider resource management charges.	Noted.
	The Discussion Paper did not indicate the preferred method of wastewater treatment, the likely costs and benefits, or timeframes.	More detailed information was not available.
	It would be useful to develop approaches whereby the risk to health associated with the potential different types of reuse could be compared with other methods of providing drinking water, such as seawater desalination.	Noted.
1.3	**Consultation**	
	Continuing community consultation is important.	Agree.
	Community education is needed in addition to community involvement.	Agree.
	The people charged with undertaking public participation	Noted.

	COMMENT OR ISSUE RAISED	EPA RESPONSE
	work should be at arms length from any parties that may directly benefit from MAR decisions.	
	The Water Corporation's perception of the attitude of Perth's residents is an obstacle to greater reuse of wastewater to provide drinking water.	Noted.
	The community involvement plan described in the Discussion Paper needs to be far more detailed in order to ensure an open and transparent process.	Proponents of MAR schemes should develop a detailed community involvement plan.
1.4	**Other**	
	Sites for MAR infiltration may need to be reserved for Public Purposes in the Metropolitan Region Scheme and the District Planning Scheme.	Noted.
	An intermediate step, where nature is seen to filter or purify the recharged water, is necessary.	Noted.
	A pipeline is preferable.	Noted.
	Neighbourhood scale third pipe schemes should be investigated.	Noted.
	There should be further consideration of the use of rainwater for domestic purposes.	Noted.
	Kitchen sinks should have one of the two sink bowls dedicated to rinsing. This water should be kept separate from the main wastewater system and discharge to a ground level tank for storage and subsequent use, for example in gardens.	Noted.
	The dry shower, invented by a submitter, should be used more widely. This uses 5L of water for a 20 minute wash, compared with conventional showers which use 90L for 10 minutes.	Noted.
	The Town of Mosman Park carried a resolution to support in principle the concept of MAR for the five applications described in the Discussion Paper, on the proviso that the wastewater meets or exceeds Class A standard and that phosphorus and levels are within acceptable levels for receiving water bodies.	Noted.
	The EPA environmental management framework developed for Perth's coastal waters 'Perth's coastal waters – Environmental values and objectives' may provide an appropriate model for management and monitoring of MAR.	Noted. This is discussed in Section 5.1.
	MAR encompasses more than ASR and ASTR. Surface recharge, such as infiltration galleries and basin recharge, should also be acknowledged.	This was acknowledged. The Discussion Paper stated that "MAR is the infiltration or injection of water into an aquifer" (Section 2, paragraph 2).
2	**ENVIRONMENT**	
	A cautious approach is advocated as remediation of a polluted aquifer, as compared to a river or creek, is costly and difficult.	Agree.
	Cost of energy should be factored into water supply. Consider alternative energy supplies.	Agree. This is discussed in regard to sustainability, Section 4.1
	MAR using treated stormwater would be preferable.	The EPA understands that the Water Corporation is investigating this. However it is noted that a large proportion of stormwater is effectively already returned to the urban groundwater system for local groundwater use via stormwater infiltration basins, and a large fraction of the remainder flows into the river systems (Section 3.3).
	There is concern about the potential for eutrophication of groundwater or surface water ecosystems, particularly on	Noted. The EPA shares this concern, as discussed in Section 5.2, and would

COMMENT OR ISSUE RAISED	EPA RESPONSE
the Mosman-Cottesloe Peninsula and in the Carabooda area.	consider this issue if such a proposal is referred to the EPA for environmental impact assessment.
The ability of the aquifer to remove unwanted dissolved substances appears to be the least well understood yet most important determinant of potentially undesirable effects.	Noted. The EPA considers that further investigation of this issue is warranted, as discussed in Section 7.
It would be useful make available a model of the relative amounts of major plant nutrients which would be added to the groundwater and dispersed through aquifer with MAR using secondary treatment as compared to the leaching of fertiliser under current practices. This is of particular relevance where groundwater may enter wetlands, either directly or via irrigation.	Noted.
The concentrations of micronutrients in wastewater after secondary treatment, and/or their attenuation in the aquifer was not discussed. If copper and/or zinc, for example, accumulate in sewage, could prolonged use of MAR result in an excess of these elements being added to the soil or groundwater, thereby inducing nutrient disorders in plants or bio-accumulation in food webs? Similarly, would toxic trace contaminants such as cadmium find their way into the food web? Can we see more discussion of such issues?	Toze (2004) states that heavy metals are easily and efficiently removed during treatment processes, with the majority in biosolids rather than the wastewater. If heavy metals are present in the wastewater, there is the potential for them to accumulate and become bioavailable for crops.
Infiltration will require vast areas of land. Infiltration will slow quickly due to sediments and nitrogen causing algal growth.	Infiltration is carried out successfully in a number of locations around the world, as discussed in Section 3. The wastewater must be treated to a suitable level to prevent infiltration problems due to clogging.
How will nitrogen, pathogens and microbes be removed from the wastewater? How will odour and personal items be removed from the wastewater? – will these end up on irrigated green space?	Wastewater treatment is discussed in Section 2.2. Solids are removed from wastewater at the first stage of treatment. Advanced treatment processes can be used to remove nitrogen, pathogens and microbes.
Introduction of a potentially contaminated substance into a pristine drinking water aquifer should be considered with caution.	Agree.
It was not stated in the Discussion Paper whether P1, P2 and P3 zones would be included or excluded from allowing MAR proposals.	The EPA's advice with regard to P1, P2 and P3 zones is given in Section 5 of this report. The EPA would not support MAR in PDWSAs until the results of further studies are available.
The contribution of intensive animal and horticultural industries and broad acre agriculture should also be acknowledged as a source of nutrient impacts on groundwater.	This is now addressed in Section 4.2.
Stygofauna may benefit from increased concentrations of nutrients or other contaminants.	This is now noted in Section 4.2.
The statement that "the outflow of nitrogen rich water into coastal waters may cause eutrophication in the marine environment" is not a balanced view as it certainly presents the worst-case scenario, and it does not present the qualifier of 'certain concentrations'.	Noted, however it is emphasised that the Discussion Paper stated nitrogen "may" cause eutrophication.
There is currently much work and knowledge being gained in this area of potential impacts due to endocrine disruptors. The discussion paper states that "the extent to which pharmaceutically active chemicals constitute a problem in Australia is difficult to ascertain". Two references are cited which the submitter considers to counter this.	The EPA agrees that work stating that endocrine disruptors do not pose an environmental or health risk has been published, however there are also a large number of studies which find that these substances do pose a risk. The abstract of the second reference cited states "Researchers are still working to define the scope of the problem." The EPA

	COMMENT OR ISSUE RAISED	EPA RESPONSE
		therefore recommend a precautionary approach.
	The statement that pathogen regrowth may occur in the aquifer is highly inaccurate with little scientific evidence to back it up. There is evidence that shows bacterial pathogens rapidly decay in groundwater environments.	The EPA note that the potential for pathogens to survive or multiply is a commonly cited concern in relation to MAR, and has been observed in field conditions. The World Health Organization 'Guidelines for the safe use of wastewater in agriculture' state that "Many pathogens are capable of survival (and sometimes multiplication) in the environment (e.g. soil, water, crops)".
	The application of the precautionary principle when considering MAR to preserve an ecosystem which would disappear without intervention raises some interesting challenges. For instance, it may be that the treatment cost to produce a water quality that has zero impact from a water quality perspective is such that the scheme does not proceed, resulting in the total loss of the ecosystem due to falling groundwater levels. A lower quality water at lower cost may prove economically viable, thus retaining the eco-system but with some impacts due to a less than pristine quality of water being supplied.	Noted. This is discussed in Section 4.1.
	The view expressed by Allison et al about the impact on marine environments by nutrients is in the extreme case, with examples at Bunbury, Halls Head, Gnarabup, Gordon Rd and Caddadup WWTP all showing minimal if any measurable impact of discharging large quantities of treated wastewater to infiltration adjacent to the coast.	Noted.
	It is stated that without MAR the potential for wastewater reuse in Perth is limited. This is not only the case in Perth, but in large cities around the world.	Agree, noted.
3	**HEALTH**	
	The Department of Health approach is supported.	DoH: Noted.
	Department of Health guidelines and approvals are necessary – MAR schemes should be regulated and monitored by a party other than the Water Corporation.	DoH: Noted and agreed.
	No confirmed cases of infectious disease resulting from the use of properly treated recycled wastewater have been reported.	DoH: Noted and agreed.
	Some rural residents drink their bore water. This should be taken into account.	DoH: Potable consumption of untreated shallow aquifer water is not supported by the Department of Health, MAR guidelines should not increase its use.
	Health considerations of horticultural produce need to be considered in terms of the potential for transfer to other food items and not just their individual end use.	DoH: Horticultural produce consumed raw requires irrigation with 'Class A' water, which acknowledges some potential incidental consumption of the water. As the above can be consumed raw, microbiological limits are onerous and cross contamination from this source is unlikely. Produce not consumed raw has lower quality water permissible. This may not protect against poor hygiene practices in kitchens. The required treatment should not be excessive, as the sub-standard food handling practices themselves are more of an issue. Similarly, flowers are not regarded as sterile in any setting and sinks regularly grow microbes when tested. Good hygiene should be instituted and not excessive treatment of the irrigation

	COMMENT OR ISSUE RAISED	EPA RESPONSE
		water as a substitute.
	Cryptosporidium parvum requires consideration – this is specifically addressed in some countries.	DoH: Agreed it is an important pathogen in wastewater. Pathogen reduction processes for MAR will all require validation (will it work); in terms of the ability to remove organisms such as *Cryptosporidium sp.*, operational testing (is it working) and post treatment verification (did it work).
	There is a lack of faith in the Department of Health given past experience.	
	Chemicals of concern are only a concern to the Health Department where MAR is proposed for drinking water supply benefits. The current draft regulation does not make this clear, for instance: • The title of Appendix **C** should read "Initial list of priority chemicals of concern for review prior to MAR projects ***for Drinking Water Supply Benefits***" • The statement at the top of page 6 should read "The list of chemicals required to be monitored for ***MAR projects for drinking water supply benefits*** in Western Australia is provided as Appendix C"	DoH: Agreed.
	The Department of Health should consider reformatting the draft regulation to very clearly differentiate between requirements for different end uses, perhaps formatting to provide a structure which reflects the classifications shown in Appendix A.	DoH: Noted.
	A risk management framework, should take into account the relative risk of other contributing factors in catchments, such as the uncontrolled discharge of contaminants to groundwater via eg septic tank systems, horticultural practices and other activities within catchments that may impact on drinking water quality.	DoH: All MAR proposals will require an extensive risk management framework, similar to the HACCP Model which is largely used by the food industry. Processes that are occurring externally to MAR within catchments are currently already managed through other regulatory land use mechanisms.
	There is no clear explanation of how MAR for public drinking water supplies will conform to the Australian Drinking Water Guidelines.	DoH: MAR water will be incorporated into the integrated water supply network that is operated by the Water Corporation. Potable water supply from the network is currently and will continue to be required to comply with Australian Drinking Water Guidelines. MAR water will not be the only source of water entering the network as it is served by existing surface water catchments and non-MAR aquifer supplies. Water abstracted from the aquifer, after the recharge process, must be of a quality that will not necessitate any further treatment before mixing with bulk water for subsequent distribution.
4	**APPLICATIONS**	
	MAR for industrial reuse is not given sufficient consideration.	The Water Corporation did not request advice on MAR for industrial reuse as industrial users of wastewater generally obtain the wastewater directly, and storage in an aquifer is not necessary. This is discussed in Section 3.1.
	Nitrogen and phosphorus concentrations specified in the Swan-Canning Cleanup Program are 1.0mg/L and 0.1mg/L respectively. Only Class A+ specifies a nitrogen level of <2-10mg/L for recycled water. The	The requirements for the water Classes specified in the Department of Health guidelines are for the protection of human health. The Department of

	COMMENT OR ISSUE RAISED	EPA RESPONSE
	nitrogen level for drinking water reuse is higher than the guideline for protection of freshwater ecosystems. It appears that recycled water would substantially increase nutrient levels in groundwater.	Environment would provide advice regarding the nutrient levels acceptable from an environmental perspective. This is likely to be developed on a case by case basis.
	High nutrient loads into groundwater would lead to algal blooms in the Swan River.	Noted.
	Applications 1 and 2 would result in raised water tables. This would contribute to the mobilisation of nutrient-rich sediments, and subsequent impacts such as adverse effects on remnant bushland.	Noted. The EPA would consider this issue should these potential applications be referred.
	Perth is one of the few cities with large sand areas above aquifers, presenting it with the potential to introduce large-scale MAR projects.	Noted.
	Large scale recharge of aquifers at Pinjara and the Gnangara Mound offer the best long term prospects from an economic perspective.	Noted.
4.1	**Improvement of groundwater resource, e.g. Mosman Peninsula**	
	The claim that there may be little attenuation of phosphorus is incorrect. It has been demonstrated at Halls Head that limestone and Spearwood sands are extremely effective in removing phosphorus from water.	The EPA understands that removal of phosphorus may be limited by preferential flow through the fractured limestone underlying this area. Rapid flow of the recharge water through large macropores would limit the opportunity for the sorption of phosphorus. This would require further investigation.
	Increased nutrient levels may impact the Swan River and ocean.	Noted.
	Equity issues – the main users of groundwater in the Mosman Peninsula are private golf courses, which benefit members only. This scheme would commit funds and water to a relatively small proportion of the population, limiting possible future uses for augmenting municipal irrigation with possibly greater public benefit that a few exclusive golf courses. This proposal also lacks the feedback of pricing controls which apply for scheme water.	Noted. This would be a matter for the proponent of a MAR scheme to consider.
	Does tertiary treatment create a by-product of contaminant enriched wastewater with only limited potential for recycling, and if so, what are the relative volumes of tertiary treated water to by-product?	Tertiary treatment, if it includes microfiltration/reverse osmosis, results in a significant reject volume (up to 20-30%). The reject contains those chemicals that were more dilute in the wastewater before tertiary treatment. It also includes a small volume of reject water created by back-flushing and cleaning the membranes, which may contain caustic or biocides for cleaning.
	This is considered to be a poor example of the use of MAR given the underlying cavernous limestone geology of the Peninsula, and the difficulties in demonstrating any groundwater mounding and thus benefits from the project.	Noted.
	This scheme has been shown to be very expensive, even without membrane treatment.	Noted.
	The Mosman Council in recent years has been changing its stormwater system from conveyance and discharge into the Swan River to infiltration. Together with a more responsible use of bores the salinity of the aquifer is reducing to satisfactory levels. MAR is therefore not necessary.	Noted.
	Chemicals of concern, such as endocrine disrupting chemicals and pharmaceuticals, may not be removed	Noted. This would require further investigation.

	COMMENT OR ISSUE RAISED	EPA RESPONSE
	following the proposed DoH water treatment requirements	
	Current groundwater depletion (with salt water intrusion) is likely to already impact on groundwater discharge from coastal seepage faces and offshore springs.	Noted.
	West Australian waters are so nutrient poor, nutrients are likely to enhance primary production and in fact be of benefit to the fishery.	Noted. This would require further investigation.
4.2	**Irrigated horticulture, e.g. Carabooda**	
	Infiltration ponds could be within 150m of an environmental sensitive area, despite the requirement for a six-month residence time in the aquifer.	Noted. This would require further investigation.
	It may be that intensive horticulture is not environmentally sustainable due to the excessive fertiliser and water application. Would horticulture accept nutrient and water limits set by Government should this occur?	Noted.
	Is secondary treatment without disinfection necessarily safe for below ground produce such as potatoes or beetroot which are cooked? Different categories of produce may share the same shelf/plate/utensil in a domestic kitchen, with a consequent risk of cross contamination if irrigation residues are present. Similarly, flowers irrigated with Class D water represent a potential health risk because flower vases may be emptied at the kitchen sink and any surface contamination with disease organisms could therefore be transferred to food or food utensils.	DoH: As above, horticultural produce consumed raw requires irrigation with ‘Class A’ water, which acknowledges some potential incidental consumption of the water. As the above can be consumed raw, microbiological limits are onerous and cross contamination from this source is unlikely. Produce not consumed raw has lower quality water permissible. This may not protect against poor hygiene practices in kitchens. The required treatment should not be excessive, as the sub-standard food handling practices themselves are more of an issue. Similarly, flowers are not regarded as sterile in any setting and sinks regularly grow microbes when tested. Good hygiene should be instituted and not excessive treatment of the irrigation water as a substitute.
	The health requirements for using water other than Class A in horticulture need to consider the current norms in fruit and vegetable handling by wholesalers and retailers, shoppers’ habits, domestic hygiene, and kitchen practices. It is simplistic to just consider the individual end use of a particular class of horticultural produce in this context.	DoH: Noted.
	It appears that biologically active substances could enter the food web of both terrestrial and wetland fauna. Removal or deactivation between injection and extraction points appears to still be a matter of optimistic guesswork. Grassed parks are feeding areas for ground birds such as magpies and pee-wees. Groundwater sooner or later enters important wetlands, and some wetlands such as Lake Jualbup, Shenton Park, are immediately adjacent to irrigated grassed areas. It is not clear that the environmental fate and effects of endocrine disruptors in water used for MAR is sufficiently well understood for the EPA to accept engineering schemes for recycling which are essentially irreversible.	The EPA has recommended that further work be carried out regarding the risks associated with the chemicals in wastewater, and the potential for chemicals in wastewater to bioaccumulate in the food chain (Section 7). The EPA considers that the environmental fate and effects of endocrine disruptors in wastewater are not sufficiently well understood at this time to support any large-scale MAR in areas of high environmental value.
	Increasing nutrient levels in the aquifer may lead to detrimental effect on the possible effect of increasing nutrient levels in the groundwater dependant ecosystems.	Noted.
	Not supported as crops will be contaminated, as reported in other countries.	Noted.

	COMMENT OR ISSUE RAISED	EPA RESPONSE
4.3	**Integrated water management in new residential areas, e.g. Alkimos**	
	The potential to retrofit existing suburbs was completely overlooked.	The EPA was not requested to provide advice on this topic.
	MAR is preferred over third pipe schemes for new areas from an economic and safety perspective. Cross connection has been reported around the world in third pipe schemes.	Noted.
4.4	**Drinking water, e.g. Pinjar borefield**	
	The concept of MAR to provide drinking water is supported.	Noted.
	MAR to provide drinking water would be catastrophic.	DoH: No intention for direct recycling of water for drinking water. Appropriate controls through process verification, operational testing and verification should ensure that all potential risks to public health, associated with MAR, can be satisfactorily managed.

DoH: response provided by the Department of Health

Also the Water Corporation made the following comment:

It is important to bear in mind the economics of MAR and other recycling schemes.

The economic regulators current estimate of the long run marginal cost of development of public water supplies is 97c/kL. If a MAR scheme can deliver public water supply for under this cost, either by substitution of existing public water supplies, or creation of new supply, this represents the least cost approach to developing new public drinking water source and thus would be funded by an increase in water rates in the same way as seawater desalination. Scenarios described in 4.3, 4.4 and 4.5 will have a significant component of public water supply benefit, and this would contribute significantly to the economics of the scheme. Conversely, scenarios 4.1 and 4.2 are likely to deliver little or no public water supply benefit.

In this case, the beneficiary of the water (golf courses, horticulturalists) would need to contribute to the scheme to assist with making the scheme financial. It is highly unusual for schemes of this nature to fully recover cost from the beneficiary. In this case, the shortfall would need to be funded by an increase in water rates.

Western Australia's economic regulator has not yet considered the implications of this situation for our local situation, but provides the following general advice:

"service providers are asked to demonstrate that their projected service levels are consistent with the standards required by their regulators and are consistent with their customers' expectations. Where service levels exceed regulatory requirements, service providers are asked to verify that consumers are willing to pay for the higher service levels."

Economic Regulation Authority, Inquiry on Urban Water and Wastewater Pricing, Methodology Paper, www.era.wa.gov.au – 15 October 2004

The Victorian economic regulator has considered the implications of water recycling schemes, and note that:

"Where recycled water services are provided in order to meet targets or projects specified by Government:

- businesses should seek to maximise the revenue earned from recycled water customers
- any revenue shortfall should be recovered from potable water customers

Where recycled water services are proposed to meet broad government policy objectives or other triple bottom line objectives:

- prices for recycled water services should cover the full cost associated with providing those services and should include a variable component in order to provide incentives to conserve recycled water *unless*
- the business has consulted with customers specifically on their willingness to contribute to the cost of recycled water services with any resulting shortfall reflected in potable water charges"

Water Price Review Executive Summary - Metropolitan Regional Business's Water Plans, Draft Decision 2005-06 to 2007-08, March 2005, Essential Services Commission

The Western Australian economic regulator is likely to adopt the same philosophy. Thus, Water Corporation would be obliged to maximise revenue earned, which would tend to favour the forms of water recycling which deliver public water supply benefits, being scenarios 4.3, 4.4 and 4.5.

Further, the current approach of licenced discharge of treated wastewater to ocean represents the least cost to the community. Thus, if a MAR scheme is proposed that does not recover cost by delivery of public water supply benefits, the Water Corporation would need to verify that the community are willing to pay for the higher service level (ie use of MAR rather than discharge to ocean) by carrying out willingness to pay surveys on customers. It seems likely that the community would be more prepared to fund schemes where triple bottom line benefits such as maintenance of groundwater dependant ecosystems can be demonstrated in addition to providing additional irrigation water supply. It also appears likely that the cost of treatment to deliver water qualities required to gain regulator approval would be a significant factor.

Finally, Water Corporation note that beneficiaries from the recharged recycled water would probably be extracting water from the aquifer using their existing bores. Defining regulations whereby an end user could be charged for water drawn from an existing bore owned by them on their own property presents a significant challenge.

EPA: Noted.

Appendix 6

List of submitters
(Draft section 16(e) advice)

Organisations:

City of Wanneroo
Department of Environment
Department of Health
Environmental and Earth Science Consultants
Water Corporation

Individuals:

Dr Troy W. Harley

Appendix 7

Summary of submissions and response
(Draft section 16(e) advice)

Response to Submissions on Draft section 16(e) Report - MAR

Water Corporation

Key Issues

1. **The advice recommends a risk based approach in principal, but in a number of places states a position that is effectively a "zero risk" stance. See in particular points 4, 16, 17, 18.**

The EPA supports a risk based approach to MAR. See below.

2. **The document states that further research is required for most scenarios, but gives no indication of what this would involve. Either the preceding discussion should reflect current knowledge gaps or the recommendation should be changed.**

A number of the issues requiring further research are highlighted in Section 4, for example, potential impacts of MAR on stygogfauna (page 16), and implications of MAR with regard to the bioavailability of heavy metals (page 17). Section 7, 'Future Work' summarises the further research required. The issues highlighted for further research are now stated under the appropriate scenario headings.

3. **The feedback from the public forums was generally supportive but cautious regarding MAR. The strategic advice does not reflect this view, and it is unclear where the conservative views expressed in the document have been sourced.**

The EPA recognises the potential for MAR to play an important role in the sustainable management of Western Australia's water resources.

4. **There is a consistent theme in the document whereby MAR in PDWSA's cannot occur until environmental risks are better understood. PDWSA's are not gazetted to protect environment but rather public health, via control of drinking water catchments. It is difficult to see how this position can be credible.**

The EPA notes that the Department of Environment is responsible for managing and protecting the State's water resources. PDWSAs are the water source for schemes supplying cities and towns. The EPA also notes that while Priority 1 areas have been set up for protection of water quality for drinking water purposes, the EPA notes that these generally coincide with areas of higher environmental value, particularly wetlands. This has been clarified in the document.

5. **The document uses the groundwater environment we see today as it's benchmark, in particular points 4,15,18,21 . A key driver for consideration of MAR is drying climate trends and resulting impact on groundwater resources and dependant environment. The benchmark therefore should really be status of groundwater resources in say 20 or 30 years WITHOUT intervention.**

In Section 4.1 'Sustainability' it is now stated that "As part of this risk assessment, both the current and future beneficial uses of the environmental system should be considered."

6. **There is currently no discussion of potential impact on the ocean environment of discharge of reverse osmosis concentrate. Finding the right balance between ocean and terrestrial impacts is one of the greatest challenges of MAR as an opportunity, and it is important that the advice to the Minister reflects this.**

Discussion of potential ocean impacts has been added in Section 4.2.1

Other issues

No	Ref	Statement	Comment	Response
1	P4 last para	Department of Health is the responsible agency for approving *health aspects* of water recycling *schemes* in WA	Insert italic comments as shown. Dept of Environment is the responsible agency for approving environmental aspects of water recycling schemes in WA.	Agree.
2	P5, S2.3	EPA Act requires assessment of the risk weighted consequences of options in decision making	Use of a risk based framework is not compatible with other statements in the document – see below	Responses below.
3	P 13, S3.4	The precautionary principle	Water Corporation would interpret this as saying that lack of full scientific certainty of all water quality impacts should not be used as a reason for postponing implementation of a MAR scheme that is required to prevent environmental degradation due to falling groundwater levels.	Noted.
4	P14, S4.1	..should the quality of water harm the environmental system, this would not be an acceptable outcome	This does not reflect a risk based approach. If the alternative is no intervention and subsequent loss of the system, is this a more "acceptable" environmental outcome? Risk assessment needs to identify LEAST impact. The following two sentences reflect this to a degree but read as a whole the three sentences appear somewhat contradictory, and the reader is left unsure of the EPA position on this issue.	Changed to state " these potential benefits must be balanced against the risks, such as the potential for decreased water quality to adversely affect the environmental system"
5	P15	..given the environmental issues associated with MAR, the implementation of schemes in high priority PDWSA's may be incompatible with the precautionary principle	PDWSA's are defined to protect human health. Why then would *environmental issues* govern whether MAR could proceed in a PDWSA? The defining factor for a PDWSA must surely be the protection of human health rather than environment	This has been amended.
6	P18-P19	Principles	The wording of the principles is different in the main text and Appendix B. They need to be consistent	DoH – Appendix version.
7	P19 Principle 6	…must be of raw bulk water quality without the need for extra treatment	The term raw bulk water quality implies water for drinking, while the principles are meant to apply to	DoH – Fixed by using Appendix version

No	Ref	Statement	Comment	Response
			all forms of MAR	
8	P19 principle 8	The major health issues of concern are chemicals and pathogens	It is the Water Corporations understanding that chemicals are only a health issue for *drinking* water proposals. This is not clear with the current wording	DoH – "Chemicals are only a concern for indirect potable schemes" has been added to end of principle 8
9	P20, 4th para	…does not assume drinking water quality as an essential objective	Discussion paper continued … *and allow for attenuation of contaminants within the aquifer.* Why has this been removed from the final document? It is an important point	
10	P21	The Department of Environment is also developing a management policy for MAR in the 2005-2006 financial year	Water Corporation supports and welcomes this initiative Most MAR schemes will need clear regulations on trading and/or cost recovery to define economics prior to implementation.	Noted.
11	P21, 3rd para	The EPP for Gnangara Mound is due to be updated	Given that Gnangara mound represents one of the most significant possible applications for MAR, it would be logical to explore possibilities for incorporation of assessment of MAR schemes into the updated EPP	Noted.
12	P22	Economic Regulatory Authority	The ERA has a greater role in regulation than the document indicates. IT is suggested that this section be expanded to reflect the full role of the ERA as described at http://www.era.wa.gov.au/water/content/owrProfile/default.cfm?section=owrProfile	Done.
13	P22, Last para	..it may be preferable for this consultation to be carried out independently of the proponents of MAR schemes.	It is not clear to Water Corporation how consultation on a specific proposal could be carried out truly independently of the proponent. Eg a consultant engaged by Water Corporation would not seem independent. The Water Reuse Steering Committee has endorsed an approach of communicating on water recycling issues through the Office of Water Strategy. It may be appropriate to reference this as a possible independent model.	Changed to "The EPA notes that it may be preferable in some cases that consultation and/or peer review of proposed schemes is carried out by an independent third party."

No	Ref	Statement	Comment	Response
14	P23, 2nd para	Use of risk management framework	The Water Corporation strongly supports the use of a risk management framework, and notes that economics of schemes would also need to be considered in making decisions on implementation of MAR schemes	Noted.
15	P23, 4th para	The EPA will not support MAR where it is considered likely to adversely affect the beneficial uses of groundwater or any other identified beneficial uses.	It is important to recognise here that taking account of drying climate trends, groundwater resources on the Swan Coastal Plain are not in equilibrium. Hence, intervention using MAR may be the only way to maintain beneficial uses of groundwater in this situation, and this should be taken into account when assessing possible water quality impacts. Correct application of a risk based assessment approach should address this	Modified to state "The EPA will not support MAR where it is considered likely, **on the basis of risk assessment**, to **unacceptably** adversely affect the beneficial uses of groundwater or any other identified beneficial uses."
16	P23, 6th para	The EPA expects proponents…to demonstrate that the recharge water… is of a quality equivalent to, or better than, the existing groundwater quality	This statement totally contradicts the use of a risk assessment approach in assessing of MAR projects. Against a backdrop of drying climate, proposals cannot be assessed in such "absolute" terms, but rather must take account of risks and benefits of intervention, including eg the greenhouse gas impact of very high levels of treatment and discharge of saline rejects to ocean if using reverse osmosis to achieve the very high qualities of water that this position would undoubtedly require Water Corporation note that, given that recycled water has human metabolised products and artificially manufactured products, it is a virtual certainty that the water will contain substances that are not present in the natural groundwater, whatever the level of treatment. Simple presence of these is not an issue, rather it is their impact in comparison to impact without intervention which should be the focus.	(This is required by the DoE in the current draft Water Quality Protection Note on MAR) Change to "The EPA expects proponents… to demonstrate that the recharge water is chemically and microbiologically compatible with the native groundwater" ~~and of a quality equivalent to, or better than, the existing groundwater quality~~.

No	Ref	Statement	Comment	Response
			Water Corporation notes that NONE of the potential applications presented in the discussion paper could meet this requirement, and, if this statement stands, there would be little benefit in continuing to investigate MAR. It is suggested that this statement be deleted.	
17	P24, 1st para	…establish with scientific certainty that the scheme will not cause degradation of the aquifer…	Water Corporation considers that establishment of scientific CERTAINTY is unachievable, and that no MAR scheme will be implemented if this principle is applied. The statement also does not reflect the use of a risk based approach It is suggested that the statement be deleted.	Change to "In cases where MAR is reliant on the treatment of water by natural processes in the aquifer, EPA support will be dependent upon whether **risk assessment provides assurance that** the scheme will not cause **unacceptable** degradation of the aquifer"
18	P24, 1st para	…or detrimentally affect the existing beneficial use of the resource.	This statement assumes that the beneficial uses remain constant, ie there is no impact due to drying climate or over abstraction. MAR may be the only way of maintaining the beneficial use into the future. It is suggested that the statement be deleted.	Suggest modification to "detrimentally affect the existing **or future** beneficial use of the resource.", to allow for changes in beneficial uses.
19	P24, 2nd para	Regulate under Part V of the act	Is a strategic approval valid?	Section 16(e) advice is not strategic approval.
20	P24, 4th para	Environmental management framework	Water Corporation supports the development of an environmental management framework	Noted
21	P24, 4th para	…for the *protection* of groundwater…	This phrasing implies that MAR does not have beneficial effects. Suggest "..protection of groundwater and maintenance or enhancement of allocatable groundwater resources." MAR would only be applied on the Swan Coastal Plain where there are benefits, and the framework would need to take account of this.	Agree

No	Ref	Statement	Comment	Response
22	P25, 1st para	Issues of concern to the EPA will be dependant on the proposed level of treatment and characteristics of the recycled water proposed to be used in MAR.	While the issues of concern noted are valid, it is suggested that characteristics of the receiving water body are equally as important.	Noted
23	P25	Ref the need for scientific certainty statement on P24 in comparison to the inevitable uncertainties of a specific application	There is significant uncertainty regarding many aspects of this possibility, including: • groundwater flow in fractured limestone • ACTUAL role played by coastal seepage faces and offshore springs, and role of water quality (including saline intrusion) in this • ACTUAL impact on the Swan River in comparison to other impacts Based on current knowledge and advice from Department of Environment, Water Corporation have made the decision not to investigate MAR on Mosman Peninsula further at this time, as it does not consider it possible to provide the level of certainty required to ever get approval for a scheme. It is hoped that DoE can effectively manage the depleting groundwater resource such that the groundwater discharge to the coastal seepage faces and offshore springs can be maintained to protect the biodiversity of the ecologically significant Cottesloe Reef Fish Habitat Protection Area	Noted
24	P26	Further research required	Based on the draft strategic advice and advice from Department of Environment, Water Corporation will not be investigating this application further	Noted
25	P29	MAR for Irrigated Horticulture. Considerable further research is required.	Discussion regarding health issues makes it clear what requirements would be for implementation of a scheme, and there is no reference at all to environmental issues for this application. Water Corporation cannot therefore understand why there	The environmental issues requiring further investigation are detailed in Sections 4 and 7.

No	Ref	Statement	Comment	Response
			would be a need for considerable further research to gain EPA support for the application. The advice needs to provide guidance on what research would be required to address specific unknowns and uncertainties. Environmental issues are only briefly mentioned in Table 2, without sufficient detail for specific examples e.g. Carabooda. There is also no consideration of relative impacts – of horticulture currently vs horticulture with recycled water (lower chemical fertiliser application/manufacture, potential increased management/control on nutrient loads impacting groundwater etc)	
26	P30	Further research is required	The advice needs to provide guidance on what research would be required to address specific unknowns and uncertainties.	The environmental issues requiring further investigation are detailed in Sections 4 and 7.
27	P30	"in house" use requires Class A standard	The table on P13 of the Draft DoH guidelines notes that Class A standard is required for urban non-potable uses with uncontrolled access. This would appear to include residential back gardens as well as "in-house" use. The text and table need to be consistent	DoH: Leave as is.
28	P30	The consideration of any specific proposal will require detailed information if any significant environmental impacts are likely	EPAs position on integrated water management in new residential areas differs significantly from that for horticulture and multiple benefits, and there is no clear reason for this in the document. It is suggested that, without further explanation of the need for and specifics of research and trials, the position of requiring detailed information is also applicable to horticultural and multiple benefits applications.	Further discussion of future work required has been added.
29	P31, 2nd para	DoE approval under section 5	Section 5 appears to deal with the interpretation of the Act, thus this statement should be checked for accuracy. By-law 5.2.5 requires the permission of the	This has been removed.

No	Ref	Statement	Comment	Response
			Water and Rivers Commission to place any chemical or other substance down a well which is capable of polluting underground water. The reference may therefore be to Section of 5 of the *bye-laws*	
30	P31, 3rd para	7GL/yr of treated wastewater discharged to the ocean through the existing outfall	The discharge from the reverse osmosis would be about four times more salty than the existing discharge, reducing buoyancy and dispersion of the stream. There is no discussion of this in the document, and review by EPA Marine Impacts branch of this issue is suggested. This review should take account of other statement in the current draft advice such as: • EPA support being dependant on scientific certainty (P24) which would push the proponent to reverse osmosis to remove any chemicals of potential concern, and hence result in the discharge of concentrate to ocean • The EPA expectation that proponents demonstrate that the recharge water… is of a quality equivalent to, or better than, the existing groundwater quality (P23). The only possible way this could be achieved for any application on Gnangara mound would be to apply reverse osmosis Finding the right balance between ocean and terrestrial impacts is one of the greatest challenges of MAR as an opportunity, and it is important that the advice to the minister reflects this opportunity, and it is important that the advice to the minister reflects this	Discussion of marine impacts has been added in section 4.2.1
31	P31,5th para	Incompatible land use	Suggest "MAR with treated wastewater *is currently classified as* an incompatible land use in a	Agree

No	Ref	Statement	Comment	Response
			PDWSA,….” This communicates the possibility of future change in the light of findings from research etc	
32	P31	EPA Position	Water Corporation acknowledges the complexity of proposing MAR in a PDWSA, and is encouraged that the National Water Quality Management Strategy acknowledges it may be the best planning option, and that EPA will assess any proposals based on merits and an assessment of risk. Investigation of this option will be a major focus for Water Corporation in the next few years, given its role as the provider of safe and reliable public drinking water.	Noted
33	P32, 1st para	EPA recommends further investigation of third pipe systems for specific applications, particularly new developments	There is no justification of this position in the document. Guidelines and regulations for “third pipe” systems have been developed in other parts of Australia and the world, and given the critical risk is health, these guidelines are transferable. Regulation of third pipe systems is well understood and covered in the national guidelines. Investigation is therefore really limited to economics of the scheme. To date no schemes considered by the Water Corporation using treated wastewater have been commercial. Use of MAR for treated wastewater is likely to reduce costs and risks significantly. This is one of the reasons Water Corporation have pursued it so vigorously. Given the local environment on the Swan Coastal	Noted

No	Ref	Statement	Comment	Response
			Plain, the least cost least risk approach for third pipe is to use native groundwater for supply to back gardens. Water Corporation have been pursuing this approach at the proposed Ranford Road development, and will continue to focus on this approach for third pipe supply	
34	P32, 4th para	The council also intends to investigate MAR as a means of water storage for times of low demand	This is one of the key reasons why Water Corporation have been investigating MAR rather than third pipe systems. It is noted that the North Adelaide Plains scheme is also investigating the use of MAR for the same purpose	Noted
35	P32, 6th para	Quantification of environmental risks	Water Corporation strongly supports the recommendation that DoE produce a strategy to address quantification of environmental risks associated with MAR, and notes that it is working with DoE and consultants to assist in production of this strategy	Noted
36	P32	List of issues requiring further work	It is disappointing that the list focussed exclusively on possible negative water quality impacts of MAR, and neglects entirely possible water quantity benefits in comparison to the "do nothing" approach in a drying climate. The likely outcome of this is that schemes will not proceed due to possible water quality impacts, and groundwater dependant ecosystems are lost due to groundwater depletion without intervention	Noted
36	P33	DoE developing WQPN on Artificial Recharge of Groundwater	This note should take account of the work being undertaken by Oceanica, the national work being done on environmental risk assessment, the need to assess risks of intervention and non-intervention, and the issue of balancing environmental water quantity benefits against possible water quality impacts. A document that simply focuses on water quality	Noted

No	Ref	Statement	Comment	Response
			would be of limited value against the backdrop of drying climate and depleting groundwater resources	
39	P34, point 3	The EPA would not support MAR in Public Drinking Water Source Areas *at this time* given the range of environmental, health and social issues which require further investigation.	Add *at this time*, to reflect potential to change position with increased knowledge, and be consistent with the position stated on page 31	Done

Additional Detailed Comments

1. Third Pipe Approach

Section 3.1 indicates that direct reuse of wastewater is considered only to provide context and that the strategic advice does not consider the direct reuse of wastewater. However, section 6 "Other Advice" focuses solely on the direct reuse of wastewater and in particular third pipe schemes for the provision of non drinking water to new developments.

Therefore, whilst it is recognised that issues not directly within the scope of the strategic advice can be commented on in the "Other Advice" section it would help if this section could elaborate further on exactly why the EPA would like further consideration of third pipe schemes. Does the EPA believe they are more sustainable than managed aquifer recharge? Did the community raise this as a particular issue during the public forums? Also why should wastewater be used in a third pipe when other lesser polluted forms of water such as groundwater or stormwater could be used in a third pipe where sufficient quantities exist before wastewater is used?

The EPA should be aware that the Water Corporation is working with regulators, developers and the community on the planning and management of third pipe schemes supplying non drinking water, and in new urban areas where new wastewater treatment plants are planned studies are being undertaken to determine how best to meet demand through scheme water, third pipes and/or managed aquifer recharge.

If the EPA does choose to comment on third pipe schemes it would be beneficial to provide a greater analysis of the costs and benefits of the schemes implemented to date. For example at Rouse Hill the recycled water was priced at least three times less than the drinking water and as a consequence the water was used for things it should not have been used for (eg filling up swimming pools) and it was used excessively.

EPA: Noted.

2. Additional Project Examples

Section 3.2 refers to a number of projects which are currently operating in Australia where wastewater or stormwater is being used. It might be worthwhile including in this section details of two projects which have recently sought Commonwealth funding through the National Water Initiative and which aim to replenish drinking water supplies with wastewater. These projects are detailed below.

Goulburn Mulwaree Council Sustainable Cities Project

This $32 million project aims to increase the secure yield of Goulburn's water supply by reclaiming effluent and returning it to the Sooley Dam catchment. This project includes:

- **construction of a new wastewater plant;**
- **construction of an advanced water reclamation plant; producing potable (drinking quality) water for transfer to Bumana Creek watercourse and into Sooley Dam via a chain-of-ponds wetland;**
- **rehabilitation of the chain-of-ponds wetland system in Bumana Creek to polish the water before the final indirect recharge of the existing storage at Lake Sooley; and**
- **the provision of off takes from the transfer pipeline to allow urban reuse, including the Racetrack and sporting field irrigation.**

Water Futures – Toowoomba

This $68 million project includes:

- **purifying 5000ML/annum of wastewater to a standard higher than drinking water and pumping this into Cooby Dam to supplement drinking water supplies;**
- **supplying the reject stream from the advanced water treatment plant to a coal mine after the reject stream has been mixed with a slightly higher quality water from the water reclamation plant;**
- **supplying 1000ML/annum of water from the advanced water treatment plant to a horticultural area;**
- **supplying 500ML/annum of reclaimed water to urban areas for non drinking uses; and**
- **supplying reclaimed water to meet future needs of a planned industrial estate.**

EPA: Details of these projects have been included.

3. Postponing new water supply developments

The last paragraph in section 3.3 makes the comment that recycling wastewater may allow for new water supply developments to be postponed. Yet recycling wastewater is a new water supply in itself. What it *may* do is delay the need for a more costly and more environmentally unfriendly water supply to be developed. It is important to understand that recycling wastewater is another means of meeting demand for water and therefore, it should be weighed up against all other potential sources of water for an area or a city. This issue is picked up under section 4.1 Sustainability.

EPA: Noted.

4. Requirement for Formal Assessment

Further clarification is sought as to when the EPA might require a formal assessment. Is it likely to also include those projects which may indirectly impact upon areas of high environmental value, i.e. where the project is upstream of these areas.

EPA: Proposals are likely to require formal assessment when they are likely, if implemented, to have a significant effect on the environment. It is not possible to provide a more detailed indication of when formal assessment may be required as the environmental issues associated with any MAR proposal will be highly site-specific.

Environmental and Earth Science Consultants

No	Comment	Response
1	The EPA report is superficial in that little detailed or subjective information is supplied in section 3.1 on the use of MAR in an international context. The EPA's report fails to provide any useful summary of how well or how badly MAR has operated elsewhere in the world, giving no clue as to whether MAR has been shown to have serious environmental or other impacts or benefits in these localities.	Noted.
2	The report trivialises the use of MAR in places such as the Thames River valley by describing the use of MAR as "inadvertent". An explanation for the use of this description of MAR is not provided. More importantly, however, the ability of UK government authorities to make conscious, informed decisions about the continuation of such "inadvertent" MAR use **and their failure to stop such usage** surely indicates that government regulators and the water-drinking public are supportive of such MAR usage.	Noted.

3	The report appears to have been deliberately written in such a way as to make the reader nervous or uncertain about the use of MAR. Such bias in an EPA report is of great concern.	Noted.
4	The EPA must acknowledge that some of its findings and recommendations have significant flow-on economic or social consequences. I believe that the EPA is not meeting broader community expectations, nor is it fulfilling the spirit of the *Environmental Protection Act*, if it chooses to provide reports that make no reference to these other consequences.	Noted.
5	I am disappointed that the EPA has not commented upon the fact that an early use of treated wastewater via MAR to replenish aquifers that currently supply much of Perth's drinking water may well overcome the need for extraction of water from the Southern Yarragadee (or at least defer the project by several decades). This $340 million project will have significant environmental impacts if remedial action is not taken and it will produce significant volumes of greenhouse gases during construction and less so during operation. Conversely, the use of treated wastewater to replenish depleted underground aquifers around Perth will potentially have significant environmental, social and economic benefits.	Noted.
6	I accept that the EPA should not provide **detailed** information on the more serious consequences arising from its findings and recommendations. Nonetheless, the public and government should be appraised of these consequences in a **general** way so that they can make more informed decisions when deciding priorities for action.	Noted.
7	The EPA has a role to analyse and question whether the Guidelines as produced by the Department of Health for the use of treated wastewater for MAR are fair and reasonable. While the Water Corporation may well address this issue in its further reports to the EPA and the public, I believe that the unquestioning acceptance by the EPA of the Department of Health's Guidelines is a deficiency within the EPA's provision of advice to the Minister for the Environment and to the public of Western Australia.	The Department of Health has primacy with regard to the provision of health advice.
8	While I generally endorse the EPA's conclusions in section 5.2 of the report, I regret to advise that I find the report to be deficient in what I consider to be essential information about the use of treated wastewater elsewhere around the world. I believe that this deficiency within the report is likely to be interpreted by the general public as the EPA being overly negative about and cautious towards the use of MAR by treated wastewater. The report fails to provide any evidence from elsewhere in the world where well-conducted aquifer recharge with treated wastewater has posed a risk to human health or to the environment.	Noted.

9	These omissions cast too dark a shadow on a proposal that deserves to have strong public support and be fast tracked so as to defer for many years the need for other more expensive and environmentally impacting water schemes	Noted.

Dr Troy W. Hartley (summarised)

No	Comment	Response
1	The EPA advice for a staged, precautionary approach is prudent and well thought out, including the suggestion that a detailed community involvement plan accompany any MAR scheme. Demonstration trials with monitoring programs provide valuable opportunities to build public confidence and trust. The community should have an opportunity to contribute to the factors to be monitored for. Any determination to move forward into subsequent stages of a MAR scheme is dependent upon effective community involvement since the decision (and particularly successful implementation of a decision) is based on scientific and technical findings *and* public acceptance and support.	Noted.

City of Wanneroo (summarised)

No	Comment	Response
1	In Section 4.4, reference should be made to the Planning (or Development) Approval process.	Done.
2	The City agrees with the issues identified in Section 7 for further consideration.	Noted.

Department of Health

No	Comment	Response
1	Department of Health (DOH) considers the draft report to be well written, a good summary of the current status of knowledge, and a positive commencement to the important processes of communication and further research. The DOH does however, have some concerns about the choice of wording in some of the recommendations and possible misperceptions that may arise.	Noted.
	The state context on page 10 and 11 reflects the previous work of the State Water Reuse Committee but not more recent strategic changes due to the increasing imperative of source development and the consideration of this over and above any 20% by 2012 guideline. It is my understanding that work currently underway regarding an overarching strategic response to reuse will be shared with the Environmental Protection Authority (EPA) and an opportunity may exist to incorporate this work in this section within available time.	Noted.
	On page 15 in the Sustainability section there is a comment that "given the range of environmental issues that the implementation of schemes in high priority public drinking water source areas (PDWSA) may be incompatible with the precautionary principle". A similar point is repeated in 4.2.1 Environmental risk. The DOH is concerned that discussions of PDWSAs and, of 50% of the metropolitan area drinking water supply coming from ground water, would lead to confusion and that those reading the document would see these comments as relating to a health risk. I presume the statements relate to specific hydro-geological and environmental conditions and not any notional impact on drinking water supply which is dealt with in Health Department guidelines. This should be clarified	Noted. This has been clarified by stating "areas of high environmental value" rather than PDWSAs.
	On page 16, still under environmental issues, a comment is made that site specific data on pathogen survival will be necessary for the EPA to evaluate any large scale MAR proposal. It should be made clear in this paragraph that this only relates to potential use of MAR for Class B and Class C schemes. Any scheme of Class A or above will be required by the DOH to demonstrate absence of pathogens either prior to spreading or in the vadose zone. In these schemes thus pathogen survival data are unnecessary	Done.
	On page 17 under Ecosystem values a comment is made that in wastewater from an industrial source heavy metals may become bioavailable for crops. It is stated that this requires further research. DOH contends that heavy metal availability for crops is a health issue not an ecosystem value and the statement is an error in fact. In Appendix 2	This has been clarified by deleting "for crops".

	of the draft DOH guidelines include a section on page 5 on heavy metals identifying the absence of these issues in previous reuse projects and a DOH requirement for a single set of data to confirm the absence. It is not the view of DOH that this should be included in ecosystem values nor that further research is required	
	On page 24 a statement is made that the Department of Environment (DOE) does not support MAR and PDWSAs. Again the DOH believes that references to PDWSA will confuse the public regarding whether this in an environmental or health issue. Personal communication from the DOE has suggested that any MAR approach in a PDWSA zone 1 would lead to a rezoning to protect the integrity of zone 1 areas. I note the DOH would not support MAR in PDWSAs prior to the completion of the three year chemical study about to be undertaken. Analysis of the results of this project would be a minimum prior to the commencement of any trial in a drinking water area.	Noted.
	On page 29 the conclusion that the EPA would require further research and trials before it would support a full scale horticulture irrigation scheme needs specific information regarding what research would be required. The DOH notes extensive use of treated wastewater for direct application to ready to eat horticultural produce in a wide variety of settings without public health risk. The DOH is unaware of any research specific to horticultural irrigation which would be required that was not generic research regarding environmental impacts of MAR	Further information on the research required regarding environmental issues has been provided.
	The conclusion regarding MAR for integrated water management in new residential areas, and repeated in Section 6, regarding consideration of third pipe systems is gratuitous and outside the scope of strategic advice on MAR. The DOH will require Class A quality water for any third pipe system and stringent governance regarding the management and ongoing maintenance of any such proposals.	Noted.

Department of Environment

1	The Department of Environment supports the concept of MAR using treated wastewater as a potentially valuable option to increase and enhance available water resources, and to address environmental problems associated with a drying climate.	Noted.
2	The DoE broadly supports the measures proposed in draft EPA strategic advice and the conclusions presented.	Noted.
3	The DoE is keen to ensure that should large scale MAR occur, it should be seen to promote water use efficiency, offset groundwater level declines and maximise benefits to	Noted.

	groundwater dependent ecosystems.	
4	The DoE would prefer not to see MAR with treated wastewater in current and future Public Drinking Water Source Areas (PDWSA) until this necessary research, both scientific and social, has been undertaken.	Noted.
5	There is some concern that MAR assumes that there is no chemical interaction with aquifer sediments and/or natural groundwater. This clearly requires further research. Recent studies carried out by the United States Geological Survey indicate changes in redox and other chemical conditions in a shallow sand aquifer (similar to our local superficial aquifer) to trigger the release of in-situ arsenic into groundwater originally bound in iron coatings on sand grains. More information needs to be obtained and research carried out on this issue.	The potential for reactions is discussed in section 4.2.1 (Groundwater). It is identified in section 7 (Future work) that further consideration of the chemistry of MAR and potential for release of arsenic is required.
6	The DoE understands that the Department of Health (DOH) has proposed to licence (and presumably audit) any MAR projects that are established on the Swan Coastal Plain. It is not clear what default regulatory means (post any required EIA pursued under Part IV of the Environmental Protection Act (EP Act) 1986) would be used, particularly as regulation under Part V of the EP Act 1986 is not presently prescribed, and alternate regulatory controls are not available under other water quality statutes administered by this Department.	The DoH has regulatory powers under sections 97, 107 2 (b) and 129 of the *Health Act 1911*. As stated in section 5 of this advice, it is the view of the EPA that Part V of the *Environmental Protection Act 1986* provides a suitable regulatory mechanism for managing the daily operation of MAR schemes
7	The draft EPA report does not address the management and disposal of reject concentrate from any reverse osmosis treatment of municipal wastewater. DoE considers that an EIA process for this may be necessary regardless of the location of the planned disposal.	This is now discussed in section 4.2.1 'Marine and surface water'.
8	Would a MAR proponent be obliged to establish any treated wastewater storage (if project is not ASR) period prior to discharge into the environment? This storage could provide for treatment equipment malfunctions or outages, balancing of out-of-specification water quality, double checking of suspect analytical results and periodic maintenance actions on the recharge system. Non-conforming waters would need a disposal solution.	This would be considered as part of any specific proposal.
9	DoE assumes surrogate testing of treated wastewater will be used to screen its suitability for MAR (e.g. TSS for solids, TOC as indicator of the potential presence of harmful organic substances, thermo-tolerant coliforms or viral indicators for microbes). This testing could be used extensively to indicate the safety and stability of the wastewater treatment process. There is some concern that there is a risk of a slug of a intractable contaminant arriving at the wastewater treatment works (e.g. an illegal dump of industrial effluent) that may disrupt the treatment plant performance and require a	This would be considered as part of any specific proposal.

	contingency program to be actioned. Such a program would necessitate time-consuming detailed analysis to profile the cause of the abnormal operating condition). We recommend that the EPA document address this issue.	
10	Where the MAR site (including trials) cannot be located in an area remote from freehold land, there should be a requirement for the proponent to address the existence of private bores within the zone of influence of the MAR site that may have a broad range of usage, including drinking. The DoE has limited regulatory powers in relation to domestic bores.	This would be considered as part of any specific proposal.
11	We believe that best management practice for sub-surface injection/infiltration of wastewater is Aquifer Storage and Recovery (ASR), where an aquifer is used for storing wastewater (and providing some treatment), which is recovered for irrigation at appropriate times. The extent of the wastewater "bubble" should be accurately determined through appropriate monitoring and modelling, and clearly demonstrated that the wastewater will not cause environmental problems through discharge to waterways or wetlands, or will not adversely effect nearby groundwater users. For this to work effectively, aquifers need to be effectively homogenous so that the movement of wastewater constituents can be accurately monitored, and there is adequate die-off of residual pathogens.	Noted. However the EPA does not consider that a homogeneous aquifer is necessary for pathogen die-off. Modelling and risk assessment will be required, based on adequate characterisation of the aquifer, to ensure that die-off of residual pathogens is adequate.
12	ASR is not presently mooted for municipal wastewater reuse on the Swan Coastal Plain, and most of the known wastewater recharge is placed in areas on or adjacent to karstic limestone near the coast. In these areas, groundwater flow paths cannot be predicted with any level of confidence, and there is inadequate monitoring to track the movement of contaminants. The effect of effluent mixed with groundwater discharging through preferential flow paths to the coastline or to the Swan River needs to be considered where fish habitats need protection.	This is noted in sections 4.2.1 and Table 2. In section 5.2 the potential for MAR on the Cottesloe Peninsula to impact the Cottesloe Reef Habitat Protection Area is identified, and it is stated that further investigation of this is required.
13	**Section 4.3 Page 19 Principle 6** More detailed consideration should be given to the quality criteria to be sustained in the receiving aquifer, related to the range of values it is called on to support. Factors to take into account include: 1. The range of resource values presently dependent on the MAR target aquifer and their relative importance. The Department of Health criteria only cover human health. 2. Information on ambient background contaminant concentrations in the aquifer (e.g. nutrient enrichment due to established land use such as irrigated horticulture). Historic human impacts on groundwater quality are now	It is noted that this is one of the principles underpinning the Department of Health guidelines, for the protection of human health. DoH does not consider these to be health issues. The EPA notes that issues 2-5 are relevant to environmental protection in relation to MAR.

	superimposed on natural background quality. We question whether MAR quality should be benchmarked against the present degraded groundwater quality. 3. The present application of the NRM strategy across WA is expected to result in revised groundwater quality goals (backed by viable attainment strategies). 4. The acceptability of introducing groundwater contaminants that are not currently present (regardless of the extent and reliability of information on concentration levels) when effects on local ecology remain uncertain. 5. Aquifer quality threshold levels should be set conservatively below that necessary to sustain water use values, to allow for abnormal operational incidents, and climate driven uncertainty.	
	Section 4.4 Regulatory requirements and guidelines DoE recommends referencing of the NWQMS document *Australian and New Zealand guidelines for fresh and marine water quality 2000.* This document provides important information on defining water values and protection criteria necessary for their retention.	Done.
	Page 23 final para Suggest addition: "At the point of withdrawal *or movement into water bodies (marine or terrestrial) supporting any defined values,* the recharge water should…."	Done.
	Page 24, para 4 NRM processes are presently in place that are expected to deliver definition of desired environmental values and water quality goals described.	Noted.
	Page 24 para 5 Suggest addition: "…under the Health Act 1911 *and planning agency approvals"*.	Done.
	5.2 Potential applications • If a public concern arises about a <u>perceived</u> impact of MAR at a specific location (real or driven by misinformation/ secondary concerns, the prime Government response custodian should be assigned (ie WC, DoH ,DOE or DPI), as subdivision may creep into the buffers assigned to the MAR application. Problems are expected in explaining to the community the relative level of risk <u>versus</u> desire for absolute guarantees of safety for human health.	Noted.
	We query the statement on page 25, para 5 attributed to the Water Corporation that *Western Australian waters are so nutrient poor that additional nutrients would be likely to enhance primary production and benefit fisheries*. We question whether evidence available that increased nutrients would benefit our fisheries.	Noted. The EPA has quoted the Water Corporation, and agrees that this required further investigation.
	We query statement on page 26, para 1: *Therefore all pathogen guidelines must be met.*	DoH: Prefer to leave as is. Assessment of starting points would be

	Subject to input by Department of Health (DoH), we propose rephrasing to stipulate pathogen requirements be at least DoH Class B provided approved time/offset distance buffer is maintained. Log reduction statement for pathogens in grey-water or stormwater is considered ambiguous, due to the anticipated variability related to local quality influences and time available for pathogen inactivation.	required.
	Subject to confirmation by DoH, we query expressing microbiological safety in terms of **log reductions** from an unspecified starting concentration. We believe that the definitive concentrations of specific microbes for projected water uses provided by the DoH in Appendix A of their Draft *Recycled Water- Groundwater Recharge Guidelines* provide a more certain outcome.	DoH: DoH does not consider this will be unspecified. The Class A guidelines set clear standards for verification. These are the equivalent of the listed log reductions based on blackwater microbe data.
	DoE suggests a need for demonstrated water efficiency in the horticultural industry be mentioned in **MAR for Irrigated Horticulture.** This will ensure that MAR is not perceived as a panacea to water shortages and/or an opportunity to increase abstraction pressuring other environmental values.	Done.
	Page 29 second para: Second sentence refers to environmental impacts, but the rest of the paragraph and section relates to health impacts – should this section read **Health impacts**?	This section has been changed.
	MAR to increase drinking water supplies • Page 31, Para 3: DoE recommends second sentence be removed as this safeguard may not be realised. • Page 31 Para 5 DoE recommends text read: *MAR is an incompatible land use in a PDWSA under the Metropolitan Water Supply, Sewerage and Drainage Act Bylaws 1981. On the Gnangara mound the PDWSA boundaries were revised under the GLUWMS following extensive public consultation.*	Done. Sentence has been removed.
	• Page 32 line 6 substitute: …*connected to each residential property* in place of *to the house.*	Done.
	Section 7. Future Work • Further discussions are recommended on EPA expectations for DOE work described in para 2. We are uncertain of extent of work/ form of quantification envisaged that may be outside the present bounds of studies by Oceanica Consultants, CSIRO & projected Premier's Collaborative Research Program. Issues noted earlier on water quality management and effects on ecosystems relate to any future work needing to be done. • How should a proponent approach a scenario where water movement or water quality outcomes downstream of the MAR site fail to meet modelled predictions?	The EPA considers this work a suitable first stage. Noted. This would be considered in the assessment of a specific proposal.

	This may arise due to changed rainfall conditions, changes to local land use, interaction of applied wastewater with substances present in the environment or long term changes to the hydraulic properties within the aquifer? A risk and decision making matrix for such scenarios is recommended. • We question long term will the land use/water balance conditions that gave rise to MAR application at a particular site (e.g to sustain horticulture or maintain water levels in wetlands) be necessarily maintained? If uncertain, up-front information is needed on whether MAR water practically can be reassigned to an alternate location or redirected into the ocean? • We recommends that the results of any MAR trials be published to inform the community on the water quality achieved by various treatment systems before recharge and the outcomes of environmental monitoring downstream of the trial sites benchmarked against national health and environmental criteria.	Noted. This would be considered in the assessment of a specific proposal. Agreed.
	Table 2 (page 28) – the need for EIA is determined by project scale. What will benchmark “**large scale”** projects as requiring EIA?	It is not possible to set criteria to define “large scale”, as the requirement for EIA is also highly dependent on the proposal characteristics and those of the receiving environment.