MANAGED AQUIFER RECHARGE (MAR) CASE STUDY

1

BOX 1 MANAGED AQUIFER RECHARGE - EXECUTIVE SUMMARY

Key findings

The West Australian managed aquifer replenishment project has:

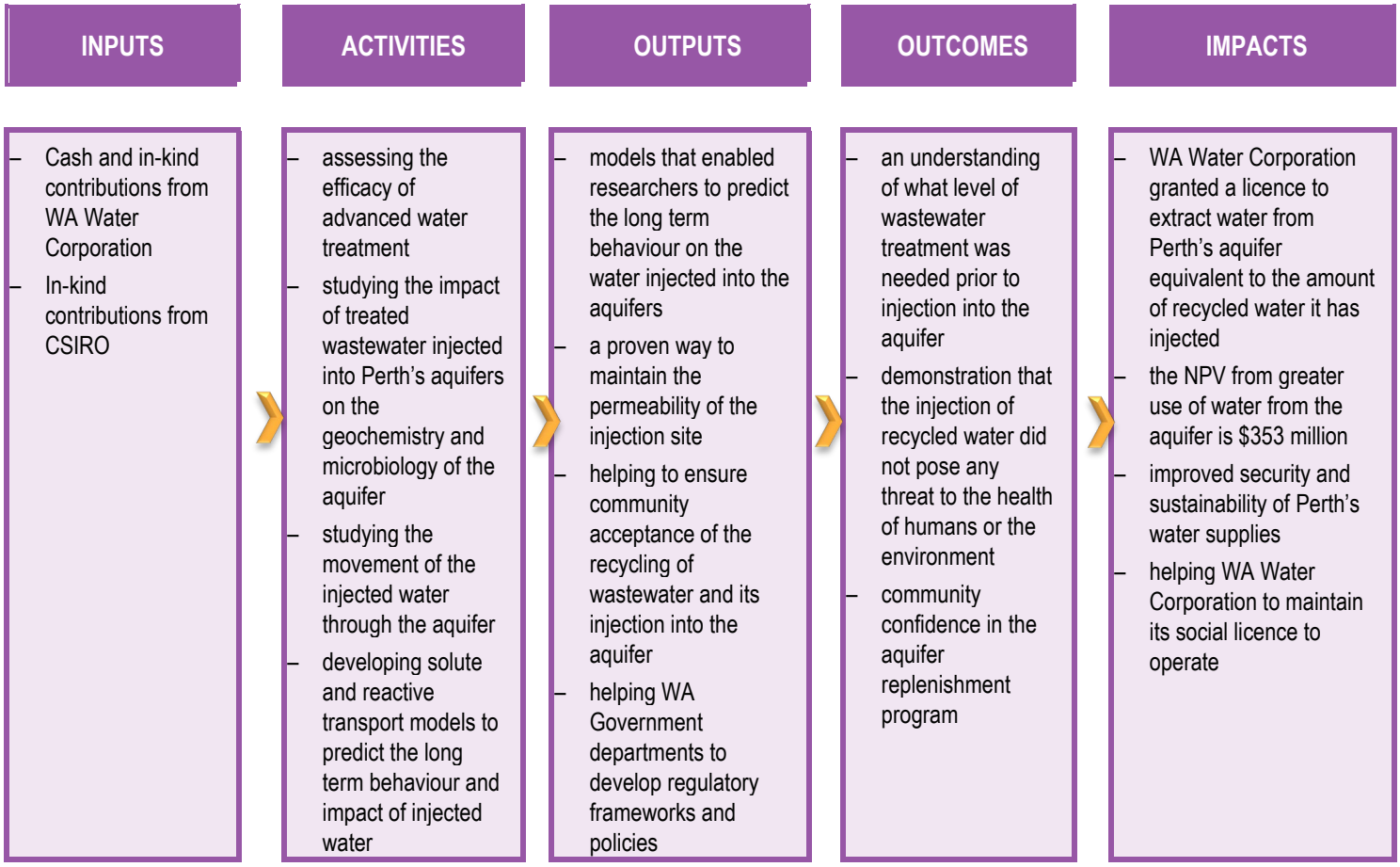
- demonstrated that the injection of recycled water did not pose any threat to the health of humans or the environment
- increased community confidence in the aquifer replenishment program and helped WA Water Corporation to maintain its social licence to operate
- enabled the WA Water Corporation to obtain a licence to extract water from Perth's aquifer equivalent to the amount of recycled water it has injected
- improved the security and sustainability of Perth's water supplies
- helped WA Water Corporation avoid costs estimated to be $356.5 million in 2017/18 dollars.

Innovation impact

The models to predict the long term geochemical and hydrological behaviour on the water injected into Perth's aquifers are innovative. As is the process developed for maintaining the permeability of the injection well site. The maintenance of permeability over time is much greater than for any similar injection well around the world.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the Managed Aquifer Recharge (MAR) project are summarised in **Figure 1.1**.

FIGURE 1.1 MANAGED AQUIFER RECHARGE CASE STUDY – IMPACT FRAMEWORK DIAGRAM



SOURCE: ACIL ALLEN

1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from the MAR project.

This evaluation is being undertaken to assess the positive impacts arising from the MAR project undertaken by CSIRO. However it can also be used to inform a range of other stakeholders. The case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of the Land & Water (L&W) Business Unit's activities as a whole relative to the funds invested in these activities.

This information in this case study is provided for accountability, communication and continual improvement purposes. This case study is primarily intended to be an input into the independent review of the L&W Business Unit however other audiences for this report may include Members of Parliament, Government Departments, CSIRO and the general public.

1.2 Background

Since the 1970's rainfall in south west WA has reduced by around 19 per cent, streamflow to Perth's dams has declined even more dramatically. In 2009, in response to the early signs of a drying climate, the WA Water Corporation released a 50-year plan to secure Perth's water supply. In 2011 this was followed by a 10-year plan. As part of the implementation of these plans Water Corporation has progressively added new sources of water that are independent of climate to help secure supplies. These sources include seawater desalination and groundwater replenishment.

Water extracted from groundwater systems is particularly important for meeting the water needs of Perth. Groundwater currently provides about 46% of Perth's total water supply. In Perth there are three aquifers at different depths:

— The superficial aquifer. This is the shallowest aquifer which stretches across the coastal plain. Perth's superficial aquifer is close to the surface, often visible at the surface as a wetland or a lake.

— The confined Leederville aquifer. This aquifer lies below the superficial aquifer, and is separated by confining layers which minimises water movement toward the surface and conversely from the superficial to the Leederville aquifer.

— The confined Yarragadee aquifer. This is the oldest aquifer under Perth. It is a good source of supply even in dry years because of its vast storage and limited connection to the surface.

Groundwater (in excess of 1500 kL per year) in aquifers can only be extracted if the Department of Water and Environmental Regulation has issued a license for that extraction to occur. This is to ensure that the extraction of water is done in a manner that is environmentally sustainable and protects public health.

Groundwater replenishment is an approach where wastewater is treated to drinking water standards, and injected into aquifers to recharge them. The injected recycled water is then stored in the aquifers which also provides further natural treatment capacity, and extracted when required through existing production wells. By injecting recycled water it is possible to reduce the reliance on rainfall to replenish the aquifers. In the long term, Water Corporation's 50-year plan indicates that groundwater replenishment could contribute to as much as 20% of Perth's drinking water supply in 2060.

However, before the required approvals could be obtained to inject recycled water into drinking water supply aquifers it was necessary to demonstrate to the Department of Health, Department of Water and Department of Environment and Conservation (now Department of Water and Environmental Regulation) and the broader community that it was safe to do so and that there would be no adverse impacts on water security, human health and the environment. In 2005 CSIRO was commissioned by the WA Water Corporation to carry out a program of research to help build the case for the Managed Aquifer Recharge (MAR) of Perth's aquifers.

1.3 Impact Pathway

1.3.1 Project Inputs

The total cost for the MAR project was about $2,257,259 million in cash and in-kind contributions (see **Table 1.1**). WA Water Corporation contributed $1,251,741 in cash and $310,000 of in-kind support. CSIRO provided in-kind support of $695,518 (just over 30 per cent of the total cost).

TABLE 1.1 SUPPORT FOR THE MAR PROJECT

Contributor / type of support	2006-07 ($)	2007-08 ($)	2008-09 ($)	2009-10 ($)	2010-11 ($)	2011-12 ($)	2012-13 ($)	2013-14 ($)	2014-15 ($)	2015-16 ($)	2016-17 ($)	2017-18 ($)
Cash												
WA Water Corporation	81,811	-	110,000	204,500	165,000	130,000	51,419	197,831	69,380	95,900	95,900	50,000
In-kind												
CSIRO	52,000	-	43,094	139,204	103,191	72,251	15,633	104,100	-	134,886	31,159	-
WA Water Corporation	-	-	-	-	-	-	20,000	20,000	230,000	20,000	10,000	10,000
Total	**133,811**	**0**	**153,094**	**343,704**	**268,191**	**202,251**	**87,052**	**321,931**	**299,380**	**250,786**	**137,059**	**60,000**

1.3.2 Project Activities

CSIRO's research for the WA Water Corporation has occurred in stages.

It began in 2005 through two key projects, the Premier's Collaborative Research Program "Characterising treated wastewater for drinking purposes following reverse osmosis treatment" and the Premier's Water Foundation "Determining Requirements for Managed Aquifer Recharge in Western Australia". These projects began to study the efficacy of advanced water treatment at a pilot plant at the Water Corporation's Beenyup Wastewater Treatment Plant and infiltration of treated wastewater sourced from the Water Corporation's Subiaco Wastewater Treatment Plant into the Superficial aquifer, the shallowest element of Perth's aquifer at CSIRO's facility in Floreat Park. The CSIRO researchers characterised the wastewater prior to and after processing in the pilot water treatment plant and studied the impact of the treated water after it was infiltrated.

In 2007 drilling commenced at the Groundwater Replenishment (GWR) Trial site, where diamond core was recovered through the Leederville aquifer (target aquifer for GWR) to allow laboratory experiments to understand the fate of recycled water. This included determining the changes the injected water had on the geochemistry of the aquifer. In particular, to assess whether the injected water caused any metals present in the aquifer to be mobilised, and solute and reactive transport modelling to predict the long term fate of the injected recycled water. CSIRO also found good evidence that any organics still present in the treated water were bio degraded following injection into the aquifer.

Injection of recycled water for the GWR Trial commenced in 2010. To verify the laboratory research, and to assess the impact of GWR at field scale, 22 monitoring wells were drilled at a distance between 20 meters and 250 meters from the injection well to study the nature of the plume of water moving through the aquifer from the injection well site.

In 2013 the CSIRO commenced a project to study the injection of recycled water into the deeper Yarragadee aquifer. The deeper part of the aquifer has more silt and fine particles than the shallower Leederville aquifer and CSIRO, together with Curtin University, wanted to study whether this caused a loss of permeability over time when recycled water was injected into the aquifer. An outcome of this research was a process to condition the aquifer in the region of the recharge bore by a program of injecting water then extracting it from the same well. This had the impact of 'cleaning out' the silt and fine particles around the injection point.

CSIRO also examined the impact of injecting water on the microbiology of the aquifer. It was thought that injecting oxygenated water into the anaerobic environment of the aquifer might alter the microbiome assemblage present and enhance growth, potentially leading to reduced permeability around the injection well.

One of the CSIRO scientists provided input to Health and Environment Government departments to help them develop appropriate regulatory frameworks and policies that would allow the adoption of large scale GWR. Putting in place those regulations was crucial to giving the public confidence in the safety of the process and Perth's water supplies.

CSIRO researchers now have an ongoing role in the ongoing monitoring and risk evaluation process. They assess the data collected every quarter to ensure that licence requirements for injection are met. CSIRO are also members of the WA Water Corporation's Technical Reference Group.

CSIRO also carried out research on how best to communicate the results of their research. The WA Water Corporation used that research to help them plan their community engagement in order to help them gain community acceptance for their plans to replenish the aquifer with highly treated recycled water.

1.3.3 Project Outputs

CSIRO developed a series of solute and reactive transport models at different scales that allowed them to characterise the water quality changes and estimate the flow of the injected water through the aquifer. These models enabled researchers to predict the long term behaviour of the water injected into the aquifers. Specifically, when injected water would reach an extraction well and what the quality of that water would be.

The well field conditioning process undertaken proved very successful in maintaining permeability of the injection site. The WA Water Corporation are achieving injection rates of 175 litres per second at each injection well. This is a very high injection rate compared rates achieved at similar aquifer replenishment schemes around the world. Since commencing injection in late 2017 the scheme has operated without any loss of permeability.

CSIRO was instrumental in helping to develop the regulatory frameworks and policies that have allowed aquifer replenishment to occur. Their support has also helped to ensure community acceptance of the recycling of waste water and its injection into the aquifer. That acceptance was demonstrated by the lack of any community opposition to the recent decision to expand the amount of injected water from 14 GL to 28 GL a year.

Publications

Five examples of publications produced over the course of this project are provided below.

— Patterson, B.M., Shackleton, M., Furness, A.J., Pearce, J., Descourvieres, C., Linge, K.L., Busetti, F., Spadek, T., (2010). *Fate of nine recycled water trace organic contaminants and metal(loids) during managed aquifer recharge into a anaerobic aquifer*. Column studies. Water Research 44, 1471-1481.

— Descourvieres, C., Hartog, N., Patterson, B. M., Oldham, C., & Prommer, H. (2010). *Geochemical controls on sediment reactivity and buffering processes in a heterogeneous aquifer.* Applied Geochemistry, 25(2), 261-275.

— Patterson, B. M., Pitoi, M.M., Furness, A. J., Bastow, T, McKinley, A. J. (2012). *Fate of N-nitrosodimethylamine in recycled water following recharge into anaerobic aquifer*. Water Research 46, 1260 - 1272.

— Seibert, S., Prommer, H., Siade, A., Harris, B., Trefry, M., and Martin, M., (2014). *Heat and mass transport during a groundwater replenishment trial in a highly heterogeneous aquifer*. Water Resources Research, 50, 9463 - 9483.

— Ginige, M.P., Kaksonen, A.H., Morris, C., Shackelton, M., Patterson, B.M. (2013). *Bacterial community and groundwater quality changes in an anaerobic aquifer during groundwater recharge with aerobic recycled water*. FEMS Microbiol. Ecol. 85, 553-567.

Awards

This project has been given a number of awards. These are listed below:

— AWA Western Australian Water Research Merit Award – 2008 –Premier's Water Foundation – Determining requirements for managed aquifer recharge in Western Australia. (CSIRO, Curtin University, University of Western Australia, Water Corporation)

— AWA Western Australian Water Research Merit Award – 2010 – Premier's Collaborative Research Project – Characterising Treated Wastewater from Drinking Purposes Following Reverse Osmosis Treatment. (Department of Health, Department of Water, Department of Environment and Conversation, Water Corporation, National Measurement Institute, ChemCentre, Curtin University, University of Western Australia, CSIRO)

— AWA Western Australian Infrastructure Innovation Award – 2013 – The Groundwater Replenishment Trial. (Water Corporation)

Innovation / commercialisation

A WA Water Corporation official commented that CSIRO had done:

Ground breaking work that delivered extremely good public benefits.

Stakeholder discussion 29 March 2018

1.3.4 Project Outcomes

An important objective of the research was to inform Water Corporation on what level of treatment of the wastewater was needed prior to injection into the aquifer.

Another was to demonstrate to Departments with responsibility for regulating the WA water industry, including the WA Department of Health, the Department of Water and the Department of Environment Conservation (now Department of Water and Environmental Regulation) that injection of recycled water was a safe and suitable process that did not pose any threat to the health of humans or the environment. This in turn allows the WA Water Corporation to obtain a licence to extract an amount of water from the aquifer that is equivalent to the amount of recycled water it has injected.

Helping to build community confidence in the aquifer replenishment was another important outcome as it helps WA Water Corporation to maintain its social licence to operate.

1.3.5 Adoption

CSIRO's research was critical to the regulators signing off on an assessment to allow WA Water Corporation to inject 14 GL a year of recycled water into the Leederville and Yarragadee aquifers. The Corporation was subsequently granted a licence to extract the same amount of water.

Approvals have subsequently been given to increase the amount of injected water to 28 GL a year, and a licence granted to the WA Water Corporation to extract an equivalent amount. The injection of 28 GL a year is expected to begin around 2019. WA Water Corporation has plans to progressively increase the amount of treated wastewater it injects into the aquifer using treated water from other treatment plants, including:

— 10 GL per year from the Subiaco wastewater treatment plant by around 2030, increasing to 20 GL a year by 2040

— 16 GL a year from the Woodland Point water treatment plant by 2040, increasing to 32 GL a year by 2050 and 48GL a year by 2065.

By 2050 the WA Water Corporation hopes to be injecting a total of 100 GL of recycled water into Perth's aquifers. This in effect means that the Corporation will then be able to extract an additional 100 GL of water from the aquifer that it otherwise would have not been able to access.

1.3.6 Impacts

WA Water Corporation staff have advised that the cost to treat and inject recycled water, and extract and treat the equivalent amount of ground water is around two thirds the cost of supplying the water through desalination. The cost of desalinated water

from existing desalination plants is around $3 per kilolitre (kL). The estimated cost of water from a new desalination plant is between $3 and $3.50 a kL.

1.3.7 Potential future impacts

ACIL Allen has assumed that desalination plants could have supplied the 'additional' groundwater that could not have been extracted if injection of treated wastewater into the aquifer had not received regulatory approval. Perth's existing plants are assumed to have been able to meet that additional demand for water up to 2025. After that date we assume that new desalination plants would need to be built.

Hence the avoided cost from being able to extract additional ground water would be one third the cost of desalinated water, namely $1 per kL up to 2025. Additional water extracted after that date is assumed to save $1.25 per kL.

1.4 Counterfactual and Attribution

1.4.1 Counterfactual

WA Water Corporation officials believe that CSIRO's research was crucial to gaining the necessary regulatory and community approvals to inject treated wastewater into Perth's aquifer and extract an equivalent amount of ground water. One official commented that:

CSIRO have done some excellent work for Water Corporation.

Stakeholder discussions 29 March 2018

1.4.2 Attribution

Based on our discussions with stakeholders ACIL Allen has assumed that 30 per cent of the benefits from this project can be attributed to CSIRO. This attribution aligns with CSIRO's contribution towards the total cost of the project.

1.5 Evaluating the Impacts

1.5.1 Cost-Benefit Analysis

Costs

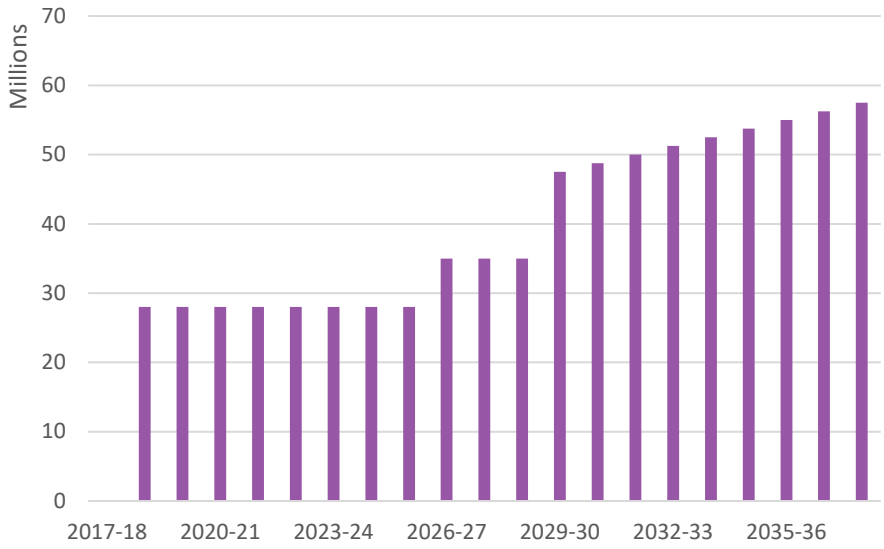
The costs of the MAR project were shown previously in **Table 1.1**. The present value of project costs is $3.48 million in 2017/18 dollars under a 7 per cent real discount rate.

Benefits

As discussed previously in Section 1.3.5, the injection of 28GL of recycled water into the aquifer is expected to commence in 2018-19. In 2029-30, this volume of injected water is expected to be augmented by wastewater from the Subiaco wastewater treatment plant. The water from that wastewater treatment plan is expected to increase from 10 GL in 2029-30 to 20 GL in 2039-40, with increments of 1 GL per year.

As noted in Section 1.3.7, the avoided cost from being able to extract additional ground water would be one-third the cost of desalinated water, namely $1 per kL up to 2025. Additional water extracted after that date is assumed to save $1.25 per kL The annual avoided water desalination costs over the next 20 years (between 2017-18 and 2037-38) are shown in Figure 1.2.

FIGURE 1.2 ANNUAL BENEFITS IN AVOIDED WATER COSTS, 2017-18 TO 2037-38



SOURCE: ACIL ALLEN CONSULTING

The present value of benefits in avoided desalinated water costs to 2037-38 is projected to be $356.5 million in 2017/18 dollars under a 7 per cent real discount rate.

Assessment of benefits against costs

The net present value (NPV) of the MAR project, obtained by subtracting the present value of costs from the present value of benefits, is estimated to be $353 million in 2017-18 dollars under a 7 per cent real discount rate. The benefit-cost ratio (BCR) of the MAR project, obtained by dividing the present value of benefits by the present value of costs, is estimated to be 102.6.

Sensitivity analysis

In the central case of the cost benefit analysis, it is assumed that savings from avoided water desalination is $1.25 per KL after 2025. If the value of savings after 2025 is higher at $1.50 per KL, the BCR increases from 102.6 to 125.6. If the value of savings after 2025 is lower at $0.75 per KL, the BCR decreases to 79.5.

In the central case of the cost-benefit analysis, the period of analysis is the next 20 years (to 2037/38). If the period of analysis is shortened to the next 10 years, the BCR decreases from 102.6 to 54.9.

A real discount rate of 7 per cent is used the central case of the cost-benefit analysis. The BCR is 162.8 and 66.7 under a 4 per cent real discount rate and a 10 per cent real discount rate respectively.

1.5.2 Externalities or other flow-on effects on non-users

The user of this project is the WA Water Corporation. It benefits from the reduced costs of supplying Perth's water. The consumers of the water supplied benefit from reduced water charges. They also benefit from the improved water security they get as a result of the aquifer recharge program. The community also benefits from a better understanding of the benefits of water recycling. Finally, there are also environmental benefits as a result of the increased sustainability of Perth's aquifers.