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Subiaco Strategic Resource Precinct Case Study: Non-Market Valuation of Recycled Water – Final Report

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Subiaco Strategic Resource Precinct Case Study: Non-Market Valuation of Recycled Water – Final Report
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Executive summary

This study explored the possible role of recycled water in transforming Subiaco Wastewater Treatment Plant (WWTP) into a Strategic Resource Precinct (SRP). Subiaco WWTP is one of the largest treatment plants in Western Australia, currently servicing a catchment of around 240,000 people that includes the Perth Central Business District. The SRP concept re-imagines WWTPs as water resource recovery plants (WRRPs) that generate valuable resources, as opposed to dealing with waste, and encourages a land use planning approach that recognises and facilitates linkages between the plant and land users around the precinct. Despite the benefits it could provide, the SRP concept has not yet been thoroughly tested, a knowledge gap that this case study seeks to address.

We investigated the extent to which recycled water use by non-residential land users in the suburbs surrounding Subiaco WWTP could contribute to the creation of an SRP. Specifically, our objectives were to:

1. investigate current and future non-residential land use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct, and understand the relationship between land use and water availability

2. investigate current and future non-residential water use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct, and identify opportunities for substituting recycled water for other water sources

3. estimate current willingness-to-pay for recycled water for non-residential use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct

4. explore future demand for recycled water for non-residential use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct under three groundwater allocation reduction scenarios.

To meet these objectives, we conducted a non-market valuation survey of existing and potential recycled water users located in or near the odour buffer zone surrounding the Subiaco WWTP. The survey used the contingent valuation and contingent behaviour methodologies, which are stated preference non-market valuation techniques. The survey collected qualitative and quantitative data. In total, we interviewed 20 non-residential organisations, each of whom holds a groundwater extraction licence. This sample included local councils, schools/educational institutions, golf courses and miscellaneous others.

We found that both land and water use are well established in the suburbs surrounding the potential SRP, and unlikely to undergo substantial change in the foreseeable future, irrespective of recycled water availability.

Further, there is currently little opportunity to substitute recycled water for existing sources, because it is not appropriate for the uses to which Scheme water is currently being applied. Nor can it offer a price advantage over groundwater (which costs $0.16 per kL, on average) unless subsidised.

Not surprisingly, therefore, our results suggest current willingness-to-pay for recycled water by existing non-residential land users is low (no more than $0.08 per kL, on average), and unlikely to justify the development of additional treatment and distribution infrastructure.

We established that willingness-to-pay is closely linked to both the price and availability of groundwater.

We also found that in most cases, organisations do not differentiate between stormwater and treated wastewater in terms of willingness-to-pay, provided that quality and safety standards are met.

Finally, it seems most organisations are currently operating comfortably within their existing groundwater allocations. Willingness-to-pay is likely to remain low unless these allocations are reduced quite substantially, and much more severely than the level of allocation cut that is currently being proposed for the next decade. So at present, there is insufficient demand for recycled water to use it as a lever to implement the SRP concept at Subiaco WWTP.

This work gives rise to the following key policy recommendations for implementing an SRP surrounding the Subiaco WWTP:

- Effort should be given to identifying new funding sources for water recycling infrastructure. The amount of funding that key stakeholders are currently willing to allocate to water recycling is typically minimal or non-existent, and certainly well below what is required to get schemes up and running. Demonstration of public benefits would be critical to any application for government funding.

- Policymakers could consider compiling information from existing recycled water users about their experiences using it, although variability between locations might mean that some experiences might not be applicable at other sites. Providing this information to prospective buyers in an easily accessible and understandable format is likely to greatly enhance their willingness to consider using/paying for recycled water. One example could be organising workshops where current and potential users can interact directly, to grow their knowledge and form networks to share information and experience.

- Recycled water policy can incorporate captured stormwater in addition to treated wastewater, given the evidence suggests organisations view the two sources as functionally equivalent.

- Strategic planning is likely to be critical for creating SRPs, to ensure that: land availability is sufficient to facilitate co-location of adjacent suitable land uses that can use wastewater treatment by-products; and that such land uses are compatible with odour buffer zone requirements.

These recommendations may be applicable to other locations, both in Australia and overseas.

Contents

1.0 Introduction

In many parts of the world, cities and surrounding urban areas are facing increasing pressure on water supplies due to population growth and climate change. Currently, around 55% of the world's population live in urban areas, and projections indicate this proportion could increase to 68% by 2050 (United Nations, 2018). Many cities are already at risk from water scarcity. For example, Padowski and Jawitz (2012) found 17% of the population across 220 United States cities are vulnerable to water scarcity. In developing countries, the proportion of the urban population vulnerable to water scarcity is likely to be much higher. In the context of ongoing population growth and climate change, the water scarcity problem is putting further pressure on already stressed water supply systems (Genius et al., 2012).

Given this worsening water scarcity problem, urban water utilities in many places may need to move beyond traditional approaches to supplying water, and consider options like water recycling (Kiparsky et al., 2016). A key advantage of recycled water is that it is generally rainfall- and groundwater-independent, which is likely to be particularly important in the context of climate change (NCCARF, 2013). Water recycling is a promising option that is attracting increasing levels of interest both within Australia and internationally (e.g. Lazarova et al., 2001, Schaefer et al., 2004, Lyu et al., 2016), and has already been integrated into water supply systems in some parts of the world (Dimitriadis, 2005). Therefore, a body of evidence already exists demonstrating that water recycling can be a viable alternative water source.[1] Water recycling typically refers to reusing treated wastewater, but may include reusing treated stormwater run-off as well (Hatt et al., 2006, Sydney Water, 2013). Treated wastewater offers a reliable and sustainable alternative to traditional ground and surface water sources (NCCARF, 2013, Friedler, 2001, Keremane and McKay, 2009, Sydney Water, 2013). Stormwater run-off is a rainfall-dependent water source, but may still complement other water sources. An alternative climate-independent water source to recycled water is desalinating seawater (Ghaffour et al., 2013, El Saliby et al., 2009), which while reliable, tends to be extremely costly.

Expanding wastewater treatment capacity to accommodate increased wastewater inflows from growing urban populations could be associated with challenges related to land use. Wastewater treatment plants (WWTPs) can be sizeable, and may occupy valuable land in urban environments that could otherwise be allocated to alternative uses (e.g. residential, recreational). For example, Iftekhar et al. (2018) estimated Australia's 2,468 WWTPs and associated odour buffer areas occupy approximately 363,000 hectares. Land use types that are permitted within WWTP odour buffer zones are restricted, and typically do not include residential developments. Such restrictions aim to prevent potential negative impacts of odour emanating from WWTPs on public health and amenity. In urban areas, these odour buffer areas may have lucrative commercial potential. Therefore, tension may arise between expanding WWTPs to improve their capacity to treat wastewater (thereby maintaining or even expanding odour buffer zone areas), and the demand for urban space for residential developments. In future land use planning, water utilities may therefore need to consider not only increasing water demand over time, but also increasing pressure on their existing land holdings driven by a need to house an increasing number of urban residents.

The concept of a 'strategic resource precinct' (SRP) – which the Water Corporation also refers to as "Buffertopia" – has been developed to manage both the water-supply challenge and residential development pressure in an integrated manner (CRCWSC, 2017). This concept re-imagines WWTPs as water resource recovery plants (WRRPs) that generate valuable resources as opposed to dealing with waste. Odour buffer zones are a critical element of the SRP concept, which encourages a land use planning approach that recognises and facilitates linkages between the plant and land around the precinct. These linkages may involve neighbouring land users using outputs from the plant (e.g. recycled water, nutrients, sludge, biogas), and/or providing inputs to the plant (e.g. knowledge, energy) (WSAA, 2017). A recent study demonstrated the Western Australian community values more highly a buffer-zone land use profile heavily weighted towards activities like nature conservation and sports/recreation than one that prioritises agriculture/horticulture and industry/commerce (Iftekhar et al., 2018). Both nature conservation and sports/recreation could make use of multiple WWTP outputs, such as water for irrigation and nutrients to foster plant growth. Establishing SRPs could therefore facilitate the use of WWTP outputs for land uses that are highly-valued by the community, and also help to justify retaining land area currently occupied by buffer zones that is under pressure from residential development. Despite the benefits it could provide, the SRP concept has not yet been thoroughly tested, a knowledge gap that this case study seeks to address.

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[1] See Appendix 1 for an overview of key advantages/disadvantages of and uses for recycled water.

This case study focuses on the Subiaco WWTP precinct in Perth, Western Australia (WA), which has the potential to be transformed into an SRP. Perth's water supply has been under increasing strain in recent decades, due to two key factors. First, rainfall has decreased due to climate change (Water Corporation, 2009, NCCARF, 2013), negatively impacting on both surface water availability and groundwater recharge (Water Corporation, 2011). Second, substantial population growth has created increasing demand for water, resulting in the over-use of both groundwater from Perth's superficial aquifers, and surface water supplies (Water Corporation, 2009). As noted above, the challenge of maintaining sufficient water supply under climate change and ongoing population growth is not unique to Perth, but is present in many different parts of the world (e.g. McDonald et al., 2011, Vörösmarty et al., 2000, Arnell, 2004).So, identifying new water sources and water management solutions could provide significant benefits for not only Perth, but many other water-stressed cities around the world.

Increasingly, key stakeholders are interested in exploring the potential to raise the amount of treated wastewater that is recycled from the Subiaco WWTP (CRCWSC, 2017). Similarly, there is interest in making better use of the substantial amount of stormwater currently passing beneath the WWTP every year (CRCWSC, 2017). Increasing the use of recycled water from the WWTP could be a key element of its transition towards becoming an SRP. Naturally, the likelihood of the Subiaco WWTP and its buffer zone transitioning into an SRP depends heavily on the extent to which there is actually market demand for the products that it is able to provide (e.g. recycled water). Therefore, this work assesses the potential market demand for recycled water from the plant, in the context of potential reductions to groundwater allocation licences in coming years. We focus on non-residential demand for recycled water for two key reasons. First, residential land use is not permitted within the odour buffer zone area that could become an SRP. Second, it is more likely that an expanded water recycling system from the Subiaco WWTP would initially focus on distributing water to a small number of large users, rather than a large number of small users, for logistical reasons.

A recent survey indicated that over half the local organisations consider a reliable and cost-effective water supply is highly important to the operation of their business, and that approximately half have plans to develop their business in the future (CRCWSC, 2017). These results may suggest an opportunity to expand the currently small market for recycled water around the Subiaco WWTP. However, we need robust evidence that sufficient demand for recycled water exists to warrant the expenditures required to establish distribution processes and infrastructure to convey treated water beyond the boundary of the WWTP (National Water Commission, 2011, Perraton et al., 2015).

Operationalisation of the SRP concept requires an in-depth understanding of the relationship between land use and water use at a local level. Further, it requires a robust understanding of what demand actually exists for recycled water. If there is high demand for recycled water in the geographical vicinity of a WWTP, the potential may exist to use recycled water availability as a lever to influence land use in that area, thereby moving towards the creation of an SRP. Conversely, if demand for recycled water is low, attempting to use recycled water availability to leverage local land use is likely to be ineffective.

Overall, this paper has four objectives:

1. To investigate current and future non-residential land use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct, and understand the nature of the relationship between land use and water availability

2. To investigate current and future non-residential water use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct, and identify opportunities for substituting recycled water for other water sources

3. To estimate current willingness-to-pay for recycled water for non-residential use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct

4. To explore future demand for recycled water for non-residential use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct under three groundwater allocation reduction scenarios.

To meet these objectives, we surveyed existing and potential recycled water users located in or near the buffer zone surrounding the Subiaco WWTP. This survey collected information about current and projected future land and water use, and assessed users' willingness-to-pay for recycled water on a per kilolitre basis both currently, and under different groundwater allocation reduction scenarios. Using information, we assessed the extent to which recycled water could contribute to establishing an SRP at the Subiaco WWTP.

2.0 Non-market valuation of recycled water

Estimating the value that existing and potential users place on recycled water from the Subiaco WWTP requires a non-market valuation approach. Non-market valuation studies aim to estimate the monetary values of 'unpriced' environmental goods and services, i.e. goods and services that are not traded in markets (Hanley et al., 2007 p.322). There are four key methods commonly implemented in non-market valuation studies. Two of these methods are 'stated preference' valuation methodologies, in which respondents are asked to state their economic value for particular environmental goods and services (Bateman et al., 2002 p.1). These methods contrast with 'revealed preference' valuation methodologies, in which the monetary value of environmental goods and services is measured by their impacts on real world markets (Hanley et al., 2007 p.332). The two key stated preference non-market valuation methodologies are contingent valuation and choice modelling, whereas the two key revealed preference methodologies are the travel cost method and hedonic pricing. A fifth non-market valuation approach is benefit transfer, in which monetary estimates for environmental goods and services that have been calculated using one of the above four approaches are applied within a new context (Bateman et al., 2002 p.22).

We conducted a search of the published, peer-reviewed literature to identify existing non-market valuation studies that estimate the monetary value of recycled water. We chose not to include materials from sources other than scientific journals (e.g. reports, conference presentations, and book chapters), to ensure that all included value estimates had been subjected to the highest level of peer review. The seven studies identified through our literature search are summarised in Table 1. The majority of these studies valued recycled water that has been treated such that it is suitable for non-potable and/or external use (e.g. agricultural irrigation). By contrast, a minority considered potable and/or indoor uses (e.g. drinking, toilet flushing), which would require a higher level of treatment. The summaries of each paper express the values estimates precisely as they are found in the relevant publication. For comparison purposes, all estimates have been converted to 2019 AUD in the final row of Table 1.

1. Abu Madi et al. (2003) explored the willingness to pay of farmers in Jordan and Tunisia (as representative of the Middle East and Northern African region more broadly) for recycled wastewater to use in agricultural irrigation. They found that farmers were unwilling to pay more than USD$0.05 per m^3, which was insufficient to cover the costs of distributing the water.

2. Alcon et al. (2010) evaluated the willingness to pay of the general population of the Segura River Basin in Southern Spain for recycled wastewater to be used in agricultural irrigation. They found the average willingness to pay per household was €5.13 per month, which equated to €0.31 per m^3. In this case, the authors concluded the estimated value justified the implementation of wastewater recycling for agricultural irrigation, given it exceeded the costs associated with water treatment (although it is not clear to what extent distribution was accounted for).

3. Blamey et al. (1999) used a choice modelling approach to estimate the value of recycled water as part of a broader package of water management alternatives. By contrast, all the other studies used the contingent valuation methodology to value recycled water alone. This study estimated the value held by households in the Australian Capital Territory for recycled water for domestic use, finding that on average, households were willing to pay an additional AUD$47 per year for access to recycled water for outdoor use, compared with having no access to recycled water at all. However, the authors also found households would need to be compensated AUD$55 to use recycled water both indoors and outdoors, relative to outdoors alone. They interpreted this result as reflecting an aversion to drinking recycled water.

4. Dupont (2013) assessed Canadian households' willingness to pay for recycled wastewater for toilet flushing to avoid summer water use restrictions. Average annual willingness to pay per household to avoid a 10% outdoor water use restriction was estimated at $128–$175 per year. For a more severe level of outdoor water use restriction (30%), average annual willingness to pay per household was estimated at $137–$186.

5. Hurlimann (2009) estimated the willingness to pay of Bendigo Bank office workers for recycled wastewater generated at their workplace in Bendigo at an on-site wastewater treatment plant. Average willingness to pay per worker was calculated at AUD$7.66 per kL for recycled wastewater trucked to their homes, to be used for household purposes. Hurlimann concluded this

comparatively high willingness to pay estimate likely resulted from the prolonged water scarcity and severe water restrictions that Bendigo residents experienced. She suggested value estimates may similarly be higher than policymakers might expect in areas with a similar history.

6. Menegaki et al. (2007) surveyed farmers in Crete regarding their willingness to use and willingness to pay for recycled wastewater to irrigate olive groves and tomato crops. They found that, on average, farmers were willing to pay €0.15 per m^3 for recycled wastewater, which equated to 55% of the fresh water price.

7. Tziakis et al. (2009) similarly examined the willingness to pay of Crete farmers for recycled wastewater for agricultural irrigation purposes (specifically olive groves). On average, farmers were willing to pay 61.2% of the fresh water price for recycled wastewater, which equated to €0.0872 per m^3.

Key themes from Table 1 indicate a need for primary data collection to accurately estimate willingness to pay for recycled water from the Subiaco WWTP. First, the most recent study was published in 2013 (Dupont, 2013), and data collection for that study took place in 2009. Second, only two studies were conducted in Australia (Blamey et al., 1999, Hurlimann, 2009), and neither collected data in Western Australia (WA). Third, based on their descriptions, all seven studies appear to have measured values for treated wastewater, but none considered how values for recycled stormwater may differ. Fourth, none of the studies elicited values from urban industrial or commercial users, instead focusing on agricultural (Abu Madi et al., 2003, Alcon et al., 2010, Menegaki et al., 2007, Tziakis et al., 2009) or household (Blamey et al., 1999, Dupont, 2013, Hurlimann, 2009) non-users of recycled water.

Given this, it was evident we needed a new valuation study for the Subiaco SRP Case Study project. Benefit transfer from existing studies is not feasible, because the available values were unlikely to be recent enough, geographically similar enough, comprehensive enough, or specific enough to apply them to existing or potential non-residential users of recycled wastewater and stormwater around the Subiaco WWTP. Reassuringly, however, the studies in Table 1 provide strong support for the suitability of stated preference techniques (and the contingent valuation methodology in particular) for eliciting willingness to pay for recycled water, the approach this study takes.

Table 1: Non-market valuation studies for recycled water

Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Lead author	Abu Madi	Alcon	Blamey	Dupont	Hurlimann	Menegaki	Tziakis
Publication year	2003	2010	1999	2013	2009	2007	2009
Data collection year	2001	2008	Not stated	2009	2007	2003	2005-2006
Country	Jordan and Tunisia	Spain	Australia	Canada	Australia	Greece	Greece
Water type	Wastewater	Wastewater	Wastewater	Wastewater	Wastewater	Wastewater	Wastewater
Water use	Agricultural irrigation	Agricultural irrigation	Household use (indoor and outdoor)	Toilet flushing	Household use	Agricultural irrigation (olives and tomatoes)	Agricultural irrigation (vineyards and almond trees)
Population	Farmers	Households	Households	Households	Bendigo Bank office workers	Farmers	Farmers
Valuation method	Contingent Valuation (DC[1])	Contingent Valuation (OE[2])	Choice Modelling	Contingent Valuation (DC)	Contingent Valuation (OE)	Contingent Valuation (OE and DC)	Contingent valuation (OE)
Value estimate (original)	USD$0.05 per m^3	€5.13 per household per month, which equates to €0.31 per m^3	AUD$47 for outdoor use (vs no use) -AUD$55 for all uses (vs outdoor use)	USD$128-$175/$137-$186 per household per year to avoid a 10%/30% outdoor water restriction (expressed in 2005 USD)	AUD$7.66 per kL for recycled water delivered to their homes (expressed in 2009 AUD)	€0.15 per m^3 of recycled water (55% of fresh water price)	€0.0872 per m^3 (61.2% of fresh water price)
Value estimate (2019 AUD)	AUD$0.10 per kL	AUD$9.32 per household per month, which equates to AUD$0.56 per kL	AUD$79 for outdoor use (vs no use) -AUD$92 for all uses (vs outdoor use)	AUD$239-$327/$256-$347 per household per year to avoid a 10%/30% outdoor water restriction	AUD$9.41 per kL for recycled water delivered to their homes	AUD$0.30 per kL of recycled water (55% of fresh water price)	AUD$0.02 per kL (61.2% of fresh water price)

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[1] DC = dichotomous choice value elicitation format.

[2] OE = open-ended value elicitation format.

3.0 Methodology

This section provides an overview of the study site and the methodological approaches chosen for survey design, sampling, implementation, and analysis.

3.1 Study site

Water supply in WA depends heavily on groundwater, which constitutes almost 40% of the water supplied through the Integrated Water Supply Scheme (Water Corporation, nd-d). The remaining 60% comes from desalinated seawater (48%), surface water (10%) and groundwater replenishment (2%). As well as being used within the mains water supply for Perth, groundwater is also used to irrigate public open space and in schools, local businesses and private gardens. In conjunction with climate change, historical and ongoing overuse of groundwater have rapidly depleted WA's aquifers in recent decades. Iftekhar and Fogarty (2017) noted groundwater levels have dropped by 2 metres in the Gnangara groundwater system over the past 35 years. The Department of Water and Environmental Regulation (DWER) is the governmental body responsible for licensing groundwater users. Only substantial and ongoing groundwater users are required to hold licenses, whereas small (e.g. private residential) and/or temporary (e.g. construction sites) users are exempt. Groundwater extraction licences specify an annual allocation limit for the licence holder in kilolitre and the duration over which the licence is valid, and may nominate any relevant special conditions. Perth's groundwater systems have been divided into areas and sub-areas, to enable DWER to better manage them. New licences are issued (or not) in accordance with whether or not the (sub-)area in question is under allocated, fully allocated, or over allocated. Allocation limits are set for (sub-) areas based on their hydrological condition and water availability.

In WA, water recycling occurs at a relatively small scale, predominantly for irrigating public open spaces like urban parks, golf courses, and playing fields (Water Corporation, 2013). At the state level, only 13.6% of treated wastewater was being recycled in 2013, and much of this occurred in regional towns, rather than the Perth area (Water Corporation, 2013). This is despite the vast majority of WA's population live in the capital city, and generate most of its wastewater.[2] However, the long-term vision for WA is that 30% of all wastewater in the state will be recycled by 2030, increasing to 60% by 2060 (Water Corporation, 2009), primarily through large-scale schemes involving indirect potable reuse, industrial use, and irrigation of public open space (Water Corporation, 2013).

In the Perth region, several water recycling schemes have been successfully implemented to date. For example, the Groundwater Replenishment Scheme at Beenyup WWTP currently recycles up to 28 million kilolitres of treated wastewater per year, which is used to recharge the Leederville and Yarragadee aquifers (Water Corporation, 2019, Water Corporation, nd-a). Since 2004, the Kwinana Water Recycling Plant has treated water from the Woodman Point WWTP to provide up to 6 million kilolitres of recycled water per year to industry (Water Corporation, nd-b, Water Corporation, 2013). Also since 2004, recycled water from the Subiaco WWTP has been used to irrigate the nearby McGillivray sporting complex, including grass ovals, hockey fields, and tennis courts (Water Corporation, nd-c, Water Corporation, 2013).

The Subiaco WWTP currently services a catchment of around 240,000 people and includes the Perth Central Business District. The plant treats 21.9 million kilolitres of sewage inflow per year (roughly 8,760 Olympic-sized swimming pools[3]). Only 0.5 million kilolitres (roughly 2.2%) of treated wastewater is currently recycled, mainly to irrigate nearby playing fields. The current Water Corporation policy is to provide access to treated wastewater 'as-is-where-is' at the WWTP boundary at no charge, where the end use is for public benefit. Any additional treatment and conveyance to the end user's site is at their cost. By contrast, where the end use is for commercial benefit, the Water Corporation seeks a joint scheme contribution from the prospective user. This joint scheme contribution is negotiated between the Water Corporation and the prospective user. Given the small percentage of treated wastewater currently being

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[2] The high level of wastewater recycling in regional versus urban areas is driven by the Water Corporation's need to identify the lowest cost and most secure wastewater disposal option. Regional areas are typically located much further from the ocean than urban Perth, have more land area available for storage and disposal, and generate comparatively small volumes of wastewater. Therefore, in regional areas, the lowest cost, most secure disposal option is typically winter storage and irrigation in other seasons. By contrast, in urban Perth, where land is at a premium and very high volumes of wastewater are generated, the lowest cost, most secure disposal option is generally ocean outfall.

[3] One Olympic-sized swimming pool holds around 2,500kL of water.

recycled, there is scope to greatly expand water recycling from the Subiaco WWTP. In addition, a major stormwater drain runs beneath the WWTP and eventually discharges into the ocean. It is estimated that between 1.5 and 3.0 million kilolitres of stormwater pass through this drain every year. Subiaco WWTP has been identified as a potential long-term source of recycled water for the Groundwater Replenishment Scheme (Water Corporation, 2019). Given this, there is some restriction to the volume of treated wastewater that could be made available for recycling. Nevertheless, treated wastewater and stormwater from the Subiaco WWTP could together provide an additional 4-5 million kilolitres of recycled water to a range of potential users in its vicinity. Figures 1 and 2 show the Subiaco WWTP and its associated buffer zone (that could be transformed into an SRP.

Figure 1: Location of the Subiaco Wastewater Treatment Plant and Strategic Resource Precinct (outlined in orange) – adapted from Water Corporation (2009)

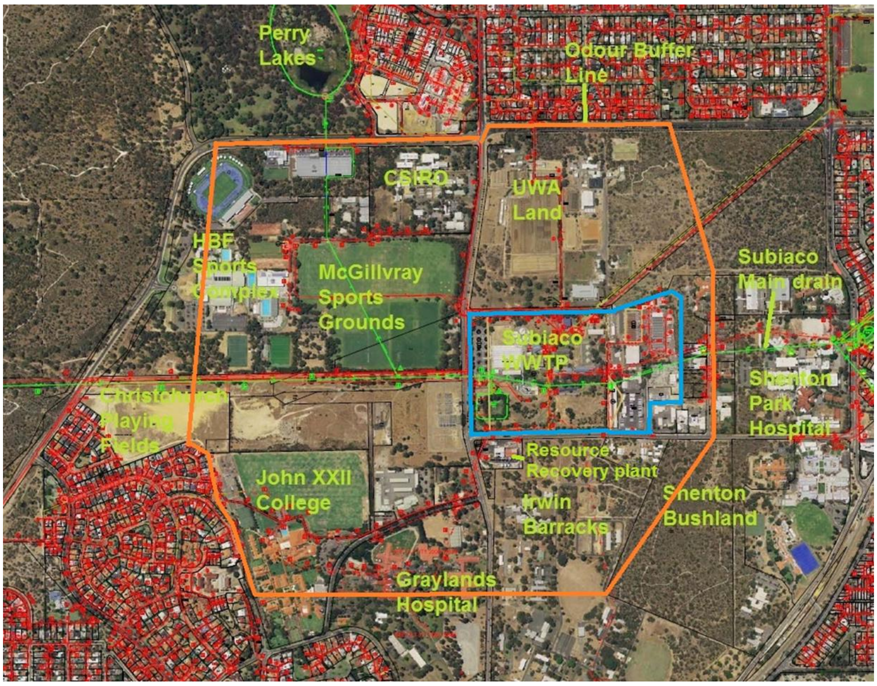

Figure 2: Location of the Subiaco Wastewater Treatment Plant and neighbouring organisations using land within the Strategic Resource Precinct (outlined in orange)

3.2 Survey method

We used contingent valuation (CV) and contingent behaviour (CB) methods in this case study, which are stated preference non-market valuation techniques. We needed to use a stated preference technique, because the value of recycled water from the Subiaco WWTP is not partially captured in any existing related market. A revealed preference methodology such as hedonic pricing would not be appropriate. And of the two stated preference methods (CV and choice modelling), CV was most appropriate. These two methods have subtly different objectives. Using CV enables the researcher to assess the non-market values associated with changes in the quality or quantity of a particular environmental good or service as a whole (Bateman et al., 2002 p.112). By contrast, choice modelling focuses on valuing the component attributes of an environmental good or service, and how people are willing to trade off changes in one attribute against another (Bateman et al., 2002 p.248-249). The objective of this study is to estimate the values held by existing or potential non-residential users for recycled water as a whole, rather than to explore the values of specific attributes. The use of the contingent valuation methodology is therefore most appropriate for the Subiaco Case Study project.

In CV studies, the valuation question (that asks respondents how much they are willing to pay for the particular environmental good or service in question) can be presented to respondents in different formats, usually via: an open-ended question; single- or double-bounded dichotomous choices; or a payment card (Bateman et al., 2002 p.138-142). Each of these common formats is associated with a range of advantages and disadvantages.

For this study, we selected a payment card mechanism. Payment cards present respondents with a series of ordered values (e.g. $0, $1, $5, $10, $20), from which they are asked to select their maximum willingness to pay for an environmental good or service. From this, researchers can infer that a given respondent’s monetary value lies within the interval between the amount they selected, and the next value listed on the payment card (Cameron and Huppert, 1989). Compared with the other common formats, payment cards are reported to: generate reliable estimates; avoid starting point bias and yea-saying; minimise the occurrence of non-response, protest and zero answers; elicit conservative values; and be well suited to low sample sizes (Bateman et al., 2002 p.138-139, Ready et al., 1996, Blaine et al., 2005). However, we acknowledge that despite these advantages, the payment card approach is still subject to certain biases surrounding the choice of values included on the card and the size of the intervals between values.

In addition to CV in its more classical form, this project employs the CB methodology. Following Bennett (2011 p.202), CB is very similar to CV, except that respondents are asked to respond to changes in environmental conditions (in this case, groundwater availability), rather than price. A key advantage of this method is that it allows researchers to explore scenarios that lie beyond the range of historical or current circumstances (Bateman et al., 2002 p.371). Including CB questions allows us to explore responses to hypothetical decreases in groundwater availability of different magnitudes. Specifically, we can determine the quantity of recycled water respondents consider their organisation would be willing to purchase at different prices, given 10%, 25% or 50% reductions in groundwater allocations.

3.3 Survey design

The survey instrument was developed iteratively in collaboration with the Water Corporation of Western Australia, and DWER. Appendix 2 contains the dates, locations and attendees of key meetings relating to project and survey development. Appendix 3 contains the final version of the survey. The survey comprises the following five sub-sections:

Section 1: Survey introduction
This section provided background and contextual information about the Subiaco WWTP, the SRP concept, and the motivation for the study.

Section 2: Current and future land use
This section asked respondents what percentage of the land that they are using is currently allocated to five land use categories: *Nature conservation, Sports and recreation, Agriculture and horticulture, Industry and commerce,* and *Other* (to be specified by the respondent if none of the above categories apply). These land use categories are based on the classifications used in a previous non-market valuation survey on land uses in buffer zones in WA (Iftekhar et al., 2018). Respondents were also asked to state their expectations regarding how their land will be used in the short-term future (roughly 3–5 years) and the longer-term future (roughly 7–10 years). The final three questions asked respondents why their organisation chose their current location, the extent to which their organisation currently bases their land use decisions on water availability, and the extent to which they think decreasing water availability in the future would affect land use decisions made by their organisation.

Section 3: Current and future water use/sources
This section confirmed the details of any groundwater allocations the organisation may hold, and established whether or not metering is in place. The following question asked respondents to complete a matrix containing the following information for each of five water sources (scheme, groundwater, rainwater, recycled water, and other): current annual consumption, current annual cost, current uses, projected change in quantity of water used in the short-term future; potential sources of additional water in the short-term future; projected change in quantity of water used in the longer-term future; and, potential sources of additional water in the longer-term future. The following four questions asked respondents how they expect their organisation's water use and management to change in the short-term and longer-term future.

Section 4: Valuation of recycled water
The first question in this section established current willingness-to-pay for recycled water, using the CV method with a payment card elicitation format. Respondents were asked to state the maximum per-kilolitre amount their organisation would currently be willing to pay for recycled water, by selecting a value from the following scale:

$0.00, $0.05, $0.10, $0.15, $0.20, $0.50, $1.00, $1.50, $2.00, $2.50, $3.00.

Respondents were asked to value the water alone, assuming that it is delivered to the edge of their property by the service provider. The second question used the CB method, asking respondents to assume different levels of groundwater allocation cut (10%, 25% and 50%), one by one. For each level of groundwater allocation cut, they were asked to estimate the total volume of recycled water their organisation would be willing to purchase at each of the listed prices from the payment card scale outlined above.

Section 5: Debriefing questions
This section first asked respondents what key factors they considered in forming their willingness-to-pay estimate, in open ended format. Respondents were then asked whether their willingness-to-pay for recycled stormwater would be different to recycled wastewater, and why. The two following questions asked respondents how certain they were of the values they provided on behalf of their organisation, and to indicate the degree to which their organisation thinks it likely that the survey results will influence future decisions regarding water policy. Respondents were then invited to share any further comments/questions/ideas they have relating to water recycling in general. Finally, some background information was collected including how long the respondent has been working for their organisation, and what their role is within it. Respondents had an opportunity to share any comments/questions/ideas relating to the survey if they wish to.

3.4 Sampling procedure

We followed a purposive sampling procedure. The sample consisted of a cross-section of non-residential organisations with substantial water requirements in the suburbs surrounding the Subiaco WWTP. Initial investigation sought to establish whether or not there was sufficient demand for recycled water within the odour buffer zone (i.e. the potential SRP) to restrict the sample to that area, but this was found not to be the case. Therefore, the sampling process was expanded to incorporate additional areas in neighbouring Perth suburbs including: Churchlands, City Beach, Claremont, Cottesloe, Crawley, Daglish, Dalkeith, Floreat, Jolimont, Karrakatta, Mosman Park, Mount Claremont, Nedlands, Peppermint Grove, Perth, Shenton Park, Subiaco, Swanbourne, Wembley, Wembley Downs, and West Leederville.

With the assistance of the Water Register (Government of Western Australia, nd), we identified 35 organisations in the suburbs surrounding the Subiaco WWTP that hold groundwater licences, due to the presence of substantial and established irrigated areas on their properties. Groundwater users with small irrigated areas (<0.2 hectares), or who are only temporarily using the resource (e.g. short-term construction projects) are not required to hold licences (Government of Western Australia, 2017), and were excluded from the sample. Such users are not likely to be ongoing and significant purchasers of recycled water. We approached each organisation via an initial invitation email, and then follow-up email and telephone contact as required to determine whether or not each organisation was willing to participate in the survey. Of the 35 organisations we contacted, 26 expressed an interest in participating.

3.5 Survey implementation

We piloted the survey in February/March 2019. This involved collecting five completed survey responses from a diverse range of respondents, and conducting three face-to-face interviews. Following the pilot phase, we made several modifications to the survey before progressing to full-scale data collection, which took place between March and June 2019. Revised responses were subsequently collected from the organisations that had participated in the pilot, so that they could be included in the final dataset.

The participation process consisted of compiling responses to the survey document, meeting with the research team to discuss those responses and provide additional qualitative insights, and then providing follow-up information as needed following the interview. In some cases, despite expressing an initial interest in being involved in the survey and submitting responses, organisations were unwilling or unable to complete the interview component. Wherever possible, we completed a telephone interview instead. In total we collected completed survey responses from 20 organisations. The sample includes a range of organisational types, such as local councils (5), schools/educational institutions (6), golf courses (4), and miscellaneous others (5). We deliberately set out to sample a range of different potential recycled water user types, to obtain as broad a range of insights as possible.

We allowed organisations to identify the contact(s) with the most relevant expertise to answer the survey. In many cases, we met with multiple individuals from the same organisation. The average respondent had worked in their role either for their current or another organisation for 11 years[4], which indicates the sample drew on a significant level of expertise. The types of roles respondents were working in included: parks, environment, or sustainability manager; maintenance, facilities, or grounds manager; business or planning manager; horticulturalist; technical or support officer; golf course director or superintendent; and general manager or chief executive officer.

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[4] Median = 12 years, Minimum = 1 year, Maximum = 25 years, Standard deviation = 7 years

3.6 Analysis

The analytical techniques used to process the survey results consist of summary statistics (mean, median, standard deviation, minimum, maximum), and summary plots (e.g. frequency distributions, pie/line graphs, scatter plots). The research team also subjectively coded the qualitative information we obtained through the open-ended questions into broad themes for discussion.

4.0 Results

The results are organised into four sections: Land use; Water use and sources; Recycled water valuation; and Other data.

4.1 Land use

4.1.1 Current land use

The aggregate area of land owned, leased or managed by the full set of organisations in our sample (20 organisations) is 2,438 hectares (Figure 3a). The majority of this aggregate land area is allocated to Nature conservation (1,089 hectares), and Sports and recreation (1,051 hectares). Comparatively small areas are allocated to Agriculture and horticulture (34 hectares), Industry and commerce (40 hectares), and Other uses (223 hectares). The average organisation owns, leases or manages 122 hectares, of which 54 hectares (24%) is allocated to Nature conservation, 53 hectares (48%) to Sports and recreation, 2 hectares (2%) to Agriculture and horticulture, 2 hectares to Industry and commerce (3%) and 11 hectares to Other uses (23%) (Figure 3b, Table 2). Additional summary statistics are included in Table 2. The median values presented in Table 2 differ substantially from the mean values due to the skewing effects of a few organisations that own, lease or manage very large areas. Land use patterns varied substantially between organisational types (Figure 4).

- Local governments own, lease or manage 1,371 hectares, the majority of which is allocated to either Nature conservation (699 hectares) or Sports and recreation (668 hectares), with a very small amount devoted to Other uses (4 hectares) (Figure 4a). The average local government organisation allocates 42% of its land to Nature conservation, 55% to Sports and recreation, and 3% to Other uses (Figure 4b).

- Schools/educational facilities own, lease or manage 265 hectares, of which substantial amounts are allocated to Nature conservation (50 hectares), Sports and recreation (94 hectares), Agriculture and horticulture (32 hectares), and Other uses (84 hectares), with a small area devoted to Industry and commerce (5 hectares) (Figure 4c). The average school/educational facility allocates 9% of its land to Nature conservation, 45% to Sports and recreation, 4% to Agriculture and horticulture, 2% to Industry and commerce, and 40% to Other uses (Figure 4d).

- Golf courses own, lease or manage 202 hectares, which is predominantly assigned to Sports and recreation (158 hectares), with some Nature conservation areas (44 hectares) (Figure 4e). The average golf course allocates 20% of its land to Nature conservation, 79% to Sports and recreation, and 1% to Other uses (Figure 4f).

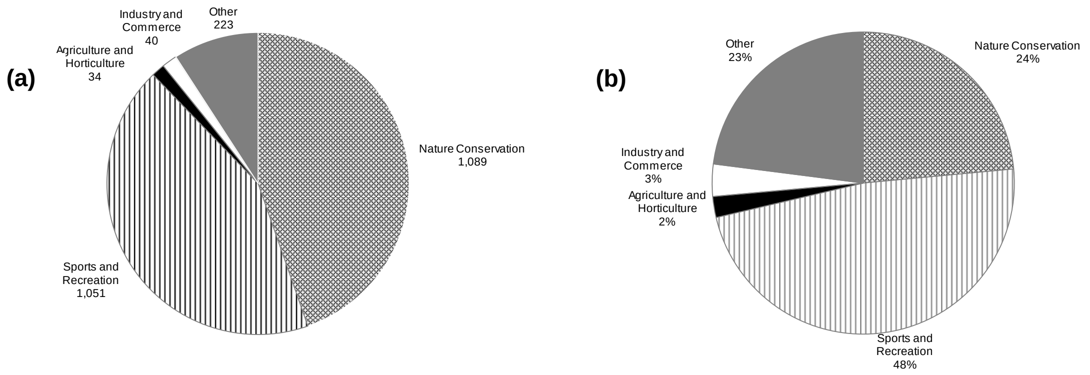

Figure 3: Area of land allocated to various uses (a) and average % of land allocated to various uses (b) for the full sample (n=20, 2,438 hectares)

Table 2: Summary statistics for current land use – areas (ha) and percentages (%)

	Mean	Median	St dev	Min	Max
Total area	**122 ha**	**53 ha**	**207 ha**	**4 ha**	**880 ha**
Nature conservation	54 ha (24%)	7 ha (18%)	132 ha (23%)	0 ha (0%)	554 ha (66%)
Sports and recreation	53 ha (48%)	14 ha (50%)	86 ha (27%)	0 ha (0%)	326 ha (100%)
Agriculture and horticulture	2 ha (2%)	0 ha (0%)	7 ha (6%)	0 ha (0%)	30 ha (20%)
Industry and commerce	2 ha (3%)	0 ha (0%)	8 ha (13%)	0 ha (0%)	35 ha (57%)
Other Use	11 ha (23%)	3 ha (10%)	24 ha (29%)	0 ha (0%)	98 ha (100%)

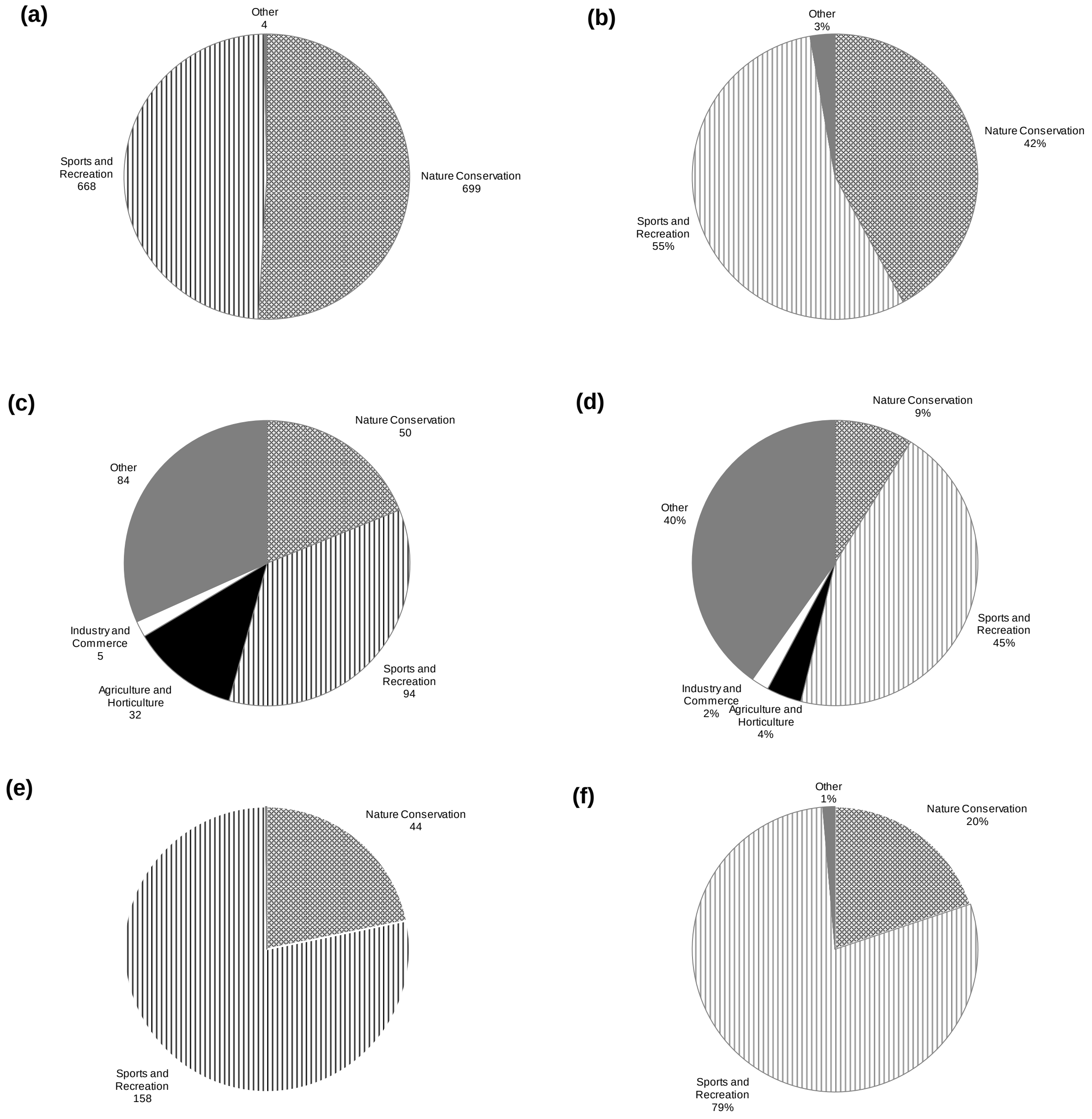

Figure 4: Area of land allocated to various uses, and average % of land allocated to various uses for Local governments (a,b), Schools/educational facilities (c,d), and Golf courses (e,f)

4.1.2 Projected future land use

The information we collected on projected land use change in the short-term (3–5 years) and longer-term (7–10 years) future is presented in Table 3, for the whole sample, and disaggregated by organisation type. For the full sample, neither the mean nor the standard deviation of values for percentage of land allocated to various uses are predicted to change more than 2%, in either the short- or longer-term. Similarly, neither the mean nor the standard deviation of values for percentage of land allocated to various uses are predicted to change more than 3% for any organisation type (Table 3). Detailed summary statistics are included in Appendix 4.

Table 3: Current and projected land use in the short- (3–5 years) and longer- (7–10 years) term future

	Current		Short-term future		Longer-term future	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Full sample						
Nature conservation	24%	23%	23%	22%	23%	22%
Sports and recreation	48%	27%	48%	27%	49%	28%
Agriculture and horticulture	2%	6%	2%	6%	2%	6%
Industry and commerce	3%	13%	4%	14%	4%	15%
Other uses	23%	29%	23%	29%	23%	29%
Local government						
Nature conservation	42%	29%	42%	29%	40%	30%
Sports and recreation	55%	31%	55%	31%	57%	33%
Agriculture and horticulture	0%	0%	0%	0%	0%	0%
Industry and commerce	0%	0%	0%	0%	0%	0%
Other uses	3%	6%	3%	6%	3%	6%
Schools/educational facilities						
Nature conservation	9%	10%	9%	10%	10%	11%
Sports and recreation	45%	14%	45%	14%	46%	14%
Agriculture and horticulture	4%	7%	4%	7%	4%	7%
Industry and commerce	2%	4%	2%	4%	2%	4%
Other uses	40%	18%	40%	18%	40%	18%
Golf courses						
Nature conservation	20%	6%	20%	6%	20%	6%
Sports and recreation	79%	5%	79%	5%	79%	5%
Agriculture and horticulture	0%	0%	0%	0%	0%	0%
Industry and commerce	0%	0%	0%	0%	0%	0%
Other uses	1%	2%	1%	2%	1%	2%

4.1.3 Factors affecting land use decisions

Virtually all surveyed organisations had been located at their present site for an extended period of time (i.e. decades or longer), and site choice decisions had typically been made well before each respondent joined their organisation. Therefore, the key reasons behind the location decision were historical. No organisation described any future plans to change its primary location, although a small number of organisations expressed the possibility that certain parcels of land may be bought or sold in the future. No respondent identified water availability considerations or proximity to the Subiaco WWTP as having driven the choice of location for their organisation.

In addition to having been established at their present location for many years, organisations also reported land uses were generally very well established. This meant very few land use decisions had been made in recent years. So, it was difficult to ascertain the degree to which water availability might constrain land use decision making, given the individuals we interviewed had not typically been responsible for such decisions. Those respondents who could recall land use decisions did not feel water availability was a key consideration in the process. Rather, they reported that a land use decision would typically be made first, with water-related considerations account for later. While water availability was not reported to affect land use decisions to any great extent at present, the vast majority of respondents noted it was a key consideration affecting land management decisions.

When asking respondents how they thought their organisation’s land use decisions might change under decreasing water availability, we directed them to consider groundwater availability reductions in particular, given there is no indication that Scheme water availability is likely to change in the future. Organisations typically reported that land uses would not change unless water availability decreases were very severe. Small to moderate water availability decreases were thought likely to result in small to moderate changes in land management. When asked about what form such land management changes might take, respondents reported a broad range of water-saving strategies, including:

- reducing turfed area within parks, on playing fields, and on golf courses
- increasing mulch and native planting areas
- hydro-zoning (related to the above two strategies)
- upgrading to more water efficient irrigation systems and technology
- hardscaping (e.g. replacing vegetated areas with carparks)
- using synthetic playing surfaces
- using scheme water (typically a last resort).

Moreover, many respondents were able to articulate a hierarchy of management changes their organisation would probably take (ranging from the easiest/cheapest to the most difficult/expensive), depending on the severity of groundwater allocation reduction. This hierarchy varied between organisations.

4.2 Water use and sources

4.2.1 Current water use

This section presents the information we collected about current water use, with particular detail about groundwater and Scheme water, which were the primary water sources for the 20 surveyed organisations.

Table 4 identifies all of the water sources that organisations mentioned, and lists the full set of uses described for each source. Scheme water and groundwater are applied to the broadest range of uses, with rainwater, recycled water and surface water applied to more restricted uses. Scheme water is used for boom-spraying, cleaning, cooling, indoor uses, irrigation of certain areas, and in swimming pools. Groundwater is used for boom-spraying, cleaning, construction, firefighting, a broad range of irrigation uses, maintaining lake levels, and in outdoor toilets. There is some overlap between Scheme water and groundwater uses, but there are unique uses for each source as well. Examples include indoor and swimming pool use of Scheme water, and construction, firefighting, and maintaining lake levels using groundwater. Rainwater is used for cooling, indoor use and irrigation, recycled water is used for irrigation alone, and surface water is used to supplement the groundwater supply.

Table 4: Reported water uses by water source

Water source	Water uses
Scheme	Boom-spraying chemicals and fertilisers Cleaning (machinery) Cooling (evaporative coolers, cooling towers) Indoor use (drinking water, toilets, showers, sinks, washing machines) Irrigation (small parks and gardens, street verges, specialised plants) Swimming pools
Groundwater	Boom-spraying chemicals and fertilisers Cleaning (machinery, buses, cars, depot facilities) Construction Firefighting Irrigation (parks, playing fields, golf courses, gardens, trees, horticulture, research crops) Maintaining lake levels Outdoor toilets
Rainwater	Cooling Indoor use (drinking water, toilets, showers, sinks) Irrigation (specialised plants)
Recycled water (from Subiaco WWTP)	Irrigation (playing fields, gardens)
Other (Surface water)	Support groundwater supply

4.2.2 Current groundwater use

This section looks in detail at organisations' current groundwater use, providing numerical, visual and qualitative information as appropriate to summarise groundwater allocations, metering, groundwater use as a percentage of allocation, groundwater use as a percentage of total water use, groundwater cost as a percentage of total water cost, and current per kilolitre (kL) cost of groundwater use. The number of observations varies considerably, because not all of the organisations we surveyed could provide all of the information we requested.

Table 5 presents summary statistics for the groundwater allocations held by the 20 organisations we surveyed. The average organisation holds an allocation for 309,841 kL, and the median organisation holds an allocation for 164,313 kL. The difference between the mean and median values is attributed to a small number of very large licence holders within the sample. Figure 5 displays the frequency distribution of groundwater allocations, demonstrating our sample encompasses a broad range of allocation sizes. However, the distribution is positively skewed, indicating that we surveyed more small allocation holders than large allocation holders. While skewed, this distribution type is likely to be representative of the full range of allocations in the area.

Table 5: Groundwater allocations – summary statistics

	Allocation
Mean	309,841 kL
Median	164,313 kL
Standard deviation	344,712 kL
n	20

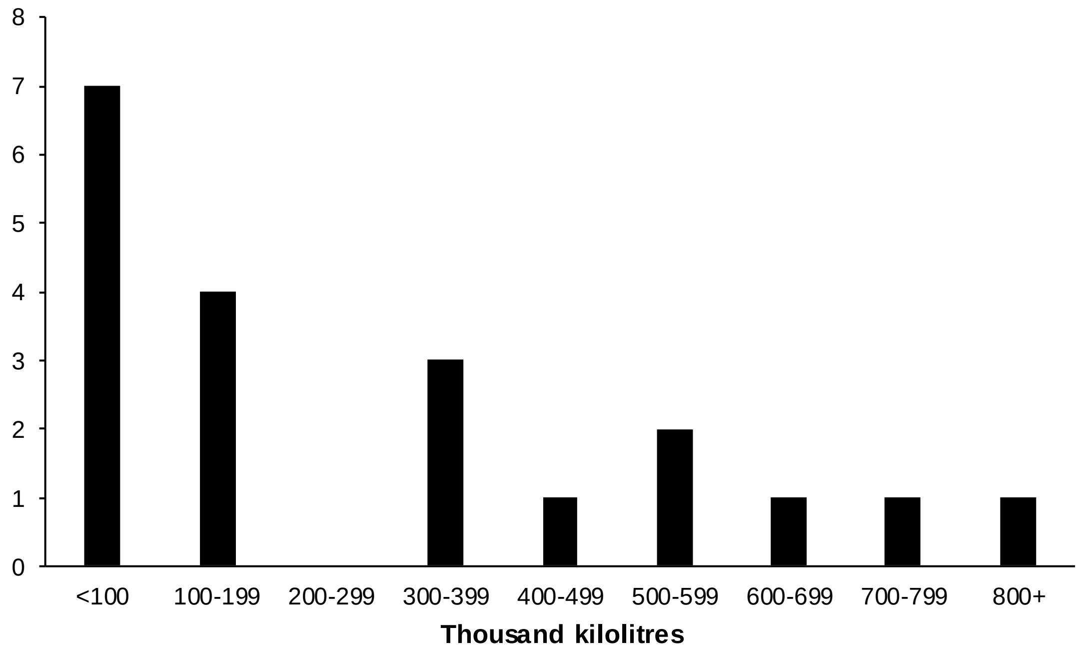

Figure 5: Frequency distribution of groundwater allocations

Of the 20 organisations we surveyed, 18 have groundwater meters in place (90%), linked to their abstraction bores. These metering systems are typically automated to adjust groundwater abstraction with weather/atmospheric conditions, and are centrally controlled. Of the two organisations without meters, one could estimate groundwater consumption by other means. Two other organisations have only recently acquired meters, one of whom was able to estimate annual groundwater consumption based on the months of data collected post-installation. One other organisation has a meter that is not regularly read, and could not estimate groundwater consumption.

Table 6 presents summary statistics for groundwater use, expressed as a percentage of licensed allocation. Three observations are missing for the reasons outlined above (one organisation with no meters, one with recently installed meters, and another with established meters that are not read).

The average organisation uses 89% of its allocation in an average year, although many organisations noted this amount fluctuates with weather conditions from year to year. The median value is 99%, which is higher than the mean due to the presence of one very low outlier (13% of allocation). Figure 6 demonstrates that all but two of the observations lie above 80%.

Table 6: Groundwater use as % of allocation – summary statistics

	Groundwater use (% of allocation)
Mean	89%
Median	99%
Standard deviation	22%
Minimum	13%
Maximum	102%
n	17

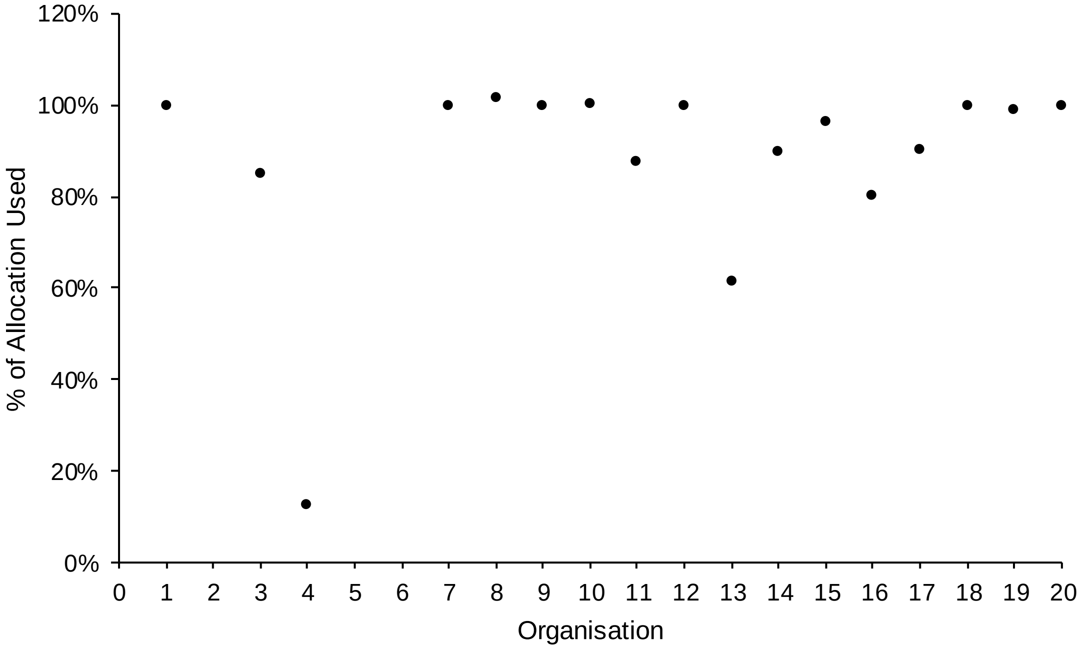

Figure 6: Groundwater use as % of allocation – scatter plot

Table 7 presents summary statistics for groundwater use, expressed as a percentage of total water use (from all sources). Five observations are missing: three are the ones outlined above (organisations that did not provide a groundwater use estimate); the other two results from a lack of data about Scheme water use, meaning we could not calculate total water use.

For the average organisation, groundwater comprises 77% of total water use, indicating the organisations we surveyed were heavily groundwater reliant. The median value is 93%, which is again higher than the mean due to a few outliers with very low values. Figure 7 visually summarises the data, and shows groundwater use exceeds 60% of total water use for all but three observations. The heavy groundwater reliance of our sample is not surprising, given our sampling process was based on seeking out organisations holding groundwater licences.

Table 7: Groundwater use as % of total water use – summary statistics

	Groundwater use (% of total water use)
Mean	77%
Median	93%
Standard deviation	33%
Minimum	5%
Maximum	100%
n	15

*Six organisations were excluded due to missing data.

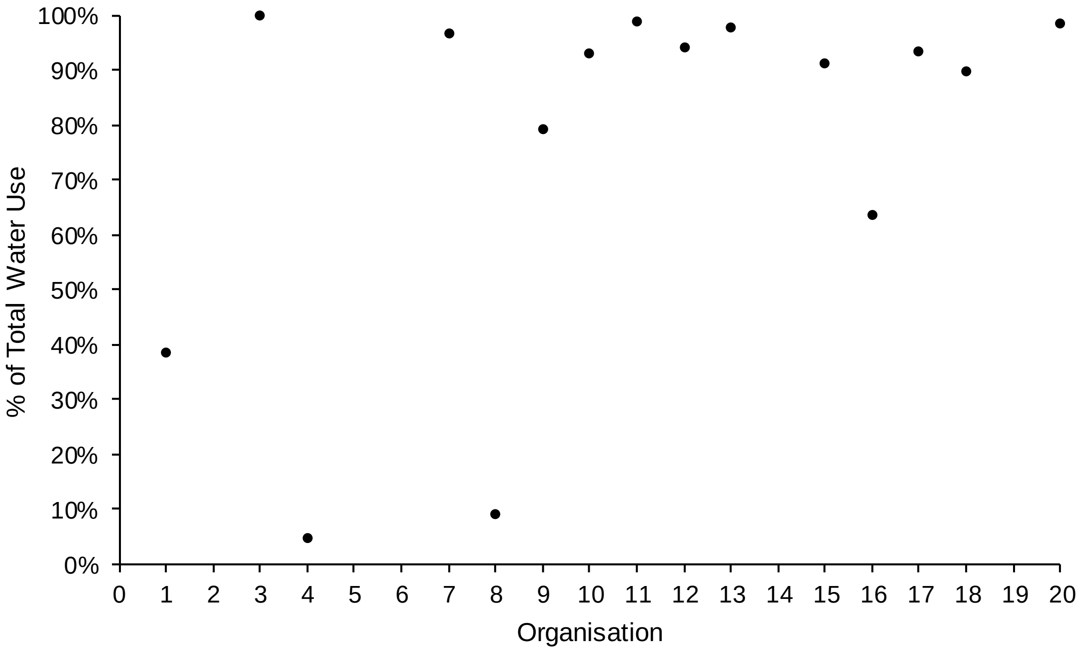

Figure 7: Groundwater use as % of total water use – scatter plot

Table 8 presents summary statistics for groundwater cost, expressed as a percentage of total water cost. Seven observations are missing: four organisations did not provide groundwater cost estimates; two organisations did not provide Scheme water cost estimates; and one provided neither groundwater nor Scheme water cost estimates.

For the average organisation, groundwater costs comprise 48% of total water costs, which is very similar to the median value of 50%. Figure 8 provides a visual summary, which splits the data into two groups. In the first group, groundwater costs as a percentage of total water costs are particularly low (6 observations), relative to the second group, in which they are high (6 observations). One observation lies around the mid-point at roughly 50%. There could be several explanations for these results. First, the costs associated with groundwater use are typically lower than those for Scheme water use, so the average percentage of groundwater costs versus total costs (50%) is lower than the average percentage of groundwater use versus total water use (77%). Second, the two groups may reflect that our sample comprises both organisations that are almost entirely groundwater dependent (e.g. local government and golf courses), and split between groundwater and Scheme water use (e.g. schools/educational facilities). Third, some organisations may have found it more straightforward to compute the full costs of groundwater extraction (e.g. pumping costs, bore and reticulation servicing and maintenance, labour costs), compared with others. Therefore, the estimates from some organisations could be incorrectly low if those organisations did not account for all relevant factors.

Table 8: Groundwater cost as % of total water cost – summary statistics

	% of total water cost
Mean	48%
Median	50%
Standard deviation	39%
Minimum	2%
Maximum	97%
n	13

*Seven organisations were excluded due to missing data.

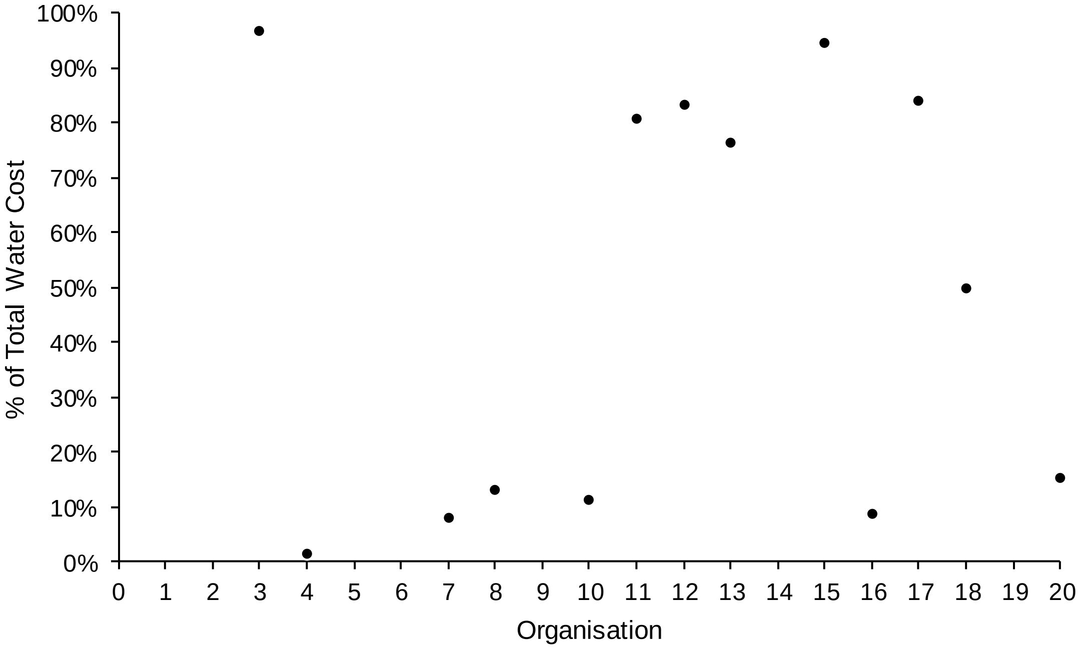

Figure 8: Groundwater cost as % of total water cost – scatter plot

Table 9 presents summary statistics for the cost per kL that organisations pay for groundwater use. Five observations are missing: two organisations could not provide groundwater cost data; and three organisations provided neither groundwater cost nor use data.

The average organisation pays $0.16 per kL for groundwater extraction. The median value is $0.09, which reflects several outlier observations with high values. Figure 9 visually summarises the data, demonstrating groundwater costs are never higher than $0.45 per kL, and are typically below $0.20 per kL. Organisations often reported these groundwater cost estimates were a key consideration when formulating their willingness-to-pay estimates for recycled water, given the uses that are currently relevant to recycled water (i.e. irrigation of turf areas in parks, on playing fields and at golf courses) typically draw on groundwater at present.

Table 9: Per kL groundwater cost – summary statistics

	Per kL cost
Mean	$0.16
Median	$0.09
Standard deviation	$0.15
Minimum	$0.01
Maximum	$0.44
n	15

*Five organisations were excluded due to missing data.

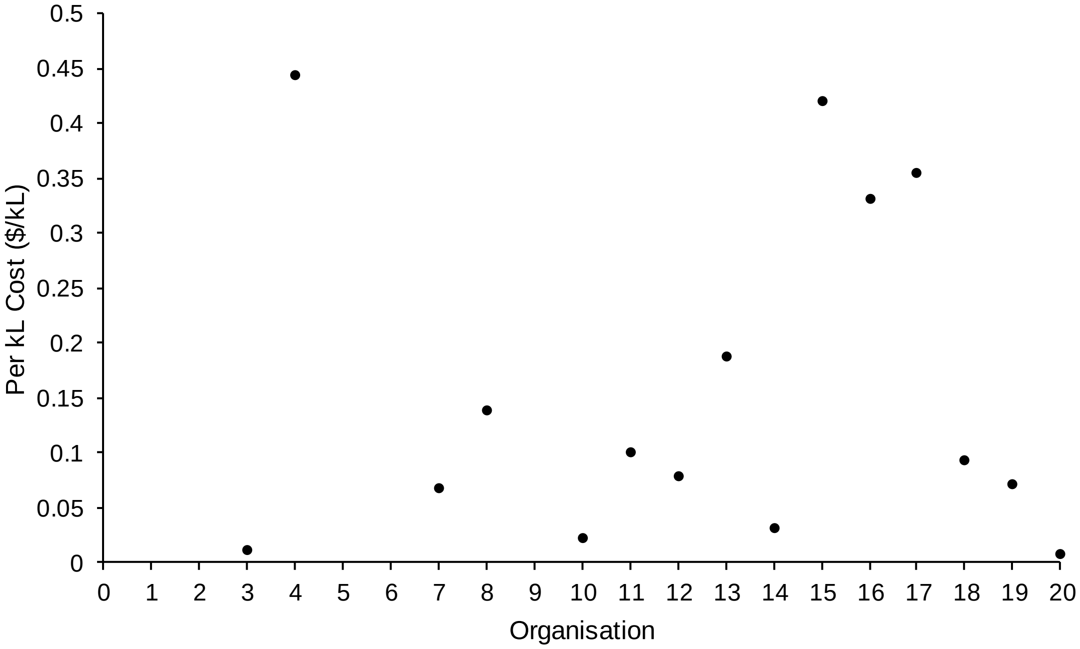

Figure 9: Per kL groundwater cost – scatter plot

4.2.3 Current scheme water use

This section looks briefly at current Scheme water use by organisations. Table 10 presents summary statistics for Scheme water use expressed as a percentage of total water use. Five observations are missing, associated with organisations that could not provide Scheme water use values, or groundwater use values (so we could not calculate total water use). Scheme water use amounts to 20% of total water use for the average organisation. The median value is 7%, which is somewhat lower than the mean due to several outliers. Figure 10 visually summarises the data, reinforcing that Scheme water constitutes a small percentage of total water use for the majority of organisations. As outlined previously, this result is not surprising given our sampling strategy, which specifically targeted large groundwater users with licensed allocations.

Table 10: Scheme water use as % of total water use – summary statistics

	Scheme use (% of total water use)
Mean	20%
Median	7%
Standard deviation	28%
Minimum	0%
Maximum	91%
n	15

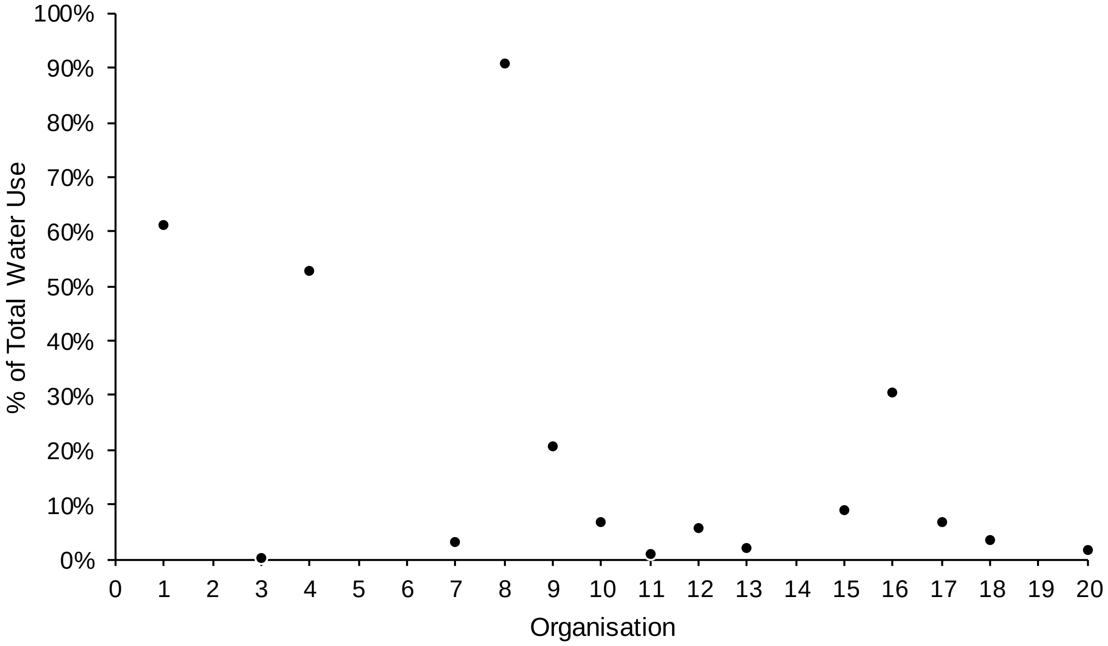

Figure 10: Scheme water use as % of total water use – scatter plot

4.2.4 Projected future water use

This section presents the information on projected short- (3–5 years) and longer-term (7–10 years) changes in groundwater and Scheme water use.

4.2.5 Projected future groundwater use

Table 11 presents quantitative information on projected changes in groundwater use in the short- (3–5 years) and longer-term (7–10 years) future. Organisations that provided this information projected very little change. Specifically, the average organisation projected a 0.2% increase in groundwater consumption in the short-term future, and a 0.4% increase in the longer-term. The median values were 0% in both cases.

Table 11: Short- and longer-term % change in groundwater use – summary statistics

	ST % change	LT % change
Mean	0.2%	0.4%
Median	0%	0%
Standard deviation	3.0%	4.0%
Minimum	–10%	–10%
Maximum	5.9%	8.9%
n	17	17

The open-ended questions provided qualitative insight to support these results. Factors identified as likely to decrease future consumption of groundwater included:

- regulatory changes (especially the DWER-driven 10% allocation reduction forecast for 2028)
- upgrades to irrigation systems and adoption of new water efficient technology
- ongoing roll-out of water saving land management techniques like hydro-zoning
- potential uptake of recycled water
- social change (increasingly environmentally aware communities demanding more sustainable water use options)
- population decreases.

Factors likely to increase future consumption of groundwater included:

- drying climate/harsher summers forcing increases in groundwater use for organisations not currently using their full groundwater allocation
- specific planned projects (e.g. land acquisitions/land use changes increasing irrigated area, new tree plantings)
- population increases (although these were generally thought likely to be offset by technological improvements).

4.2.6 Projected future scheme water use

Table 12 presents quantitative information on projected changes in Scheme water use in the short- (3–5 years) and longer-term (7–10 years) future. As for groundwater, organisations that provided this information projected very little change. Specifically, the average organisation projected a 2% decrease in Scheme water consumption in the short-term future, and a 0.5% increase in the longer-term future. The median values were 0% in both cases.

Table 12: Short- and longer-term % change in scheme water use – summary statistics

	ST % change	LT % change
Mean	–2.0%	0.5%
Median	0%	0%
Standard deviation	8.3%	5.0%
Minimum	–33.3%	–9.0%
Maximum	6.7%	16.7%
n	17	17

The open-ended questions provided qualitative insight to support these results. Factors identified as likely to decrease future consumption of Scheme water included:

- upgrading bathroom fittings such as toilets and sinks
- managing leaks
- adopting water efficient technologies such as thermal blankets for swimming pools that reduce evaporation rates
- decreasing population.

Factors likely to increase future consumption of Scheme water included:

- population increases (although these were again thought likely to be offset by technological improvements)
- construction of additional buildings in site redevelopment projects and associated increases in population density.

4.2.7 Other sources

A small set of organisations reported use of other water sources infrequently. Four organisations reported using rainwater tanks, but this source constitutes a small/negligible proportion of their total water use in each case (<1% in three out of the four). Two organisations reported recycled water use from the Subiaco WWTP, which constitutes approximately 35% of their total water use (although supply interruptions over the past year meant this percentage was much lower during this period). Other sources included unmetered surface water harvesting to supplement groundwater supply.

4.3 Recycled water valuation

This section presents the results of the valuation questions, including both the CV and CB questions. We provide different analyses for the whole sample, as well as disaggregated by organisation type.

4.3.1 Contingent valuation – current willingness-to-pay for recycled water

Table 13 presents summary statistics for the price per kL that organisations are currently willing to pay for recycled water. One observation is missing, for an organisation that did not specify current willingness-to-pay.

The average organisation was willing to pay up to $0.08 per kL for recycled water. The median value was $0.00 per kL, which differs from the mean due to two outlier organisations that stated particularly high willingness-to-pay values compared with the others. Figure 11 visually summarises the data, revealing that for all but two organisations, maximum willingness-to-pay for recycled water is $0.10 per kL or lower. The figure codes data points by organisation type: local governments are represented by small internal dots, schools/educational facilities by filled grey dots, golf courses by internal dashes, and other organisations by filled black dots. This coding provides little evidence that willingness-to-pay is associated with organisation type.

Table 13: Current per kL willingness-to-pay for recycled water – summary statistics

	Per kL WTP
Mean	$0.08
Median	$0.00
Standard deviation	$0.15
Minimum	$0.00
Maximum	$0.50
n	19

*One organisation was excluded due to missing data.

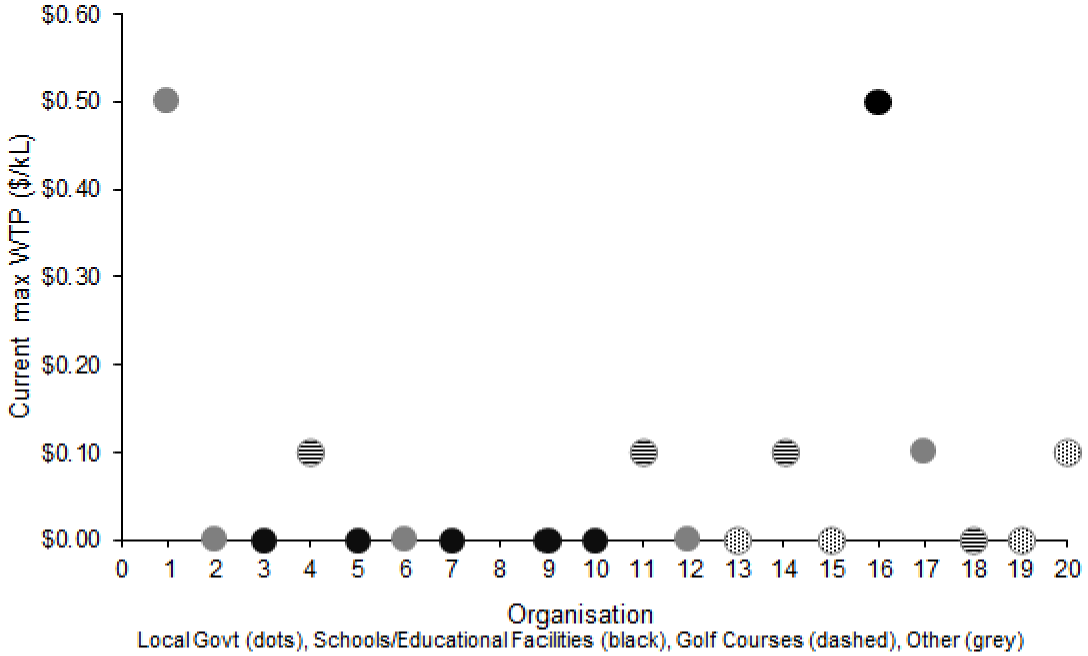

Figure 11: Current per kL willingness-to-pay for recycled water – scatter plot

4.3.2 Contingent behaviour – demand for recycled water under different allocation scenarios

Figure 12 displays the total volume of recycled water that organisations would be willing to purchase at various price points under the 10% (dashed line), 25% (dotted line) and 50% allocation (black line) reduction scenarios, respectively. Four observations are missing, from organisations that did not provide responses to the CB questions. If recycled water was delivered to organisations' property boundaries free of charge, altogether the 16 surveyed organisations would take just under 1,500,000 kL (total volume of recycled water) under a 10% allocation reduction scenario. The corresponding values for the 25% and 50% allocation reduction scenarios are just over 2,000,000 kL and just over 3,000,000 kL, respectively. At $0.05 per kL, the total volume of recycled water demanded declines sharply, and levels off from $0.10 per kL onwards, particularly in the 10% and 25% allocation reduction scenarios. The total volume of recycled water demanded gradually approaches zero as the price increases towards the Scheme water price (roughly $2.40 per kL).

Figure 13, Figure 14, and Figure 15 present the equivalent graphs for local governments, schools/educational facilities, and golf courses, respectively. The small number of observations for each organisation type means these results should be interpreted with caution.

Four local governments responded to the CB questions (Figure 13). Collectively they would be willing to take roughly 100,000 kL under a 10% cut, 400,000 kL under a 25% cut, and just under 1,000,000 kL under a 50% cut, if recycled water was provided free to their property boundary. As for the full sample results, volume demanded declined sharply through $0.05 per kL to $0.10 per kL, followed by a more gradual decline as the price of recycled water increases. Under the 50% allocation reduction scenario, the total volume demanded remains fairly high up to $0.20 per kL, beyond which it declines sharply. This result may reflect the essential nature of the services local governments provide to society (e.g. parks and recreation spaces for communities), which would be significantly threatened under a large allocation reduction, and might warrant substantial financial investment (e.g. in purchasing recycled water) to maintain. The comparatively lower volumes demanded for the 10% and 25% allocation reduction scenarios likely reflect that many organisations reported reductions of these magnitudes may be achieved through management changes, making it unnecessary to purchase recycled water.

Four schools/educational facilities responded to the CB questions (Figure 14). Collectively, they would be willing to take just over 50,000 kL under a 10% cut, roughly 175,000 kL under a 25% cut, and just over 350,000 kL under a 50% cut, if recycled water was provided free to their property boundary. Unlike the full sample and local government results, the total volume of recycled water demanded remains fairly constant up to $0.15 per kL, after which it declines sharply initially, and then gradually towards zero as the price approaches the Scheme price level. Under the 10% allocation reduction scenario, the steep decline occurs after $0.50 per kL, and the shallower decline after $1.00 per kL. Under the 25% allocation reduction scenario, the steep decline occurs after $0.15 per kL, and the shallower decline after $1.00 per kL. Under the 50% allocation reduction scenario, the steep decline occurs after $0.15 per kL, and the shallower decline after $1.00 per kL. Notably, the total volume demanded is particularly high under the 50% allocation reduction scenario and remains so over a wide range of prices. This result may reflect the value that schools/educational facilities place on their playing surfaces and grounds, which are often highly visible to the general public, and therefore shape public perception of the institution. And like local governments, these spaces would be very likely to be significantly threatened by a large allocation reduction such as 50%, and use could not be addressed through management changes alone. This fact may drive the high observed value of recycled water demanded, even at prices up to $0.50 per kL.

Four golf courses responded to the CB questions (Figure 15). Collectively, they would be willing to take around 500,000 kL under a 10% cut, just under 800,000 kL under a 25% cut, and roughly 950,000 kL under a 50% cut, if recycled water was provided free to their property boundary. For golf courses, the decline in total volume demanded is immediately steep under all allocation reduction scenarios, meaning that demand decreases drastically as soon as recycled water is associated with a price. This steep decline becomes more gradual after $0.05 per kL under the 10% and 25% cuts, and after $0.10 per kL under the 50% cut. The pattern of decline in total volume demanded could have various explanations. Perhaps golf courses are more willing or able to make management changes that drastically reduce water consumption, such as converting large fairway areas to native plantings. As a result, their willingness to take recycled water at any cost is lower, even under an allocation reduction as severe as 50%.

Figure 16 displays the same results as those in Figure 12, but expressed as a percentage of current groundwater allocation. If recycled water was delivered to organisations' property boundaries free of charge, they would be willing to purchase roughly 25%, around 35% and just over 50% of their current allocation under the 10%, 25% and 50% cuts, respectively. Therefore, organisations may be willing to take a higher volume of recycled water than the volume of groundwater being taken away from them. Somewhere around the $0.05 per kL price point, organisations appear to simply replacing the lost groundwater allocation. This result likely reflects the costs of extracting groundwater – a reduction in groundwater use generates cost savings that can subsequently be allocated to purchasing recycled water. As the price increases beyond $0.10, demand declines gradually up to the Scheme price level (around $2.40 per kL) at which point it falls to zero.

Figure 17, Figure 18, and Figure 19 present the equivalent graphs for local governments, schools/educational facilities, and golf courses, respectively. As outlined above, the small number of observations for each organisation type means that these results should be interpreted with caution.

Local governments would be willing to take recycled water equivalent to roughly 5%, 17.5% and 40% of their current groundwater allocation under 10%, 25% and 50% cuts, respectively, if it was delivered free of charge to their property boundary (Figure 17). Therefore, unlike the full sample results, local governments would take somewhat less than the amount of groundwater they were losing. The pattern of decline in demand as price increases strongly resembles that observed in Figure 13.

Schools/educational facilities would be willing to take recycled water equivalent to roughly 5%, 15%, and just under 35% of their current groundwater allocation under 10%, 25% and 50% cuts, respectively, if it was delivered free of charge to their property boundary (Figure 18). Like local governments, schools/educational facilities would take less than the amount of groundwater they were losing Again, the pattern of decline in demand as price increases resembles that observed in Figure 14.

Golf courses would be willing to take recycled water equivalent to just over 40%, around 65% and just under 80% of their current groundwater allocation under 10%, 25% and 50% cuts, respectively, if it was delivered free of charge to their property boundary (Figure 19). Therefore, unlike local governments and schools/educational facilities, golf courses would take substantially more than the amount of groundwater they were losing. As for the overall results, at the $0.05 per kL price point, golf courses look to be replacing what they lost. Once again, the pattern of decline in demand as price increases resembles that observed in Figure 15.

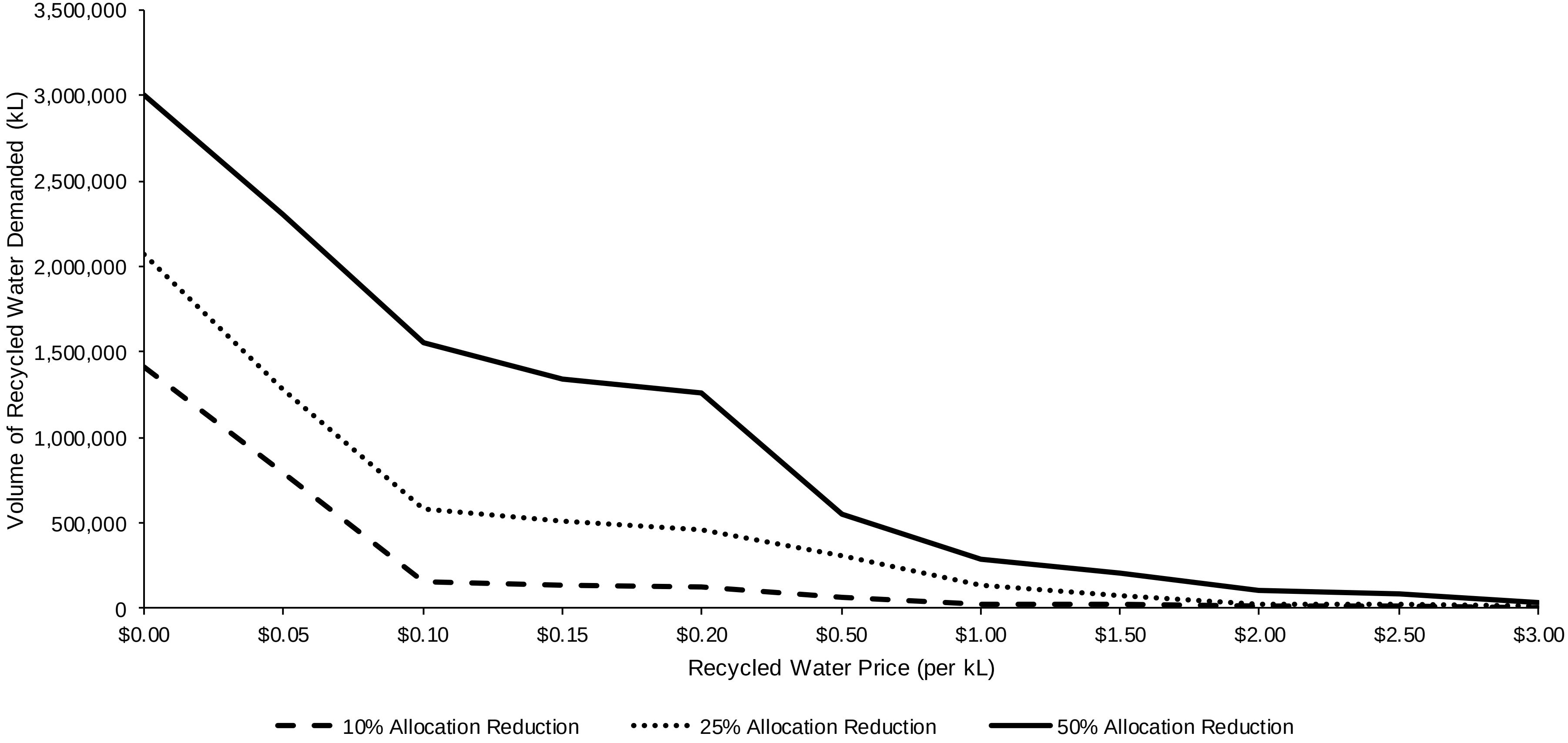

Figure 12: Overall demand curve – volumes demanded under 10%, 25% and 50% allocation reduction scenarios (n=16)

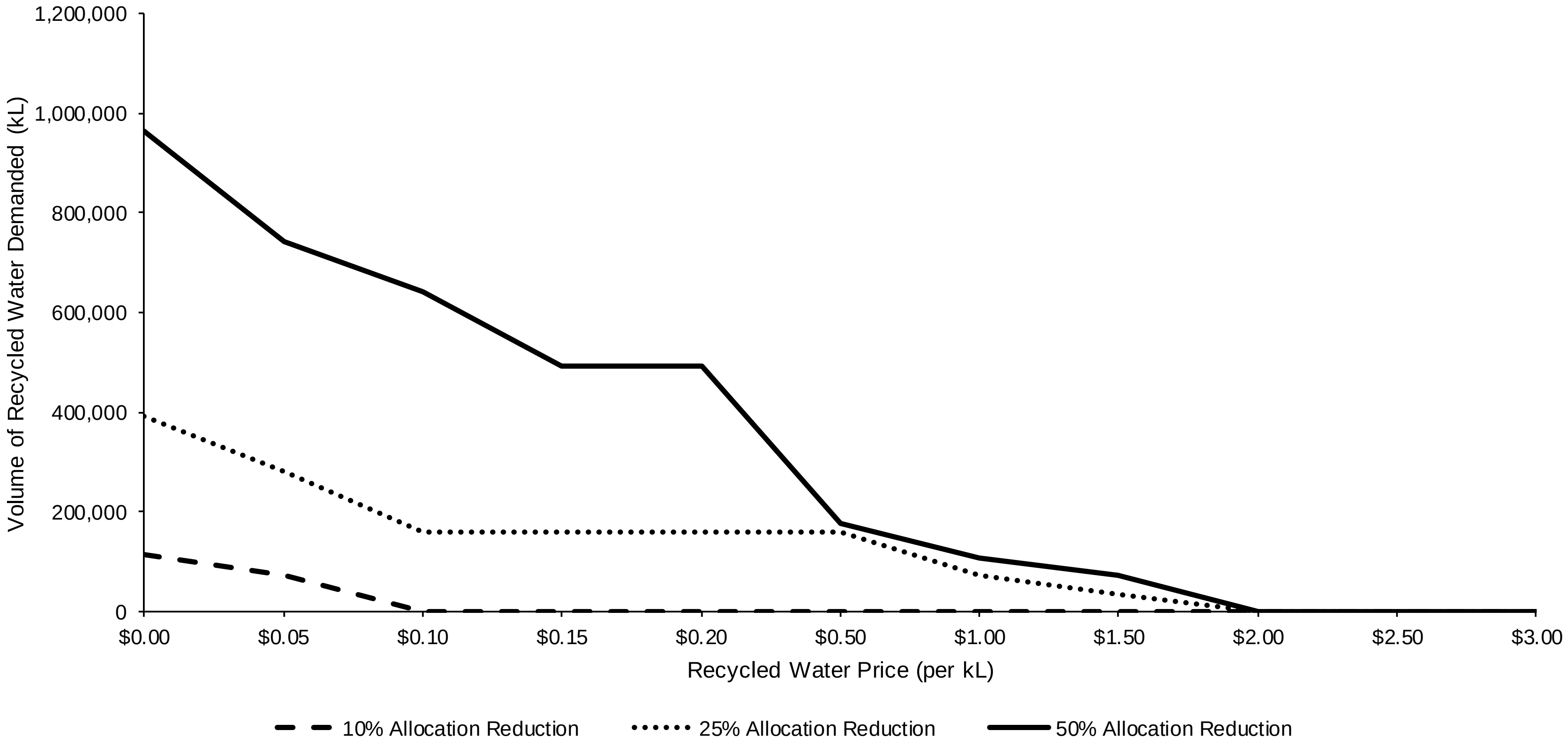

Figure 13: Local government demand curve – volumes demanded under 10%, 25% and 50% allocation reduction scenarios (n=4)

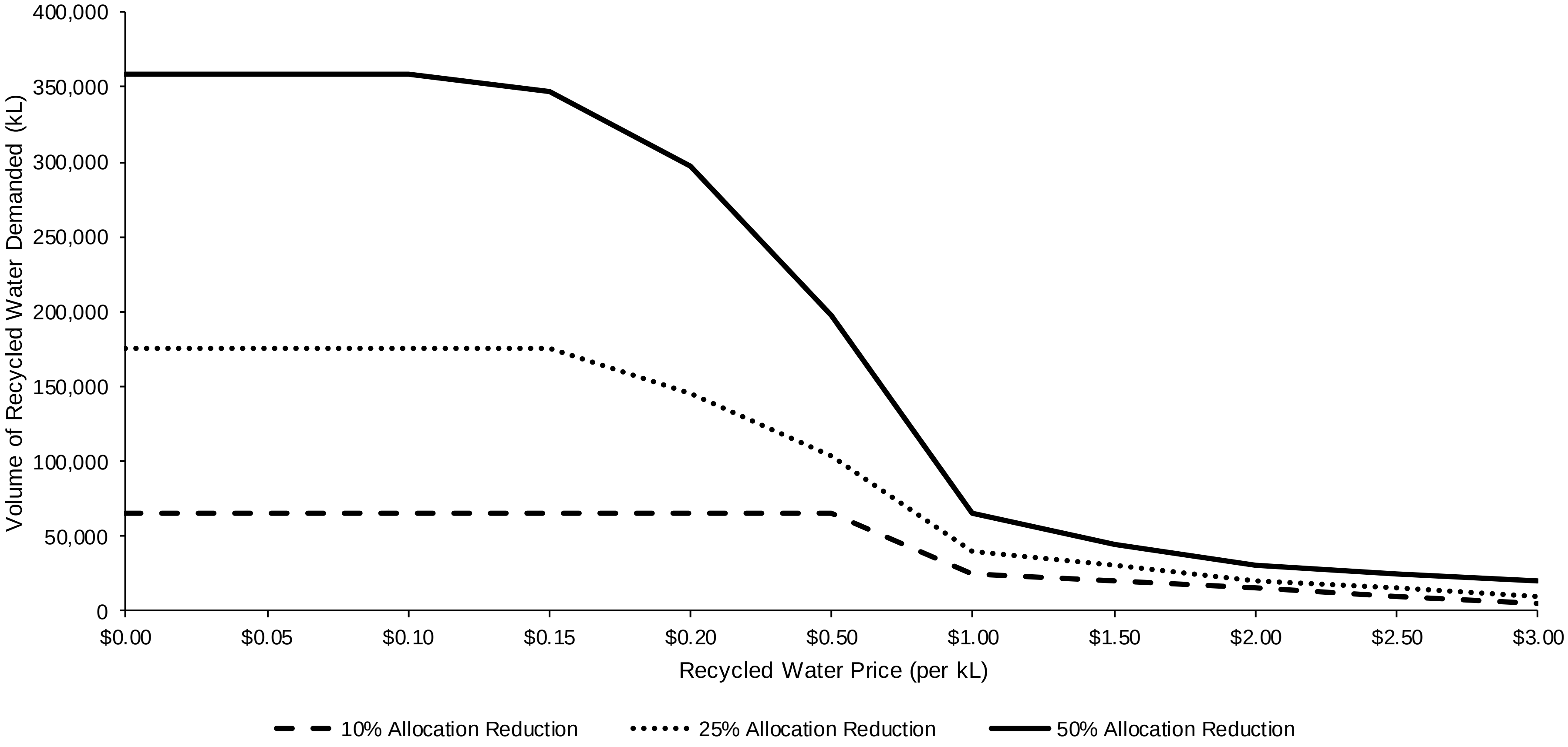

Figure 14: Schools/educational facilities' demand curve – volumes demanded under 10%, 25% and 50% allocation reduction scenarios (n=4)

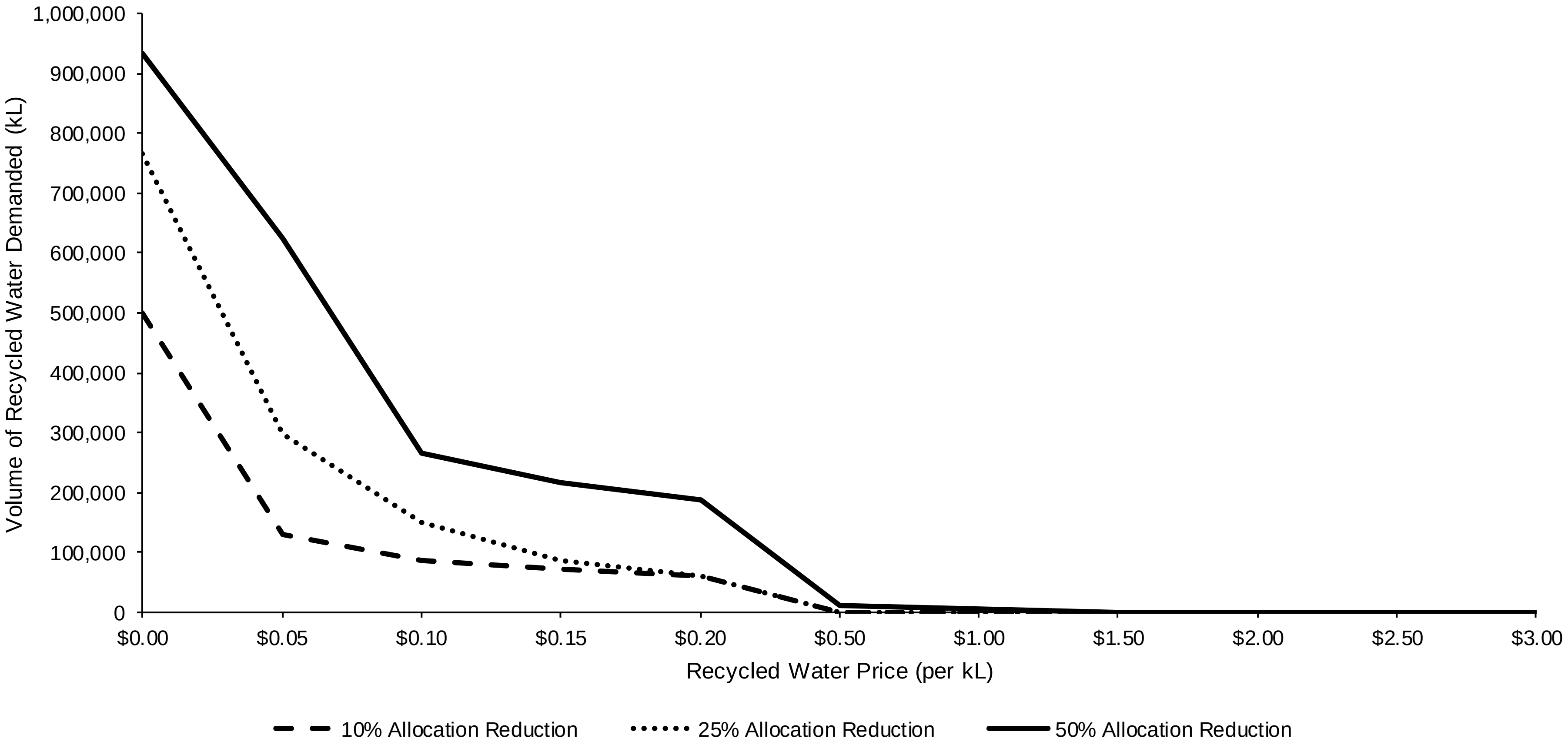

Figure 15: Golf courses' demand curve – volumes demanded under 10%, 25% and 50% allocation reduction scenarios (n=4)

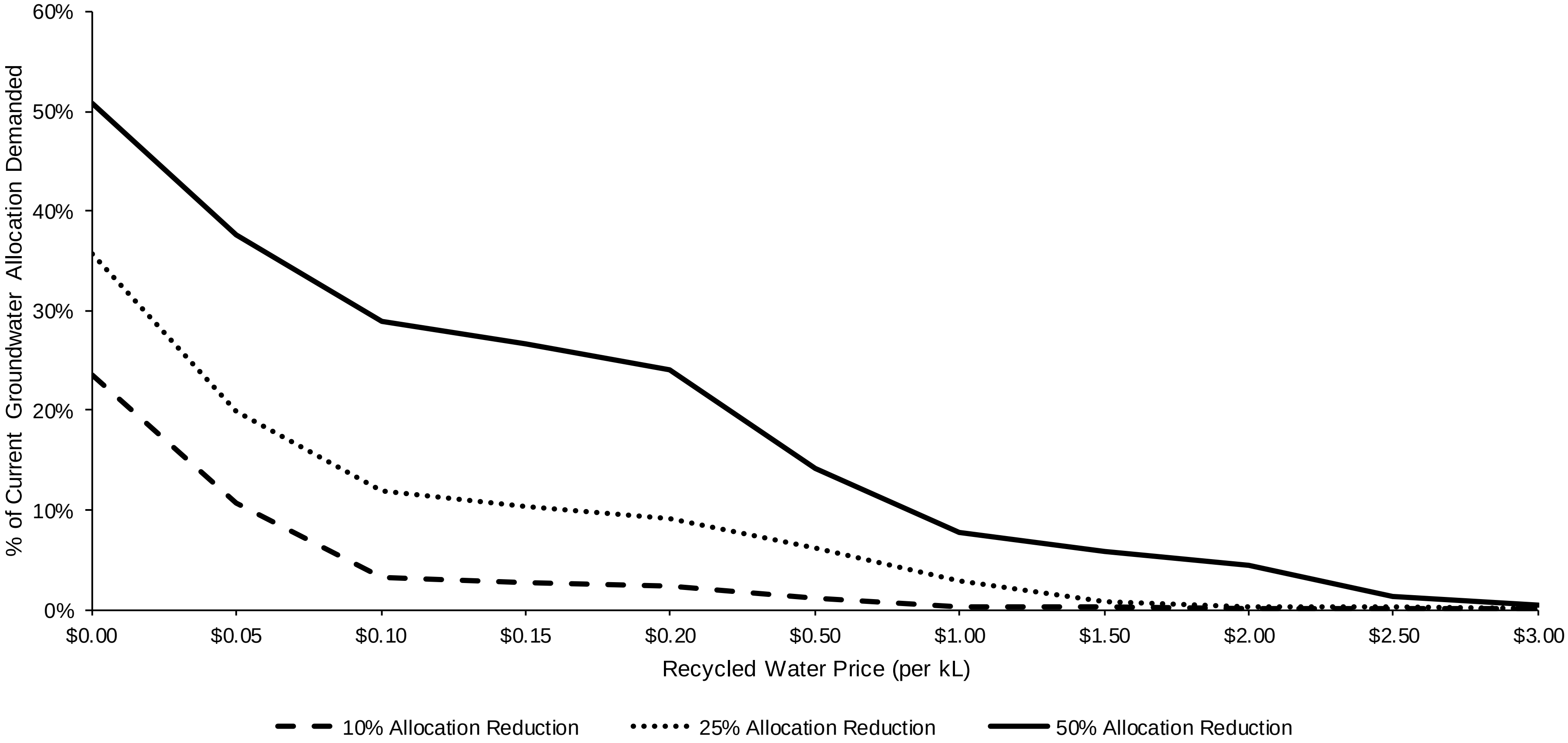

Figure 16: Overall demand curve – % of current allocation under 10%, 25% and 50% allocation reduction scenarios (n=16)

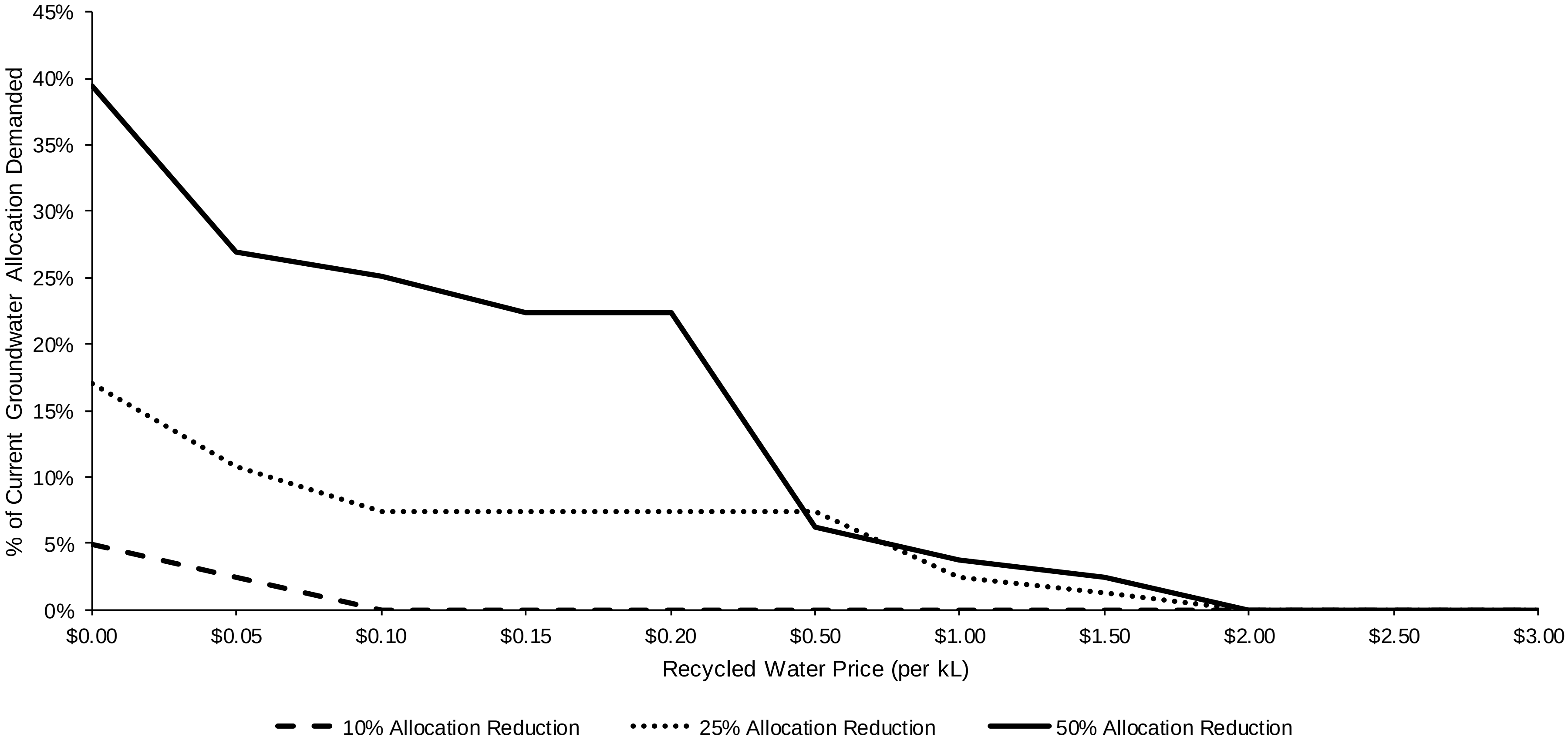

Figure 17: Local government demand curve – % of current allocation under 10%, 25% and 50% allocation reduction scenarios (n=4)

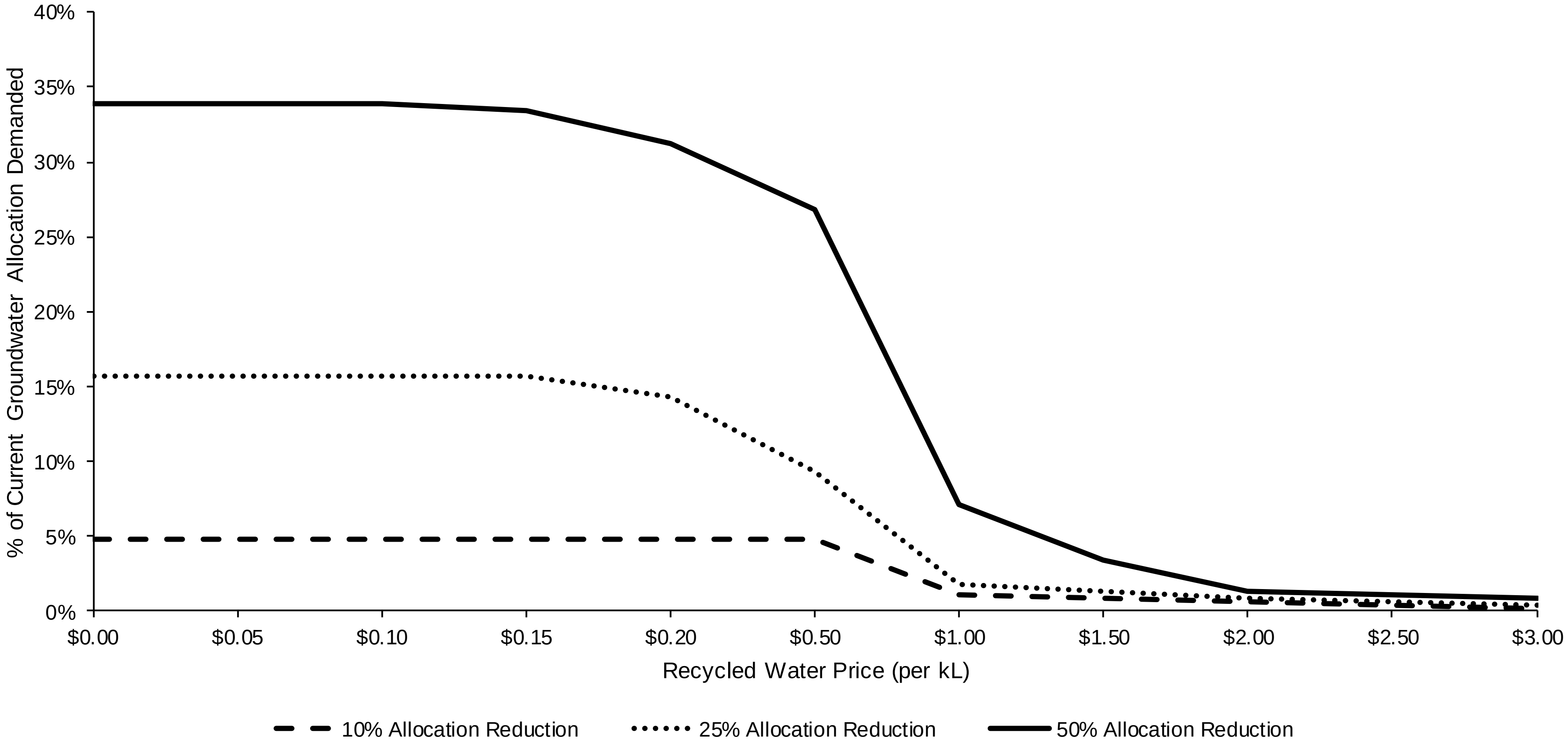

Figure 18: Schools/educational facilities' demand curve – % of current allocation under 10%, 25% and 50% allocation reduction scenarios (n=4)

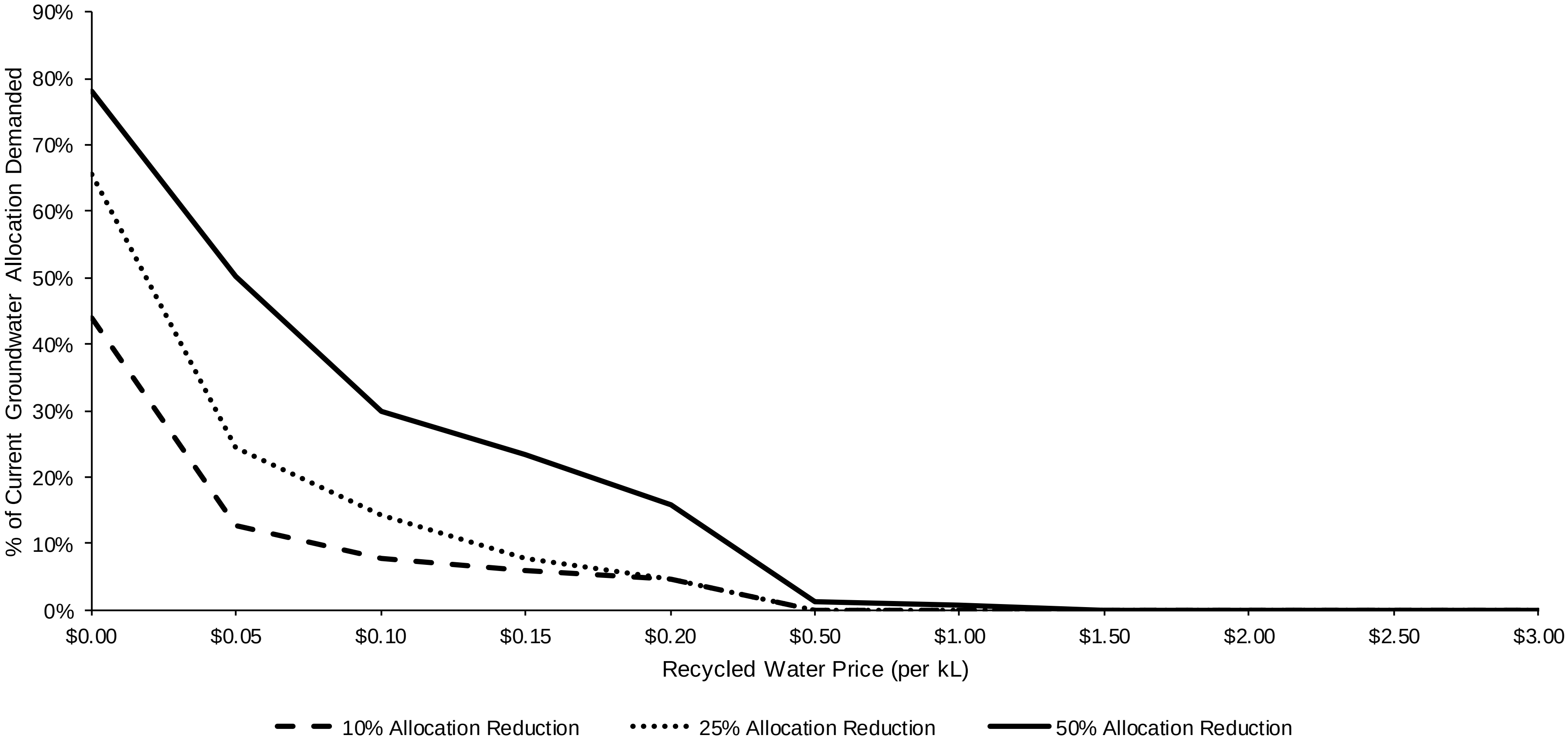

Figure 19: Golf courses' demand curve – % of current allocation under 10%, 25% and 50% allocation reduction scenarios (n=4)

4.3.3 Factors driving willingness-to-pay for recycled water

This section presents qualitative information collected to support the CV and CB questions. Respondents identified a broad range of factors as influencing their willingness-to-pay for recycled water. They are summarised in Table 14, which also includes information about the number of times they were spontaneously mentioned by respondents, and how often they emerged in general discussion of other parts of the survey (which involved direct prompting/probing by the interviewer in some cases).

The most commonly cited factor influencing willingness-to-pay for recycled water was how its associated costs could be incorporated into the current budget. Many respondents were concerned that their current budget allowed little space for additional costs. Some respondents noted that reductions in groundwater use (whether due to the 10% DWER cut or other factors) could generate some bore operational cost savings, although these savings were not thought likely to be large. Nevertheless, reduced groundwater costs might free up some funding to purchase recycled water. Overall budget was cited spontaneously nine times, and was very often discussed during interviews.

Another key factor was the current costs of groundwater extraction. For many respondents, groundwater use is not currently associated with a per kL charge, making it difficult to justify expenditure on recycled water. However, if the full costs of recycled water were lower than the costs of extracting groundwater (i.e. bore operations, servicing and maintenance), then it could become an attractive option. However, the majority of respondents considered this was unlikely to be the case, given the treatment and likely distribution costs associated with water recycling that the Water Corporation would seek to recoup. This factor was mentioned spontaneously seven times, and often came up in general discussion.

Five factors were spontaneously mentioned by respondents four times each:

- Current Scheme water costs, which sometimes came up in general discussion too. Respondents typically noted Scheme water costs as an absolute upper limit for a recycled water price. However, the volume of Scheme water that could currently be substituted for recycled water was typically very small, in the overall context of the water use profile, and certainly not enough to justify the costs (not least the transaction costs) of changing sources. Most respondents felt they would only be driven to pay up to the Scheme water price for recycled water if access to groundwater was severely reduced.
- Infrastructure costs, specifically the capital expenditure required to establish water recycling systems. These were thought to be prohibitive for individual businesses to bear alone, in the context of already tight budgets. Infrastructure costs often came up in general discussion, even if they had not been spontaneously mentioned in response to this question.
- Maintaining the quality of service or amenity to users. Some organisations reported a point at which they would no longer be willing to make land use or management changes to generate water savings, in the interest of maintaining their primary functions to their patrons. Certain irrigated areas were essentially ‘sacrosanct’, meaning organisations may well be willing to incur very substantial costs to maintain them. These areas were typically associated with high cultural values or were essential to the organisation’s key purpose.
- The fourth and fifth factors revolved around safety, human health and water quality. Even when these factors were not spontaneously mentioned in response to the designated question, they were almost invariably raised by respondents at some point. Respondents viewed proof of adequate water quality as a prerequisite to their willingness to buy recycled water. Of concern were the potential negative impacts to human health, and to the vegetated systems the water would irrigate.

The remaining factors were spontaneously mentioned by respondents three times or less. These were: the organisation’s capacity to make management changes instead of purchasing recycled water; the environmental benefits of using recycled water; the reliability of supply; positive or negative community perceptions of recycled water use; the logistics of the drying time requirements[5] for recycled water; potential staining of facilities due to recycled water use; alternative investment

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[5] After recycled water has been used for irrigating playing fields, there is a mandatory waiting time before people can actually play on them to avoid health and safety risk.

options; cost savings through fertiliser reductions when recycled water is used; the current price being paid for recycled water; risk management; and concerns about water pressure.

Table 14: Factors influencing willingness-to-pay for recycled water

Factor	Number of times spontaneously mentioned	How often discussed
Overall budget	9	Very often
Current costs of groundwater extraction	7	Often
Current Scheme water costs	4	Sometimes
Infrastructure costs	4	Often
Maintaining quality of service/amenity to users	4	Sometimes
Safety/human health (related to water quality)	4	Very often
Water quality	4	Very often
Capacity to make management changes instead	3	Often
Environmental benefits of using recycled water	3	Rarely
Reliability of supply	3	Very often
Community perception (positive or negative)	2	Sometimes
Logistics of drying time (related to water quality)	2	Sometimes
Staining of facilities	2	Rarely
Alternative investment options (related to overall budget)	1	Rarely
Cost savings through fertiliser reductions (related to water quality)	1	Sometimes
Current price paid for recycled water	1	Rarely
Risk management (related to reliability and safety/human health)	1	Rarely
Water pressure (related to reliability)	1	Often

4.3.4 Willingness-to-pay for recycled stormwater

This section presents qualitative information about potential differences between willingness-to-pay for recycled stormwater as opposed to treated wastewater. Of the 20 organisations in our sample, 18 provided usable responses to the open ended question about stormwater. Of these 18, 14 (78%) indicated their willingness-to-pay for recycled stormwater would not in principle be different from recycled wastewater, provided recycled stormwater quality was suitable for their needs and complied with health regulations. By contrast, two respondents (11%) stated their willingness-to-pay for recycled stormwater would be lower than for recycled wastewater, because: they assumed the treatment costs for stormwater would be lower than those for wastewater; they assumed nutrient levels in stormwater would be lower than those in wastewater, necessitating additional fertiliser costs; and their organisation already had stormwater initiatives. The remaining two respondents (11%) were unsure whether or not their organisation's willingness-to-pay for recycled stormwater would be different than for recycled wastewater.

4.4 Other data

This section presents the results of two quantitative questions included in the debriefing section. The first asked respondents how certain they were about how much their organisation would be willing to pay for recycled water, and the second asked them how likely they thought it was that policy makers would use the results of this study to develop water policy. Both questions were measured on a 0–10 scale, and respondents were free to mark the scale at any point of their choice.

Table 15 presents the summary statistics for the first question (certainty about the willingness-to-pay estimates). Two observations are missing, because two organisations declined to answer. The average respondent gave a certainty value of 5.4 out of 10. The median value was similar, at 5.8 out of 10. The lowest value given was 1, and the highest was 9. These results indicate respondents displayed a reasonable degree of uncertainty about how their organisation might approach the decision to purchase recycled water (or not), and how they might respond to changes in both recycled water and groundwater availability in the future.

Table 15: Certainty about WTP estimate (0–10 scale) – summary statistics

	Certainty about WTP
Mean	5.4
Median	5.8
Standard deviation	2.4
Minimum	1
Maximum	9
n	18

*Two organisations were excluded due to missing data.

Table 16 presents the summary statistics for the second question (likelihood that the survey will influence policy). One observation is missing, because an organisation declined to answer. The average respondent gave a likelihood value of 5.1 out of 10. The median value was very similar, at 5 out of 10. The lowest value given was 1, and the highest was 8.

Table 16: Likelihood that survey will influence policy (0–10 scale) – summary statistics

	Likelihood influence policy
Mean	5.1
Median	5
Standard deviation	1.8
Minimum	1
Maximum	8
n	19

*One organisation was excluded due to missing data.

Appendix 4 contains additional analyses, including: detailed summary statistics relating to future land use (Tables A4.1–A4.4); the number of bores operated by organisations (Table A4.5, Figure A4.1); frequency distribution analysis of current willingness-to-pay estimates (Figure A4.2); and, additional CB analyses (Figures A4.3, A4.4).

5.0 Discussion

This study had four main objectives:

1. To investigate current and future non-residential land use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct, and understand the relationship between land use and water availability
2. To investigate current and future non-residential water use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct, and identify opportunities for substituting recycled water for other water sources
3. To estimate current willingness-to-pay for recycled water for non-residential use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct
4. To explore future demand for recycled water for non-residential use in the suburbs surrounding Subiaco WWTP's potential Strategic Resource Precinct under three groundwater allocation reduction scenarios.

Based on our literature review, the above four issues have not been explored in either in the Australian context, nor the world as a whole.

Objective 1 Discussion

With regards to the first objective, our case study characterised land use for different types of organisations in the suburbs surrounding Subiaco WWTP and potential SRP. Overall, the two major land uses by the organisations in our sample are nature conservation and sports and recreation, although land use profiles vary by organisation type. Additionally, we determined land use is not likely to change significantly either in the short- or longer-term future. Our work demonstrates land use decision making is fairly rare in this area, given the well-established nature of organisations within it, and that whenever land use decisions have been made, water availability was not typically a key consideration. Therefore, any significant change in water demand as a result of land use change around the Subiaco WWTP is unlikely. Nor does it seem likely that water availability decreases will result in land use change, unless they are very severe.

However, while land use decisions are not closely tied to water availability, our work demonstrates an important relationship between land management decisions and water availability. Therefore, the way land is managed within a given land use category (e.g. nature conservation, sports and recreation etc.) strongly reflects how much water is available. For example, organisations can manipulate the ratio of turf to native planting area in response to water availability. So although changes in groundwater availability may not affect land use, they could greatly influence land management. Further, most organisations could articulate a hierarchy of land management changes that they would implement in response to increasingly severe groundwater reductions. Purchasing recycled water was not generally rated as a preferred initial response to cutbacks.

These results have important real world implications. They suggest that the 10% groundwater allocation reduction that DWER indicated will be in place by 2028 is not likely to increase demand for recycled water. Instead, organisations will adopt alternative water saving management practices at little or no cost to themselves. Indeed, some of the organisations we sampled were very confident of being able to achieve a 10% reduction without incurring any monetary costs. Some organisations have already reduced their groundwater consumption to 10% below their allocation, meaning they will not have to change land use or management to comply with the new policy. For example, some organisations had adopted new irrigation technology to improve water efficiency, maintaining service levels and reducing operating costs. These findings parallel those of Mennen et al. (2018) relating to irrigation practices by local parks in Perth.

Our results also provide little evidence that proximity to a recycled water source could be used to leverage desirable land use change in the Subiaco WWTP odour buffer zone, thereby assisting its transition to an SRP. Organisations in the area are very well established, and are not likely to be open to shifting location either in the short- or longer-term future. Most organisations are managing comfortably within their current groundwater allocation, and at minimal cost. They do not need to purchase or take on recycled water to maintain their core purpose. Moreover, they have significant concerns about the reliability and quality of recycled water, and the cost of distribution infrastructure.

These results imply that to transition the odour buffer zones of long-established WWTPs into SRPs (to protect them from increased pressure to be developed for highest value use), then this will likely require looking beyond current non-residential organisations within or adjacent to the buffer zone. It raises a general challenge, in that transitioning established WTTPs into SRPs may depend on the extent to which there is actually land available to accommodate new organisations that are attracted by low cost access to recycled water and other treatment by-products. A further challenge involves ensuring the activities proposed of new organisations must be compatible with existing land uses and zoning within and adjacent to the buffer zone.

That is, creating successful SRPs will require a strategic planning approach. This may be especially relevant for relatively new WWTPs in developing areas, where land uses are not yet established. Creating SRPs at long-established WWTPs is likely to depend on land availability and compatibility of new land uses/activities with odour buffer zone requirements.

Objective 2 Discussion

With regards to the second objective, organisations in the suburbs surrounding the Subiaco WWTP and potential SRP predominantly use Scheme water and groundwater. The sampled organisations tended to be heavily groundwater reliant, rather than Scheme reliant. This was anticipated, given we selected organisations that hold groundwater licences for substantial and ongoing groundwater use. However, groundwater costs were typically equalled by Scheme water costs within a given organisation’s overall water budget, which is expected given the high price of Scheme water (roughly $2.40 per kL) relative to groundwater. On average, groundwater costs were $0.16 per kL, although a skewed distribution meant the median organisation pays $0.09 per kL.

The uses to which groundwater is currently applied are well suited for substitution[6] with recycled water, especially irrigating turf or garden areas. However, recycled water is not of sufficient quality to substitute for typical Scheme water uses such as drinking or bathing. Scheme water is rarely used for irrigation, and even when it is, it is used in small quantities. Therefore, it is unlikely that recycled water could constitute an alternative water source to Scheme water at this time. Most organisations are using almost their full groundwater allocation in an average year, although some have reduced their consumption by 10% in advance of the anticipated DWER reduction. Even those organisations that have not yet made the 10% reduction have clear ideas about how it could be achieved at minimal cost and inconvenience. Beyond the 10% reduction, very minimal changes in either Scheme or groundwater use are projected for the short- or longer-term future.

These results imply that expanding the market for recycled water in the suburbs surrounding the Subiaco WWTP and potential SRP could be problematic in the foreseeable future. Recycled water could offer a clear price advantage relative to Scheme water. However, for the organisations we sampled, recycled water is not of sufficient quality to be a viable substitute for the relevant uses. By contrast, recycled water could substitute for current groundwater uses, but is not likely to offer a price advantage to prospective users, given the very low costs currently associated with groundwater extraction. Organisations have little incentive to purchase recycled water instead of continuing to extract groundwater with existing bores. Further, this situation is not likely to change over the next decade. Large-scale uptake of recycled water is therefore likely to occur during this period only if it is offered to consumers at a very low cost, or free of charge.

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[6] “Substitution”, in this context, refers to replacing one standard and source of water (e.g. desalinated potable water for irrigation with non-potable recycled water) to achieve benefits such as reduced costs, and improved environmental and/or social outcomes.

Objective 3 Discussion

With regards to the third objective, our results show willingness-to-pay for recycled water is low. This result supports our findings for objective 2; i.e. large-scale uptake of recycled water would occur only at very low or no cost. The average organisation is currently willing to pay no more than $0.08 per kL for recycled water, although for the median organisation this value is $0.00 per kL. Our sample size was too small to permit a rigorous comparison between organisation types. However, for indicative purposes, the mean willingness-to-pay was lowest for local governments ($0.03 per kL), followed by golf courses and schools/educational facilities ($0.08 per kL) and other groups ($0.12 per kL).

As outlined in our literature review, a small body of existing work assesses the non-market value of recycled water, although not in the context of non-residential urban use. Because of key differences between our study and the existing literature in terms of geographical location, study methodology, water use type, and water user type, caution should be taken in comparing our results directly with other studies'. Nevertheless, broadly speaking, our values do compare favourably with those obtained for agricultural irrigation by Abu Madi et al. (2003), Alcon et al. (2010), Menegaki et al. (2007) and Tziakis et al. (2009). Converted to 2019 AUD, these values are $0.10, $0.56, $0.30 and $0.02 per kL, respectively. See Gunawardena et al. (2017 p.62-66) for a broader review of the wastewater management-related non-market valuation literature.

Many of the surveyed organisations are currently operating comfortably within their current groundwater allocation limits, resulting in zero willingness-to-pay for recycled water. For those organisations that are currently struggling to stay within their current allocation, willingness-to-pay is typically based on the costs of groundwater extraction. However, the mean willingness-to-pay for recycled water ($0.08) is less than the average cost of groundwater use ($0.16). This result may indicate organisations perceive recycled water as an inferior water source to groundwater. Possible explanations for this are outlined below.

The observed willingness-to-pay in our case study makes sense in the context of the current cost of groundwater to organisations, which consists purely of the costs of operating, servicing and maintaining extraction bores. To offer a price advantage, recycled water must be offered to consumers at a lower price than they currently pay for groundwater, which is minimal. It is not clear how this could be achieved given the inevitable costs associated with treating and distributing recycled water. External subsidisation (e.g. by State or Federal governments) may be a solution, although grant funding would require demonstrating clear public benefits.

Objective 4 Discussion

With regards to the fourth objective, the CB analysis revealed a clear and strong relationship between groundwater availability and demand for recycled water. Within each allocation cut scenario, we observed the expected inverse relationship between price and quantity demanded. Specifically, demand decreased as assumed recycled water price increased. This result reassures us that respondents understood the intuition of the question. It was supported by the between-scenario results, which indicated demand for consistently higher volumes of recycled water under the 50% cut scenario, compared with the 25% and 10% scenarios.

If recycled water was available to consumers at not cost (e.g. through subsidisation), they may be willing to substitute their lost groundwater allocation for recycled water. This result was evident across all three scenarios, but especially apparent for the 50% reduction scenario, in which the sampled organisations would demand roughly 3,000,000 kL (3 GL). And it provides encouraging evidence that organisations are not averse to using recycled water on principle. However, higher prices drastically reduced demand for recycled water. As soon as respondents assumed recycled water was priced, the quantity demanded rapidly decreased, plateauing around the groundwater price range, and falling to zero at the Scheme water price. Our work provides some support for variability between organisations in terms of how they would respond to potential allocation cuts, but our dataset is too small to rigorously assess this hypothesis.

These results are not surprising, given land management changes are typically the preferred initial response to allocation cutbacks. Many organisations seemed willing to reduce their level of service/amenity to some extent rather than pay for recycled water. For example, a local government might convert some playing field areas to native plantings that do not require irrigation, or reduce irrigation frequency such that parks simply dry up to some degree. While this approach may seem logical and justifiable from a budgetary (cost saving) perspective, it is possible that some organisations did not consider the full value provided to users by well irrigated areas, including non-market elements.

Other discussion points

Beyond the key results discussed above, two key themes emerged from informal discussions during interviews with respondents: key conditions for a successful recycled water scheme; and options for recycling water in the future. These are explained more fully below.

Theme 1: Key conditions for a successful recycled water scheme

All respondents agreed we need to better use the large quantities of treated wastewater and stormwater currently being released into the ocean, especially given the pressures created by climate change and Perth's growing population. They identified five key conditions for a successful recycled water scheme operating out of the Subiaco WWTP in the future.

- Reliable water supply: The reliability of supply was very important to respondents, because even short-term water supply interruptions could seriously affect their operations. Generally, respondents considered facilities at the Subiaco WWTP may require significant upgrades to deliver a larger-scale water recycling scheme. Respondents also identified communication about interruptions as an important issue.

- Consistent water quality: At present, respondents were concerned about whether recycled water would consistently meet required quality standards. They suggested that if a lack of confidence meant that they needed to conduct their own testing, then this would generate additional costs to them and further decrease their willingness-to-pay.

- Timely and accurate information: Respondents indicated they needed more information about the experience of existing users of recycled water from the Subiaco WWTP. That is, respondents want evidence that the product performs well (in terms of reliability of supply) and has no serious side-effects, either for vegetation or human health. They were particularly interested in existing users' experience over several years.

- Assistance to upgrade infrastructure: Respondents reported they would incur significant infrastructure costs to expand their use of recycled water—first to deliver water to the property border and then to distribute water within the property. Most respondents indicated they would require assistance (such as funding from the Federal and/or State governments) to upgrade their infrastructure. Some respondents indicated governments should bear all the costs, while others considered governments should at least share the costs with businesses.

- A realistic price for recycled water: Respondents indicated Water Corporation must be willing to negotiate a reasonable price for recycled water. Some respondents suggested recycled water should be supplied free of charge, while others suggested at most the price should recover the cost of any additional treatment needed to make it suitable for irrigation. This was particularly the view of respondents willing to invest in infrastructure. This view also reflects the availability of groundwater.

These conditions reflected respondents' experience with or knowledge of other recycled water schemes.

Theme 2: Future recycled water options

Organisations expressed a range of views about the future of recycling treated wastewater and stormwater:

- The Water Corporation could inject/infiltrate all available treated wastewater/stormwater (e.g. through managed aquifer recharge), and thereby remove the need for groundwater allocation reductions altogether.

- Buyers of recycled water could have it distributed to them via the aquifers. This would be far more practical and cost-effective than laying down new pipes, because there would be no additional infrastructure costs.

- Groundwater allocations could be relative, rather than absolute. Each year, experts could determine how much groundwater could safely be extracted, based on the current condition of the aquifer. Users would then be entitled to a fixed proportion/percentage of that total volume.

- Groundwater allocations/consumption could be associated with a cost, rather than free of charge, to reduce consumption. This might drive demand for recycled water.

- Water recycling policy should be targeted to new and developing suburbs. Those areas are over allocated, and yet developing rapidly. There could be high demand for recycled water for new land uses as they are being decided upon/established. By contrast, there is likely to be lower demand for recycled water in inner city areas, which are fully allocated (rather than over allocated), and in which land uses are already long-established. One exception could be infill developments, which could better use rainwater capture, greywater recycling, and third pipe systems.

6.0 Conclusion

This report provides important insights into the potential to transform the Subiaco WWTP and surrounding odour buffer zone into an SRP through an expanded water recycling scheme. We characterised current land and water use, identifying that both are well established in the suburbs surrounding the potential SRP, and unlikely to undergo substantial change in the foreseeable future. We also determined that there is currently little opportunity to substitute recycled water for existing sources. It is not appropriate for the uses to which Scheme water is currently being applied. Nor can it offer a price advantage over groundwater unless subsidised. So, it is not surprising that our results suggest current willingness-to-pay for recycled water by existing non-residential land uses is low, and unlikely to justify the development of additional treatment and distribution infrastructure. Willingness-to-pay is closely linked to both the price and availability of groundwater. And in most cases, organisations do not differentiate between stormwater and treated wastewater in terms of willingness-to-pay, provided that quality and safety standards are met.

Overall, this study indicates that the expansion of water recycling from the Subiaco WWTP is not feasible at this time unless certain key conditions (or perhaps combinations thereof) are met. First, most organisations are currently operating comfortably within their existing groundwater allocations. Willingness-to-pay is likely to remain low unless these allocations are reduced quite substantially, and much more severely than the level of allocation cut that is currently being proposed for the next decade. Second, potential users must be confident an expanded system can provide reliable and high quality water supply for users. As well as likely requiring new infrastructure (discussed next), instilling this confidence requires providing potential users with timely and accurate information about the efficacy of recycled water. Third, the capital costs of establishing recycled water distribution infrastructure appear to be prohibitive. A large-scale water recycling system will likely need novel funding solutions that appropriately distribute the costs and benefits of the system. These solutions will likely include grants/subsidies from governmental or other bodies. Fourth, progressing this issue to a meaningful extent will require open discussion to foster understanding and compromise between different parties.

The results of this study give rise to the following key policy recommendations:

- Effort should be given to identifying new funding sources to establish water recycling infrastructure. The amount of funding that key stakeholders are currently willing to allocate to water recycling is typically minimal or non-existent, and certainly well below what is required to get schemes up and running. Importantly, demonstrating public benefits would be critical to any application for government funding.

- Policymakers could consider compiling information from existing recycled water users about their experiences using it, although variability between locations might mean that some experiences might not be applicable at other sites. Providing this information to prospective buyers in an easily accessible and understandable format is likely to greatly enhance their willingness to consider using/paying for recycled water. One example could be organising workshops where current and potential users can interact directly, to grow their knowledge and form networks to share information and experience.

- Recycled water policy can incorporate captured stormwater in addition to treated wastewater, given the evidence suggests organisations view the two sources as functionally equivalent.

- Strategic planning is likely to be critical for creating SRPs, to ensure that: land availability is sufficient to facilitate co-location of adjacent suitable land uses that can use wastewater treatment by-products; and that such land uses are compatible with odour buffer zone requirements.

Future research could extend the current work by using non-market valuation techniques to estimate the value of recycled water to non-residential users elsewhere in Perth, Australia, or abroad. This research would yield insights into how values vary depending on key characteristics of the study area (e.g. climate variations, inner-city versus outer-city, established versus developing areas).

Additionally, future work could use non-market valuation to estimate residential willingness-to-pay for recycled water in our study area, namely the suburbs surrounding the Subiaco WWTP and potential SRP, especially those undergoing redevelopment to higher densities. It could provide key information about whether or not aggregate residential demand and willingness-to-pay would justify the expenditure associated with establishing community bores and third pipe recycled water distribution networks. It could also be useful to identify wider beneficiaries who might be persuaded to co-fund such schemes.

This case study used a small sample to collect detailed qualitative information to support the quantitative results. Future work could build on this research, to develop a more quantitatively-oriented design that would be suitable for much larger sample sizes. Further future research could explore how substantial increases in the availability of recycled water might attract compatible land uses to the vicinity of WWTPs, both within and beyond SRP boundaries. Finally, future research could consider how potential demand for products other than recycled water (e.g. sludge, nutrients, and biogas) might contribute to transforming the Subiaco WWTP and surrounding odour buffer zone into an SRP.

Appendices

Appendix 1: Advantages/disadvantages of and uses for recycled water

Recycled water offers several key advantages compared with other possible sources. First, collection infrastructure already exists in many parts of the world (i.e. sewage and drainage systems). Second, the facilities required to treat collected water to a usable standard similarly already exist in many places (i.e. wastewater treatment plants), and the water is often already being treated to a high standard before it is released into the environment. Therefore, all that may be required to recycle water is to develop storage and/or distribution infrastructure that can deliver it to where it is needed, when it is needed. Recycled water may be stored in aquifers until it is required (Water Corporation, 2019), provided legislative arrangements are in place that allow the party responsible for adding water to the aquifer to retain ownership of it. Aquifer storage may also provide a distribution method, with those purchasing recycled water able to access it via their existing groundwater bores. Naturally, this approach relies on the buyer and sellers of the water being geographically located such that both have access to the same aquifer. In some cases, new distribution infrastructure may be required (i.e. laying new pipes), which may generate potentially substantial costs. Nevertheless, recycling water may avoid some of the large upfront and ongoing costs associated with alternative water sources, such as building and operating desalination plants (Wade Miller, 2006). Furthermore, recycled water may offer further advantages over desalination in terms of reduced energy consumption and greenhouse gas emissions (Lam et al., 2017).

Depending on the level of treatment that occurs, recycled water can be (and has been) applied to both potable and non-potable uses. These uses are summarised below in Table A1, along with some key advantages and disadvantages of each, and some relevant references.

Potable use of recycled water requires the highest possible level of water treatment (Tram Vo et al., 2014), and due to poor public acceptance has rarely been implemented to date (Dishman et al., 1989, Marks et al., 2006, Dolnicar and Schäfer, 2009, Robinson et al., 2005). Nevertheless, some examples exist of both direct and indirect potable reuse projects. Indirect potable reuse projects have been implemented in Australia, the United States and Singapore (Duong and Saphores, 2015, Leverenz et al., 2011, Dupont, 2013, Water Corporation, nd-a). In these projects, recycled water is used to recharge potable aquifers to supplement the existing potable water supply. A few examples of direct potable reuse projects exist in Namibia and the United States (Duong and Saphores, 2015, du Pisani, 2006, Leverenz et al., 2011), in which recycled water is added to the potable water supply directly, without first passing through an aquifer.

Far more common than potable reuse is applying recycled water to various non-potable uses, as detailed in Lu and Leung (2003) and Urkiaga et al. (2008). Non-potable water uses can be broadly categorised as follows: agricultural irrigation; fire protection; groundwater recharge; household use (e.g. toilet flushing, cleaning, car washing, gardens); industrial use (e.g. cooling, process and boiler feed water, dust control); landscape irrigation (e.g. road verges and gardens); public open space irrigation (e.g. golf courses, parks, playing fields); and environmental uses (e.g. groundwater recharge, urban river or lake flow supplementation, ecological restoration). Non-potable reuse of recycled water has been implemented across a wide range of geographical areas, including Australia (Hurlimann, 2009, Hatt et al., 2006, Sydney Water, 2013), Europe (Angelakis et al., 1999, Bixio et al., 2006), North America (Wade Miller, 2006, Schaefer et al., 2004), and China (Chen et al., 2017, Lyu et al., 2016).

Table A1.1: Uses for recycled water, key advantages and disadvantages, and relevant references

Use	Key advantages	Key disadvantages	Relevant references
Agricultural/forestry irrigation	Reduced need to use synthetic fertilisers on agricultural crops Reduced nutrient disposal burden for wastewater treatment plants Increased potable water availability for other uses due to substitution More reliable irrigation water supply May facilitate increased agricultural/forestry development	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants Irrigation with recycled water may reduce the public's willingness to buy agricultural/forestry products	Angelakis et al. (1999); Borboudaki et al. (2005); Chen et al. (2017); Duong and Saphores (2015); Friedler (2001); Garcia and Pargament (2015); Lazarova et al. (2001); Lu and Leung (2003); Reznik et al. (2017); Schaefer et al. (2004); Tram Vo et al. (2014); Urkiaga et al. (2008); Verlicchi et al. (2012); Yang and Abbaspour (2007)
Fire protection	Increased potable water availability for other uses due to substitution	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants	Borboudaki et al. (2005); Chen et al. (2017); ; Lazarova et al. (2001); Lu and Leung (2003); Urkiaga et al. (2008)
Household non-potable (e.g. toilet flushing, cleaning, car washing, garden watering)	Increased potable water availability for other uses due to substitution More reliable household water supply	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants Households may find using recycled water around the home unpalatable, and/or refuse to use it at all	Chen et al. (2017); Duong and Saphores (2015); Garcia and Pargament (2015); Hurlimann and McKay (2007); Lazarova et al. (2001); Lu and Leung (2003); Mainali et al. (2014); Schaefer et al. (2004); Tram Vo et al. (2014); Urkiaga et al. (2008); Wang (2011); Willis et al. (2011)
Industrial use (e.g. cooling, process and boiler feed water, dust control)	Increased potable water availability for other uses due to substitution More reliable industrial water supply	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants	Chen et al. (2017); Duong and Saphores (2015); Garcia and Pargament (2015); Lazarova et al. (2001); Tram Vo et al. (2014) Lu and Leung (2003); Schaefer et al. (2004); Urkiaga et al. (2008)
Landscape irrigation (e.g. road verges, gardens)	Increased potable water availability for other uses due to substitution More reliable landscape irrigation water supply	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants	Borboudaki et al. (2005); Chen et al. (2017); Duong and Saphores (2015); Lazarova et al. (2001); Lu and Leung (2003); Schaefer et al. (2004); Tram Vo et al. (2014); Urkiaga et al. (2008)
Potable use	Increased availability of potable water More reliable supply of potable water	Treating recycled water to a potable standard could be expensive Potential public health risks if water is not adequately treated for pathogens The general public may find drinking recycled water highly unpalatable, and/or refuse to drink it at all	Bixio et al. (2006); Duong and Saphores (2015); du Pisani (2006); Dupont (2013); Hurlimann (2009); Leverenz et al. (2011); Lu and Leung (2003); Tram Vo et al. (2014); Urkiaga et al. (2008)

Use	Key advantages	Key disadvantages	Relevant references
Turf irrigation (e.g. golf courses, parks, playing fields)	Increased potable water availability for other uses due to substitution More reliable public open space irrigation water supply	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants The general public may find direct contact with parks or playing surfaces that have been irrigated with recycled water to be unpalatable, and/or refuse to use them at all	Garcia and Pargament (2015); Jones (2015); Lazarova et al. (2001); Lu and Leung (2003); SA Water (nd); Schaefer et al. (2004); Urkiaga et al. (2008)
Environmental use (e.g. groundwater recharge, urban river or lake flow supplementation, ecological restoration)	Increased potable water availability for other uses due to substitution More reliable environmental water supply Ecological improvements Reduced aquifer salinisation if recycled water is injected into aquifers permanently Provision of an additional natural water treatment stage if recycled water injected into aquifers to be used at a later time	Potential environmental and public health risks if water is not adequately treated for pathogens and pollutants The general public may find recreational use of rivers/lakes supplemented with recycled water to be unpalatable, and/or refuse to use them at all	Chen et al. (2017); Duong and Saphores (2015); Garcia and Pargament (2015); Hagare et al. (2015); Lazarova et al. (2001); Lu and Leung (2003); Tram Vo et al. (2014); Urkiaga et al. (2008); Verlicchi et al. (2012); Yang and Abbaspour (2007)

Appendix 2: Key project and survey development meetings

Meeting date	Location	Attendees
24 May 2017	Bendat Basketball Stadium, Floreat	UWA[1]: Sayed Iftekhar, James Fogarty Other: attendees from various stakeholder groups
21 August 2017	Water Corporation, Leederville	UWA: Sayed Iftekhar WC: Ian Kininmonth, Peter Howard, Corey Dykstra, Stephen Beckwith, Suzanne Brown, David Hughes-Owen, Jason Mackay, Ashley Price
13 February 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar, James Fogarty WC: Ian Kininmonth, Helen McGettigan
19 March 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar, James Fogarty WC: Ian Kininmonth DWER: Ursula Kretzer
14 May 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar WC: Ian Kininmonth, Peter Howard, Helen McGettigan, Natasha Burkett, Nadine Riethmuller, Antonietta Torre
22 May 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar WC: Ian Kininmonth, Peter Howard, Helen McGettigan, Natasha Burkett, Nadine Riethmuller, Antonietta Torre
21 August 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth
6 September 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth, Peter Howard, Nadine Riethmuller, Antonietta Torre WGA: Danni Haworth, Russell Martin
4 October 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth, Peter Howard, Corey Dykstra, Helen McGettigan, Russell Lamb
22 October 2018	Water Corporation, Shenton Park	UWA: Louise Blackmore WC: Ian Kininmonth Other: various attendees at the Innovation Precinct Open Day
9 November 2018	Water Corporation, Leederville	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth, Peter Howard, Corey Dykstra, Russell Lamb
16 November 2018	University of Western Australia, Crawley	UWA: Sayed Iftekhar, James Fogarty, Louise Blackmore WC: Ian Kininmonth DWER: Ursula Kretzer
22 February 2019	University of Western Australia, Crawley	UWA: Sayed Iftekhar, Louise Blackmore, James Fogarty WC: Ian Kininmonth Various other IRP2 Case Study Project Partners
20 March 2019	University of Western Australia, Crawley	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth, Russell Lamb, Nick Turner
22 March 2019	Water Corporation, Leederville	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth, Russell Lamb, Corey Dykstra DWER: Ursula Kretzer
12 June 2019	Westralia Plaza, Perth CBD	UWA: Sayed Iftekhar, Louise Blackmore WC: Ian Kininmonth DWER: Ursula Kretzer

[1] UWA=University of Western Australia, WC=Water Corporation, DWER=Department of Water and Environmental Regulation, WGA=Wallbridge Gilbert Aztec.

Appendix 3: Survey instrument

Participant information form

Recycling treated water from the Subiaco Wastewater Treatment Plant

(UWA Ethics Approval Number RA/4/20/4974)

Introduction

This survey is being conducted by researchers at the University of Western Australia to better understand the current and future demand for recycled wastewater and stormwater from the Subiaco Wastewater Treatment Plant. The Subiaco Wastewater Treatment Plant has significant potential to supply recycled waste water and stormwater. This project forms part of a larger national research program being undertaken by the Cooperative Research Centre for Water Sensitive Cities, of which the Water Corporation is a research partner.

Participation

You have been invited to participate in this survey because the organisation you represent is an existing or potential user of recycled wastewater and/or stormwater from the Subiaco Wastewater Treatment Plant.

Participation will consist of answering the questions contained within this survey on behalf of your organisation, to the best of your knowledge. However, if more information is required please feel free to share the survey with your colleagues. You will be provided with this survey in advance of an interview with a member of the research team. This will allow you time to gather the necessary information to respond as accurately as possible to the questions.

The survey contains questions about current and future land and water use on the property your organisation owns or is using, and about your organisation’s willingness to pay for treated water under a range of different groundwater allocation reduction scenarios.

Expected benefits

Findings from this study will be useful for understanding the potential for recycling treated water from the Subiaco Wastewater Treatment Plant. This will ultimately contribute to more sustainable management of water resources in Perth.

Research team

Dr Sayed Iftekhar	Tel: +61 08 6488 4634	Email: mdsayed.iftekhar@uwa.edu.au
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Cooperative Research Centre for Water-Sensitive Cities, Centre for Environmental Economics and Policy (CEEP) and UWA School of Agriculture and Environment, University of Western Australia

Risks

There are no risks beyond normal day-to-day living associated with your participation in this project. Moreover, you are invited at the end to comment on the survey if you wish.

Privacy and confidentiality

All comments and responses are anonymous and will be treated confidentially unless required by law. The names of individual persons are not required in any of the responses.

In accordance with regulatory guidelines, the information collected in this research project will be stored as per UWA's management of research data policy. Please note that non-identifiable data collected in this project will be summarised and may be used as comparative data in future projects.

Consent to participate

Completion of the Participation Consent Form on the following page indicates your consent to participate in this project.

Questions/further information about the project

If you have any questions or require any further information, please contact one of the research team members listed above.

Concerns/complaints regarding the conduct of the project

Approval to conduct this research has been provided by the University of Western Australia, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time.

In addition, any person not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the Human Ethics Office at the University of Western Australia on (08) 6488 3703 or by emailing to humanethics@uwa.edu.au.

All research participants are entitled to retain a copy of any Participant Information Form and/or Consent Form relating to this research project.

Participant Consent Form

I, ………………………………………………………., have read the information provided and any questions I have asked have been answered to my satisfaction. I agree to participate in this survey, realising that I may withdraw at any time without reason and without prejudice.

I understand that all identifiable (attributable) information that I provide is treated as strictly confidential and will not be released by the investigator in any form that may identify me. The only exception to this principle of confidentiality is if documents are required by law.

I have been advised as to what data is being collected, the purpose for collecting the data, and what will be done with the data upon completion of the research.

I agree that research data gathered for the study may be published, provided my name or other identifying information is not used.

________________________________ ________________

Participant's signature Date

Subiaco Case Study Survey – Final Version

Questionnaire introduction

This questionnaire explores the potential for recycled water use from the Subiaco Wastewater Treatment Plant (WWTP). In recent years, the Strategic Resource Precinct concept has been developed to transform the way the WWTPs and their surrounding odour buffer zones are managed, by viewing them as generating valuable resources as opposed to waste products. The Subiaco WWTP Strategic Resource Precinct is shown in Figure 1.

The Subiaco WWTP currently services a catchment of around 240,000 people and includes the Perth central business district. The plant treats 21.9 million kilolitres of sewage inflow per year (roughly 8,760 Olympic-sized swimming pools).[7] Only 0.5 million kilolitres (roughly 2.2%) of treated wastewater is currently recycled, mainly for use in the irrigation of nearby playing fields. Therefore, there is scope to greatly increase the amount of treated wastewater that is recycled. In addition, a major stormwater drain runs beneath the WWTP and eventually discharges into the ocean. It is estimated that between 1.5 and 3.0 million kilolitres of stormwater passes through this drain every year.

Treated wastewater and stormwater constitute a potential resource which could be valuable for Perth in the context of growing demand for water (due to population growth) and reductions in water supply (due to a drying climate and reduced groundwater allocations). While there is currently uncertainty surrounding future groundwater allocation cuts, it is possible that they could range from mild (e.g. 10%) to severe (e.g. 50%), meaning that users who rely heavily on this water source may have to consider alternative options.

Some 4-5 million kilolitres of treated wastewater and stormwater could be made available to potential users in the foreseeable future, depending on the extent to which demand for the water exists. Therefore, this questionnaire assesses demand for recycled water from its existing and potential users across a range of different groundwater allocation reduction scenarios.

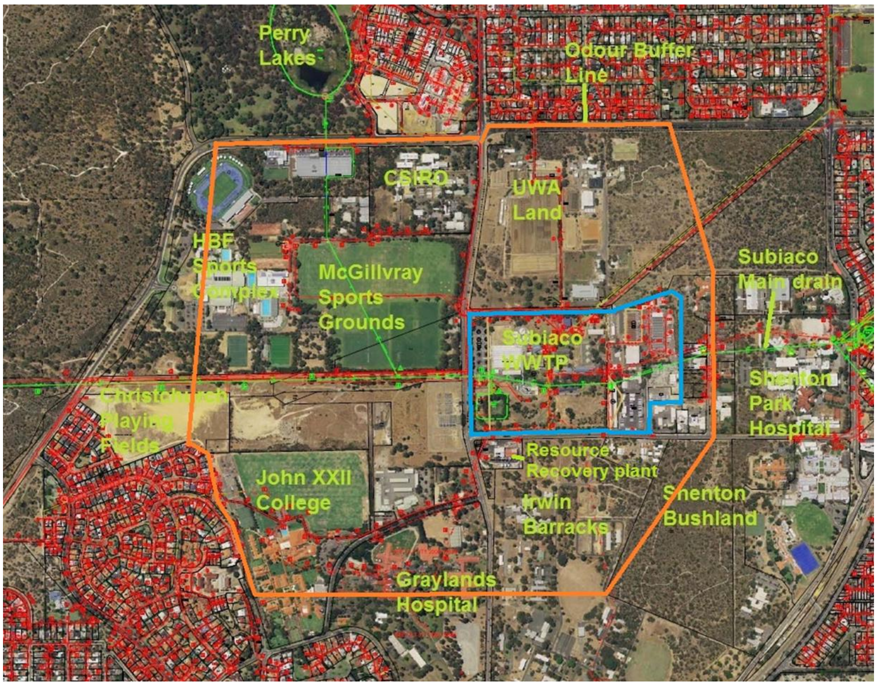

Figure 1: Location of the Subiaco Strategic Resource Precinct

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[7] One Olympic-sized swimming pool holds around 2,500kL of water.

Section 1: Current and future land use

Question 1.1: Please complete the table below to the best of your knowledge. When we refer to your organisation’s property, we mean the entire land area that your organisation owns or leases, even if the organisation does not actively manage the whole area (e.g. there are areas of remnant vegetation that fall within the property boundaries, but are not actively managed by your organisation). For each of the land uses listed in the table that are relevant to your organisation’s property, please indicate:

- **Current land use (%):** please indicate the approximate percentage of your organisation’s property that is *currently* allocated to each of the listed land uses. Some space has been provided to allow for a more detailed explanation if required.
- **Land use in the short-term future (%):** please indicate the approximate percentage of your organisation’s property that you expect will be allocated to each of the listed land uses in the *short-term future (roughly 3–5 years).*
- **Land use in the longer-term future (%):** please indicate the approximate percentage of your organisation’s property that you expect will be allocated to each of the listed land uses in the *longer-term future (roughly 7–10 years).*
- **Total land area (ha):** please indicate the total land area that is currently owned or used by your organisation, and the total land area that you expect will be owned or used by your organisation in the *short-term future (roughly 3–5 years)* and the *longer-term future (roughly 7–10 years).*

Land use	Land use (%)	Short-term future (%)	Longer-term future (%)
Nature conservation Nature conservation areas are managed to protect native plants and animals and provide some access for passive recreation activities e.g. access to walk trails			
Sports and recreation Sporting and recreation areas provide spaces for organised sport and informal play and exercise, relaxation and social interaction. They include: ○ grassed ovals and playing fields for sport e.g. football, soccer, rugby, cricket, and athletics, ○ gardens and open parklands, community gardens, corridor links, amenity spaces, community use facilities e.g. playgrounds			
Agriculture and horticulture Agricultural and horticultural areas could include: ○ aquaculture ○ vineyards, orchards and market gardens ○ plants, nurseries and green houses ○ fodder production or pasture (including turf farms), ○ livestock			
Industry and commerce Industrial/commercial areas include: ○ renewable energy e.g. biogas, waste to energy, solar and wind farms ○ warehouses ○ transport depots ○ general and light industry e.g. manufacturing, assembly or repairs ○ waste transfer and recovery e.g. transfer stations, enclosed composting.			
Other (please specify)			
Total land area (ha)			

Question 1.2: Why did your organisation choose to locate their premises at their current site, to the best of your knowledge?

Question 1.3: To what extent do you think your organisation *currently* bases their land use decisions on water availability, to the best of your knowledge?

Question 1.4: To what extent do you think your organisation would make different land use decisions *in the future* if water availability were to *decrease*, to the best of your knowledge?

Section 2: Current and future water use/sources

Question 2.1: If relevant, what is your current groundwater allocation?

Question 2.2: If relevant, do you have a meter that accurately measures your groundwater consumption?

Question 2.3: Please complete the table below to the best of your knowledge, including the following information:

- **Current annual consumption:** please indicate approximately how much water your organisation uses annually in kilolitres (kL) from each of the listed sources.
- **Current annual cost:** please indicate approximately how much money your organisation spends on water per year in Australian Dollars (AUD) from each source. Please include both the cost of the water itself, and any associated costs (e.g. pumping costs, the servicing/maintenance of bores or other machinery).
- **Current uses**: please list all of the main water uses that are relevant on your organisation's property, both indoors and outdoors (some examples might include: heating, ventilation and cooling; industrial processes; irrigation for agriculture/horticulture, playing fields, landscaped areas, verges and street trees; maintaining natural/artificial water bodies; non-potable indoor use in kitchens/toilets/laundries; outdoor use in private spaces like gardens).
- **Projected change in consumption in the *short-term future***: for each of the listed sources, please indicate how much you think annual consumption will change in the *short-term future (roughly 3–5 years)*. Please use a + sign to indicate increases e.g. +2kL, and a – sign to indicate decreases e.g. -2kL.
- **If relevant, potential source(s) of additional water in the *short-term future***: if relevant, for each of the listed sources, please indicate where you think additional water will be sourced from in the *short-term future (roughly 3–5 years).*
- **Projected change in consumption in the *longer-term future***: for each of the listed sources, please indicate how much you think annual consumption will change in the *longer-term future (roughly 7–10 years)*. Please use a + sign to indicate increases e.g. +2kL, and a – sign to indicate decreases e.g. -2kL.
- **If relevant, potential source(s) of additional water in the *longer-term future***: if relevant, for each of the listed sources, please indicate where you think additional water will be sourced from in the *longer-term future (roughly 7–10 years)*.

Water source	Current annual consumption (kL)	Current annual cost ($)	Current uses	Projected change in consumption (kL) in the *short-term future (~3–5 years)*	Potential source(s) of additional water in the *short-term future (~3–5 years)*	Projected change in consumption (kL) in the *longer-term future (~7–10 years)*	Potential source(s) of additional water in the *longer-term future (~7–10 years)*
Scheme							
Groundwater							
Rainwater (e.g. in tanks)							
Recycled water (e.g. greywater recycling)							
Other							
Total							

Question 2.4: In the *short-term future (roughly 3–5 years)*, and assuming no change in groundwater allocations, do you expect your organisation's *overall water consumption* will (**tick** one):

☐ Increase
☐ Decrease
☐ Not change

Why? (Some reasons might include population changes, demand changes, water efficient technology adoption, land use changes, regulatory changes)

Question 2.5: In the *short-term future (roughly 3–5 years)*, and assuming no change in groundwater allocations, do you expect your organisation's *water management practices* will (**tick** one):

☐ Change
☐ Not change

How and why? (Some reasons might include population changes, demand changes, water efficient technology adoption, land use changes, regulatory changes)

Question 2.6: In the *longer-term future (roughly 7–10 years)*, and assuming no change in groundwater allocations, do you expect your organisation's *overall water consumption* will (**tick** one):

- ☐ Increase
- ☐ Decrease
- ☐ Not change

Why? (Some reasons might include population changes, demand changes, water efficient technology adoption, land use changes, regulatory changes)

Question 2.7: In the *longer-term future (roughly 7–10 years)*, and assuming no change in groundwater allocations, do you expect your organisation's *water management practices* will (**tick** one):

- ☐ Change
- ☐ Not change

How and why? (Some reasons might include population changes, demand changes, water efficient technology adoption, land use changes, regulatory changes)

Section 3: Valuation of recycled water

Question 3.1: Willingness to pay for recycled wastewater assuming no change to current groundwater allocation

Assume that the government has announced a plan to make recycled wastewater available to interested parties. Similar to other water supply infrastructure, the government will install the infrastructure required to bring an appropriate flow of recycled wastewater to the edge of your property only. Unlike groundwater extraction, there is no limit to the amount of recycled wastewater available to individual users. Further, for recycled wastewater, there is no fixed water access charge, only a single level volumetric water charge. The total price you would pay for using recycled wastewater is therefore the volume of water used multiplied by the per kL price for recycled wastewater.

Assume that your current groundwater allocation remains unchanged. On the payment card below, we have listed different amounts of money ranging from **$0 per kL** to **$3 per kL**. Starting on the left-hand side ($0) and moving across to the right-hand side ($2), please ask yourself: “Is my organisation *currently* willing to pay this amount for recycled wastewater? Or would the organisation rather not pay this amount and not have the water?” When you reach the *maximum* amount that your organisation would *currently* be willing to pay for recycled wastewater, please place a **tick (✓)** in the space below it.

Price	$0.00	$0.05	$0.10	$0.15	$0.20	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00
Willing to pay?											

Question 3.2: Willingness to pay for recycled wastewater under different groundwater allocation cut scenarios

For all of the following scenarios, assume that the government announces that there will be specified cuts to individual groundwater allocations. This announcement is made two years prior to the implementation of the cuts. This means that there is time to adjust practices in response to the cut in groundwater extraction limits. One option would be to purchase recycled wastewater to fill the possible shortfall created by the allocation cut.

As outlined above, assume that the government will install the infrastructure required to bring an appropriate flow of recycled wastewater to the edge of your property only. Unlike groundwater extraction, there is no limit to the amount of recycled wastewater available to individual users. Further, for recycled wastewater, there is no fixed water access charge, only a single level volumetric water charge. The total price you would pay for using recycled wastewater is therefore the volume of water used multiplied by the per kL price for recycled wastewater.

Assume the government announces a *10% reduction* in your groundwater allocation. That would imply a reduction of ______ kL in your groundwater allocation. If recycled water was available at the edge of your property, in response to the cut, how much recycled wastewater would you purchase at each of the following per kL prices? Please write a volume in **each box**.

Price	$0.00	$0.05	$0.10	$0.15	$0.20	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00
Quantity (kL)											

Now assume the government announces a *25% reduction* in your groundwater allocation. That would imply a reduction of ______ kL in your groundwater allocation. How much recycled wastewater would you purchase at each of the following per kL prices? Please write a volume in **each box**.

Price	$0.00	$0.05	$0.10	$0.15	$0.20	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00
Quantity (kL)											

Finally, assume the government announces a *50% reduction* in your groundwater allocation. That would imply a reduction of ______ kL in your groundwater allocation. How much recycled wastewater would you purchase at each of the following per kL prices? Please write a volume in **each box**.

Price	$0.00	$0.05	$0.10	$0.15	$0.20	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00
Quantity (kL)											

Section 4: Debriefing questions

Question 4.1: What key factors did your organisation consider when thinking about how much it would be willing to pay for recycled wastewater?

Question 4.2: Would your organisation's willingness to pay be different for recycled *stormwater*, as opposed to wastewater? Why (not)?

Question 4.3: Please indicate on the following scale how certain you were of how much your organisation would be willing to pay for recycled wastewater:

1 2 3 4 5 6 7 8 9 10

Very uncertain Very certain

Question 4.4: Please indicate on the following scale how likely your organisation thinks it is that policy makers will use the results of this survey to guide future decisions related to water recycling:

1 2 3 4 5 6 7 8 9 10

Very uncertain Very certain

Question 4.5: Does your organisation have any additional comments/questions/ideas to share related to water recycling *in general*?

These questions are related to your background

Question 4.6: How long (in years) have you been working for the organisation on behalf of which you are responding to this questionnaire?

Question 4.7: What is your role within the organisation?

Optional Question: Does your organisation have any additional comments/questions/ideas to share related to this questionnaire?

Thanks for completing the questionnaire!

Appendix 4: Additional information

Future land use

This section presents the information we collected on projected land use change in the short-term (3–5 years) and longer-term (7–10 years) future, for the whole sample, and disaggregated by organisation type. Table A4.1 demonstrates that neither the mean nor median values for percentage of land allocated to various uses are predicted to change by more than 2%, in either the short- or longer-term future. Similarly, neither the mean nor median values for percentage of land allocated to various uses are predicted to change by more than 3% for any organisation type (Tables A4.2-A4.4).

Table A4.1: Full sample – percentage of land allocated to each land use currently, and in the short- and longer-term future

	Current					Short-term future (3–5 years)					Longer-term future (7–10 years)				
	Mean	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**
Nature conservation	**24%**	18%	23%	0%	66%	**23%**	18%	22%	0%	66%	**23%**	16%	22%	0%	66%
Sports and recreation	**48%**	41%	27%	0%	100%	**48%**	41%	27%	0%	100%	**49%**	41%	28%	0%	100%
Agriculture and horticulture	**2%**	0%	6%	0%	20%	**2%**	0%	6%	0%	20%	**2%**	0%	6%	0%	20%
Industry and commerce	**3%**	0%	13%	0%	57%	**4%**	0%	14%	0%	63%	**4%**	0%	15%	0%	68%
Other uses	**23%**	10%	29%	0%	100%	**23%**	10%	29%	0%	100%	**23%**	10%	29%	0%	100%

Table A4.2: Local government – percentage of land allocated to each land use currently, and in the short- and longer-term future

	Current					**Short-term future (3–5 years)**					**Longer-term future (7–10 years)**				
	Mean	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**
Nature conservation	**42%**	60%	29%	0%	63%	**42%**	60%	29%	0%	63%	**40%**	60%	30%	0%	63%
Sports and recreation	**55%**	37%	31%	26%	100%	**55%**	37%	31%	26%	100%	**57%**	37%	33%	26%	100%
Agriculture and horticulture	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%
Industry and commerce	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%
Other uses	**3%**	0%	6%	0%	14%	**3%**	0%	6%	0%	14%	**3%**	0%	6%	0%	14%

Table A4.3: Schools/educational facilities – percentage of land allocated to each land use currently, and in the short- and longer-term future

	Current					**Short-term future (3–5 years)**					**Longer-term future (7–10 years)**				
	Mean	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**
Nature conservation	**9%**	5%	10%	0%	23%	**9%**	5%	10%	0%	23%	**10%**	5%	11%	0%	25%
Sports and recreation	**45%**	47%	14%	25%	60%	**45%**	47%	14%	25%	60%	**46%**	50%	14%	25%	60%
Agriculture and horticulture	**4%**	1%	7%	0%	18%	**4%**	1%	7%	0%	18%	**4%**	1%	7%	0%	18%
Industry and commerce	**2%**	0%	4%	0%	10%	**2%**	0%	4%	0%	10%	**2%**	0%	4%	0%	10%
Other uses	**40%**	35%	18%	15%	67%	**40%**	35%	18%	15%	67%	**40%**	35%	18%	15%	67%

Table A4.4: Golf courses – percentage of land allocated to each land use currently, and in the short- and longer-term future

	Current					Short-term future (3–5 years)					Longer-term future (7–10 years)				
	Mean	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**
Nature conservation	**20%**	20%	6%	15%	25%	**20%**	20%	6%	15%	25%	**20%**	20%	6%	15%	25%
Sports and recreation	**79%**	78%	5%	75%	85%	**79%**	78%	5%	75%	85%	**79%**	78%	5%	75%	85%
Agriculture and horticulture	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%
Industry and commerce	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%	**0%**	0%	0%	0%	0%
Other uses	**1%**	0%	2%	0%	5%	**1%**	0%	2%	0%	5%	**1%**	0%	2%	0%	5%

Additional analyses

Table A4.5: Number of bores – summary statistics

	Number of bores
Mean	11
Median	5
Standard deviation	14
Minimum	1
Maximum	45
n	20

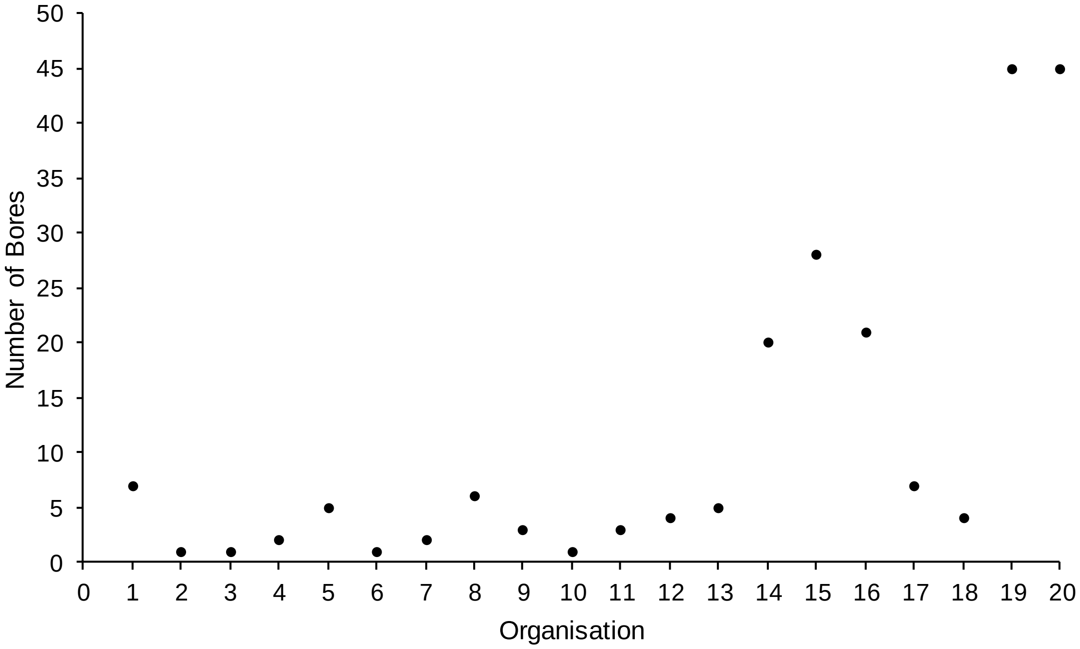

Figure A4.1: Number of bores – scatter plot

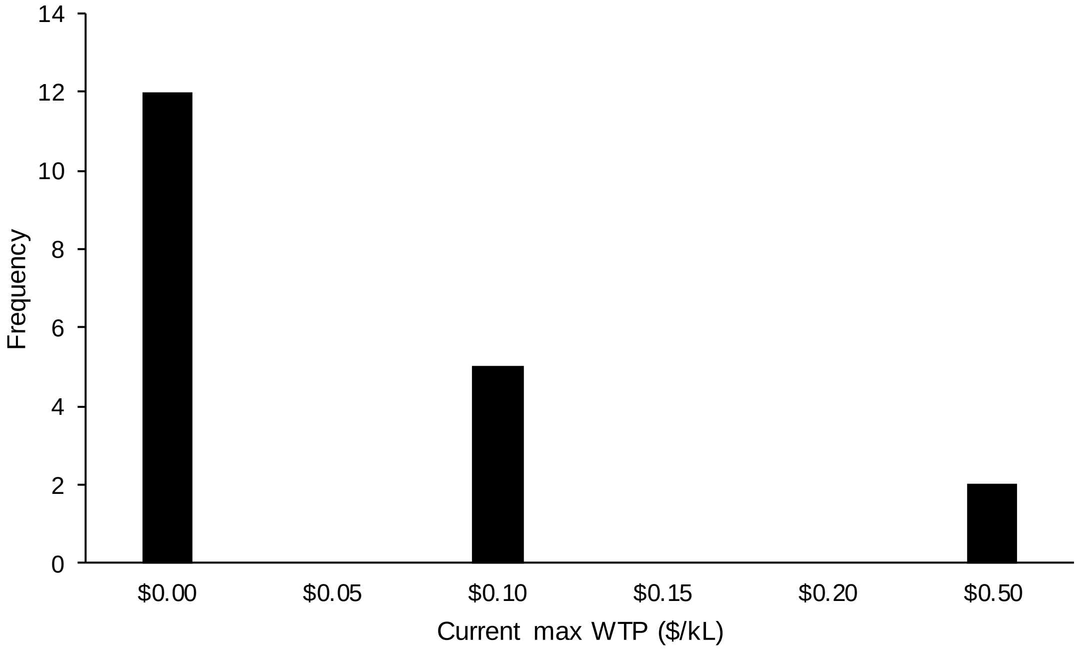

Figure A4.2: Current per kL willingness-to-pay for recycled water – frequency plot

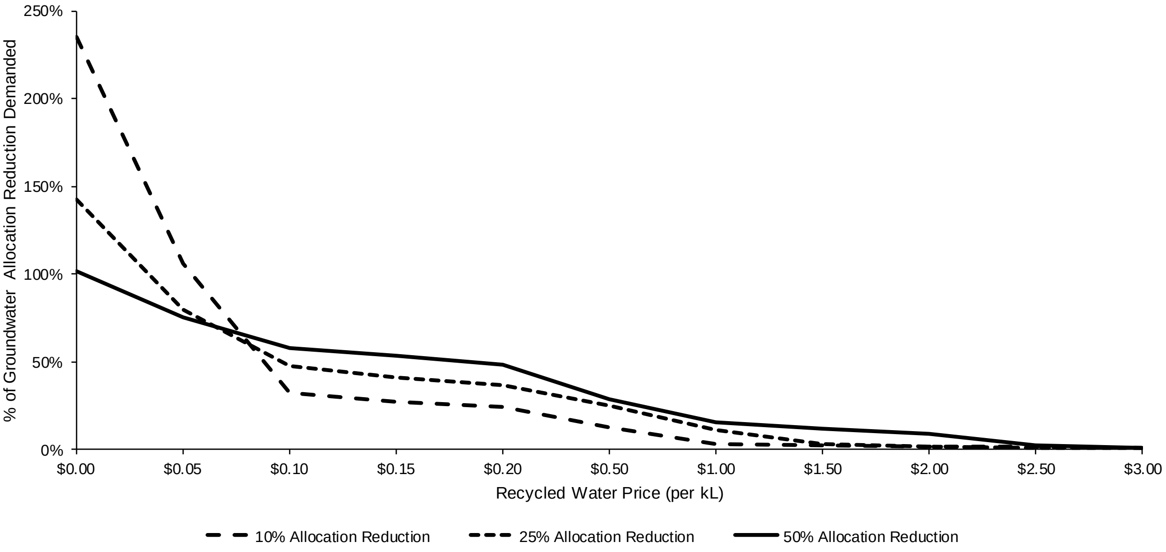

Figure A4.3: Overall demand curve – % of allocation reduction under 10%, 25% and 50% allocation reduction scenarios (n=16)

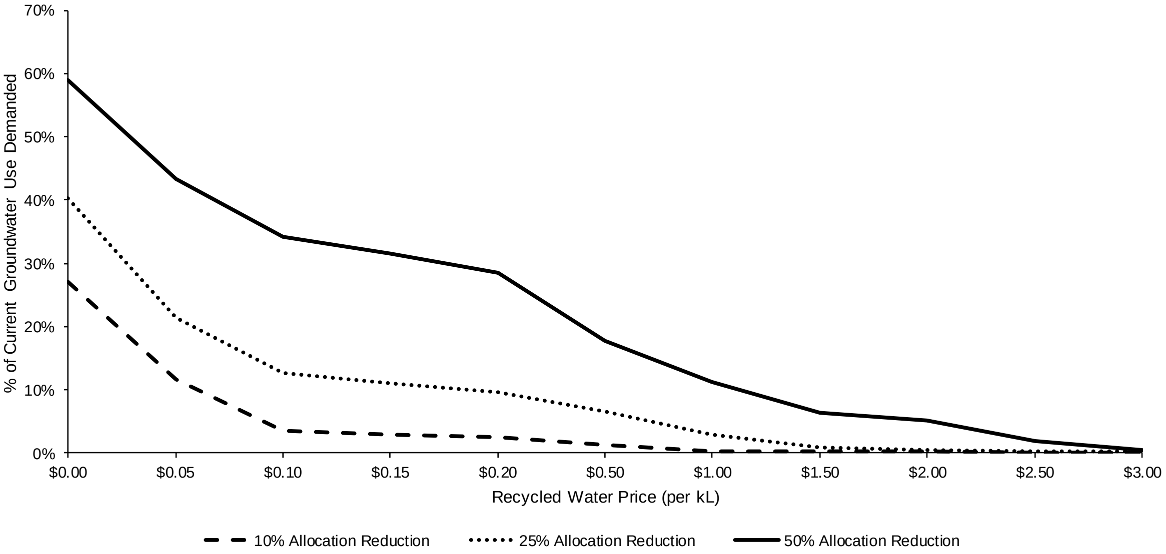

Figure A4.4: Overall demand curve – % of current consumption under 10%, 25% and 50% allocation reduction scenarios

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