WATER SERVICES
ASSOCIATION OF AUSTRALIA

ALL OPTIONS ON THE TABLE

URBAN WATER SUPPLY OPTIONS FOR AUSTRALIA

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Urban water supply options for Australia

August 2020

Water Services Association of Australia (WSAA) is the peak industry body representing the urban water industry. Our members provide water and sewerage services to over 24 million customers in Australia and New Zealand and many of Australia's largest industrial and commercial enterprises.

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More information

Please contact info@wsaa.asn.au

Foreword

Adam Lovell

EXECUTIVE DIRECTOR
WSAA

Droughts and floods are a fundamental feature of Australia's history and provide a backdrop to any discussion on future water security and water supply options. While this report seeks to increase understanding around the attributes of different supply options it also aims to initiate an ongoing conversation. Our intent is that it will be a living document, to be updated as more information and data from existing and new projects becomes available.

While 2019 and 2020 will be recorded in history for the COVID-19 pandemic, they will also be remembered for record drought across large parts of Australia and record bushfires followed in some areas by record rainfall and floods. In addition, there has been a record number of towns carting urban water supplies in from other sources, a record number of towns on Level 5 water restrictions and other towns in agricultural and mining centres relying on water for business and employment.

One thing that has been clear among these records: arguments at political levels on water security solutions remain heavily polarised and local communities suffer from lack of information and the opportunity to have their say.

This report aims to inform water security discussions with the community and stakeholders and to increase understanding around the attributes and costs of different water supply options. Existing information about Australian water supply options is limited, often out-dated, and not easily accessible. This report has collated and updated the latest available data from existing and newly planned projects and outlines contemporary and consistent information on each option.

No water supply option on its own is likely to meet all the needs of a city or regional town: the reality is that combinations of options need to be considered.

Droughts and floods are a fundamental feature of Australia's history. However, what separates the Australian situation from many international comparisons is the severity of climate change. Together with rapid population growth, planning for long term water security is more critical than ever. Robust and sustainable water industry planning means having all options on the table for consideration by local communities.

The report, compiled through the generous data provision of water utilities across the country and interrogated and analysed by Marsden Jacob, is intended for use by water utilities, stakeholders, governments and communities to better understand the features of different water supply options. Each option includes case studies to showcase local application/use of that option. While it provides the largest data set so far collated of real water supply options and projects it does not substitute for analysis by individual utilities and communities in their own local context.

Executive summary

The Australian urban water industry needs to continue moving towards a diversified portfolio of water supply options to meet the water security needs for Australia's rapidly growing cities and regional centres in the face of climate change and drought.

Australia's climate continues to get hotter and drier - heat increases demand for water and the drying climate reduces the water we have available. Most of Australia's urban water supply is dependent on surface water including dams and other rainfall dependent options. In total across Australia 82 per cent of urban water is sourced from surface water.

While dams remain an option in some areas, we can no longer rely on dams alone to deliver water security in major metropolitan areas because:

- There are very few suitable sites
- Future yields are uncertain due to climate change
- Waterway health is increasingly in focus
- Community expectations are changing.

In response, we need to optimise the use and investment in a diverse portfolio of water supply sources. Optimising the use of multiple rainfall dependent and independent sources increases our ability to balance resilience, security, cost and other network constraints, while also meeting the diverse and evolving expectations of our customers and communities. Balancing supply and demand efficiently requires us to consider a diverse range of water supply sources.

At present, in some Australian states and territories not all options for water supply are on the table for planning decisions. This could inhibit effective selection of the lowest long-term cost and most resilient resourcing options.

We call on governments to allow all options for water supply to be on the table for planning decisions. Every urban community has its own context, but all options for water supply should be on the table for those communities to consider and support.

Irrespective of the source of water, Australian water utilities provide their communities with high quality water that meets the requirements of the Australian Drinking Water Guidelines.

Each Australian city and community should consider all options on the table within their local context. By understanding all of the options available, we can be more resilient to respond to change and implement water supply options to provide water security to Australian cities and regions.

The views of customers and communities are vital to shaping water supply decisions. We support water utilities and governments engaging openly and transparently to understand customer and community values and expectations, and to enable customers and community to be informed and make choices. Each option displays a different set of characteristics which can make it valuable to achieve water security and other community outcomes.

The Productivity Commission noted in 2020 that removing inefficient policy bans and mandates related to recycled water and stormwater would enable urban water utilities to consider opportunities that respond to local circumstances and achieve better or lower cost outcomes.

The Infrastructure Australia 2019 Audit found **"Ensuring all options are on the table, and can be deployed when required, is likely to be essential for governments and operators to effectively and efficiently ensure secure supply over the long term."**

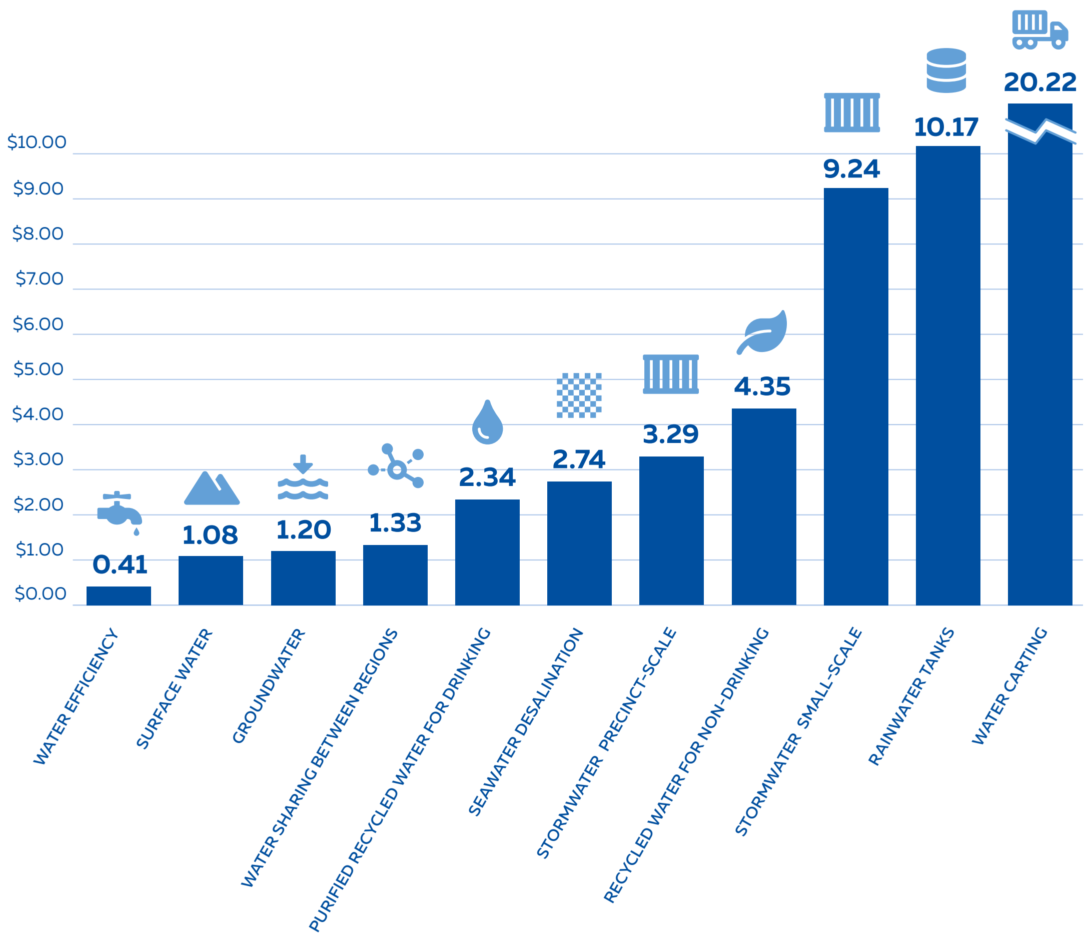
Our report examines the broad role each option can play in the water supply mix including the indicative costs of each option, noting that most options are more expensive than the dams built many years ago and paid for by previous generations.

Our analysis found:

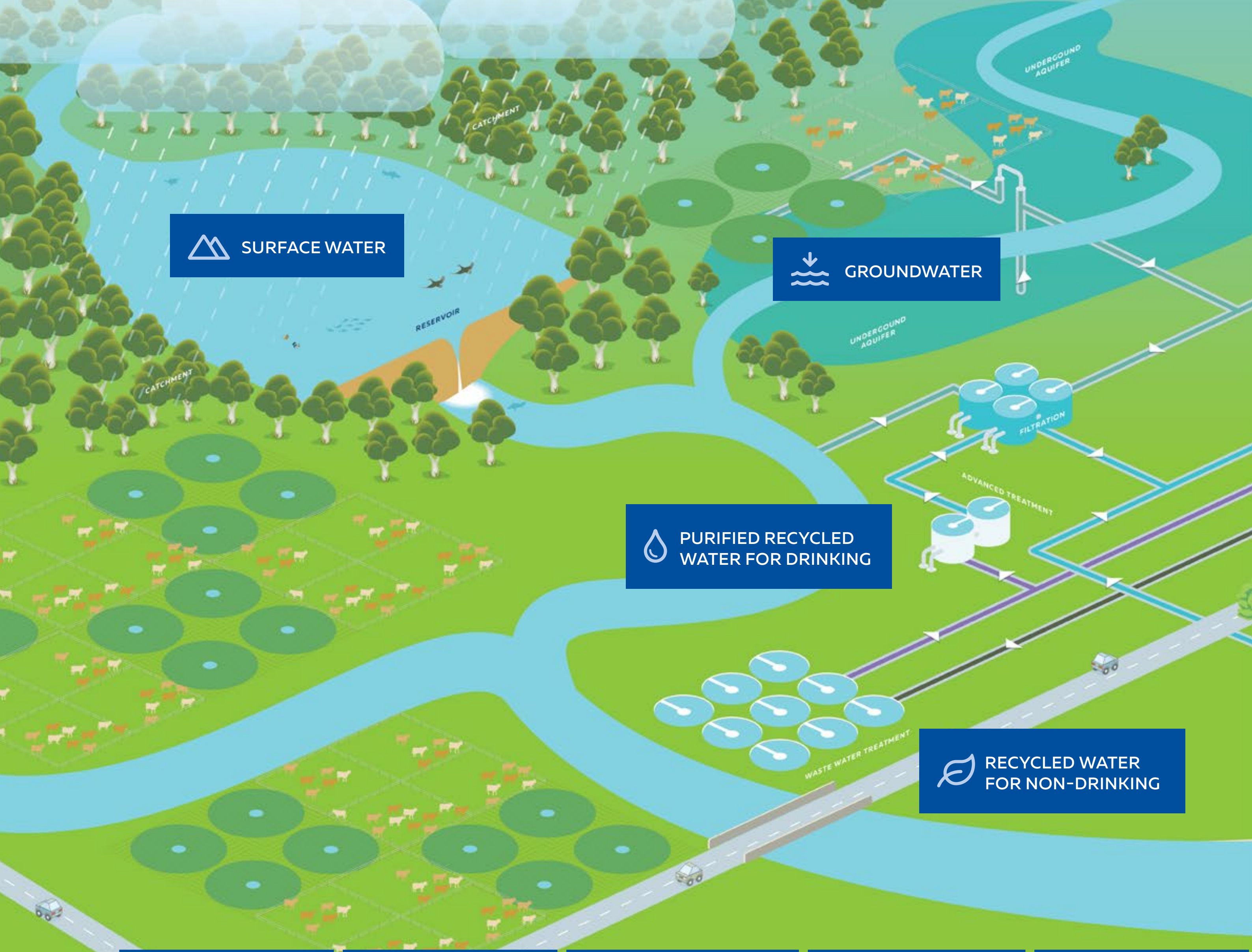
- The cost of water from purified recycled water for drinking is comparable to water from seawater desalination.
- The cost of recycled water for non-drinking is relatively high, because while this option includes lower cost projects that use recycled water for agriculture and industrial processes, it also includes higher cost projects including where pipework is duplicated to provide recycled water to households.
- Decision-makers should also consider wider considerations including environmental and social impacts or benefits, avoided or delayed infrastructure costs, and broader liveability benefits, as these are not included in our cost estimates.

At present, in some Australian states and territories not all options for water supply are on the table for planning decisions. This could inhibit effective selection of the lowest long-term cost and most resilient resourcing options.

FIGURE 1 Costs of water supply options included in WSAA study LEVELISED $/KL 2019-20



Urban water cycle



Groundwater

Can offer a relatively low-cost, reliable supply of water, even in times of drought. Involves wells to extract the water from groundwater aquifers and associated infrastructure to treat and transport the water.

Rainwater tanks

A water tank used to collect and store rain water runoff from a household rooftop via pipes, used for non-drinking water purposes. Can provide multiple benefits, eg. reduced demand on drinking water and liveability benefits.

Purified recycled water for drinking

Sourced from waste-water and stormwater treated to meet the Australian Drinking Water Guidelines through multiple levels of treatment and disinfection for drinking water use. A cost- and energy-effective option used by over 35 cities worldwide, eg. Perth.

Recycled water for non-drinking

Sourced from waste-water and treated to provide water for non-drinking purposes including irrigation, industrial and household uses. Reduces demand on drinking water systems, avoids discharge of wastewater to the environment.

Seawater desalination

Seawater treated to remove salts to create water suitable for drinking. Provides a cost-effective rainfall-independent source of water, while energy intensive many desalination plants are powered by renewable energy.

Stormwater harvesting and reuse

Collecting, storing and treating stormwater from urban areas for reuse for non-drinking purposes. Schemes provide multiple benefits to communities, including improving liveability and health benefits through the provision of green and blue infrastructure.

Surface water

Water is collected from rivers, dams and weirs and then treated and transported for drinking water. Is an important part of our existing water supply portfolio. Dams and reservoirs store water for future use, however are reliant on rainfall and are less resilient to climate change.

Water carting

Transporting small volumes of water (generally by truck) either within a catchment or between catchments. Is generally a high cost last resort option for water supply to communities, but can be viable for small remote communities.

Water sharing between regions

Pipelines connecting two or more major water sources to transport water from one catchment to another. Allows water supply in a region to be optimised by moving water between catchments by moving water between catchments and to communities with less water.

Water efficiency

Projects to reduce water use, including the supply of water efficient appliances, leak repairs, and behaviour change. While not a source of water, using water wisely will always be part of the water security equation in Australia.

Moving towards a diversified portfolio of options

Since the Millennium Drought, the urban water industry has worked to secure climate resilient sources of water through both supply side (e.g. desalination, recycled water) and demand side (e.g. leakage reduction, water efficiency, behavioural change) interventions. As the climate continues to shift and population grows and changes, the urban water industry must continue to ensure we can support and enhance our communities and the environment.

Balancing supply and demand efficiently requires us to consider a diverse range of water supply sources, including traditional drinking water sources as well as new or alternative sources such as recycled water and stormwater reuse.

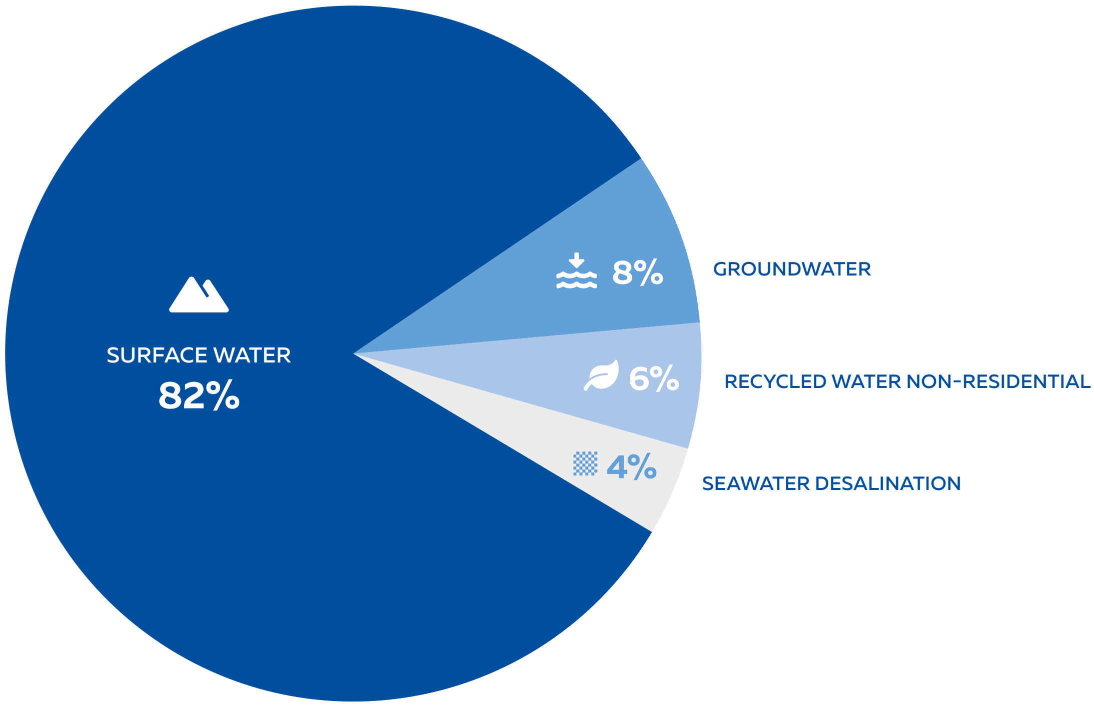
Diversifying water supply is driven by:

- Water supply resilience and security in the face of climate change, population growth and drought
- Customer expectations and acceptance
- Technological improvements
- Environmental protection, waterway health and ecosystem decline
- Transitioning to the circular economy.

At present, in some Australian states not all options for water supply are on the table for planning decisions. This could inhibit effective selection of the lowest long-term cost and most resilient resourcing options. While most of our major cities have turned to seawater desalination plants as a reliable and climate resilient source of water, it is not always the lowest cost or most efficient water supply option.

Options which are constrained, and in some cases may be subject to implicit policy bans, include purified recycled water for drinking, stormwater harvesting and water sharing (particularly rural and urban trade).

FIGURE 2 Existing sources of urban water in Australia 2018-19 (BOM, 2020)



In Australia the primary limitations are not technical, but rather around public perception and political will. In practice it makes sense to have a portfolio of options available, which includes both supply and demand side opportunities, to ensure water resilience for cities and regions. In the case of purified recycled water for drinking, experience globally and in Western Australia, has shown that any potential community concerns can be addressed through effective education and engagement.

As recently as 2004, all Australian capital city water utilities relied on surface water or groundwater for drinking water supplies. In recent years the urban water industry has invested to increase rainfall-independent water supply options. However, in 2018-19, surface water sources provided 82 per cent of water supplied to Australia's urban cities and communities (Figure 2).

Changes to streamflows

Australian water supplies are facing decreased streamflows into rivers and dams, our reliance on these rainfall dependent water supply options is a risk to the water security of our cities and communities.

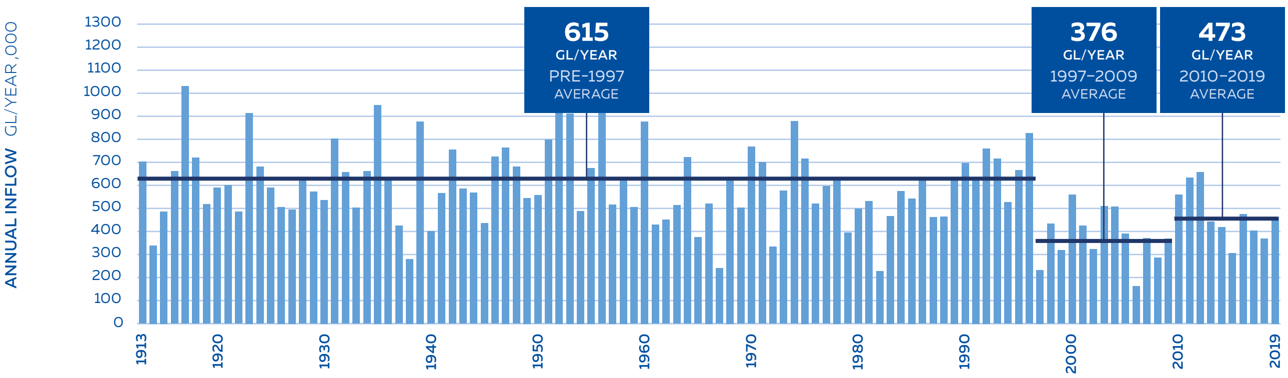
Climate change, variability and drought is having a profound impact on our water supply. Australia is experiencing some of the driest conditions on record, with declines in rainfall since 1999 of up to 11 per cent in southeast Australia and up to 26 per cent in southwest Australia (BOM and CSIRO, 2018).

The observed long-term reduction in rainfall across southern Australia has led to even greater reductions in streamflows, and inflows into rivers and dams. For example, before 1975, Perth's dams would receive an average of 420 billion litres of streamflow each year, enough to supply the city even now. In comparison, during 2019 Perth's dams received just 44 billion litres of streamflow. Declines in streamflow have also been observed in four drainage divisions in southern Australia: the Murray-Darling Basin, South East Coast (Victoria) and South East Coast (New South Wales) (which include Sydney and Melbourne), and the South Australian Gulf (which includes Adelaide). In each of these drainage divisions between two thirds and three quarters of streamflow records show a declining trend since the 1970s (BOM and CSIRO, 2018).

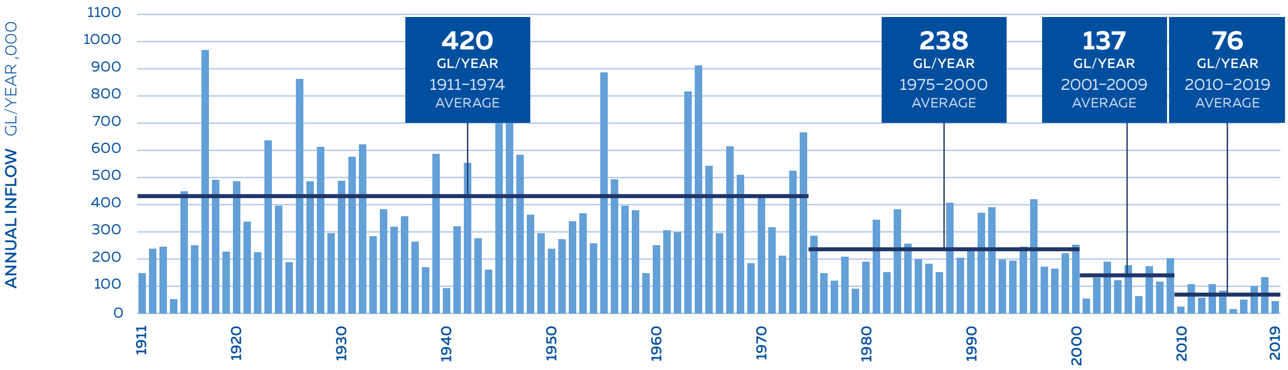
Streamflow has increased in northern Australia, since the 1970s, in places where rainfall has increased (BOM and CSIRO, 2018).

FIGURE 3 Declining streamflows over time GL/YEAR = BILLION LITRES PER YEAR

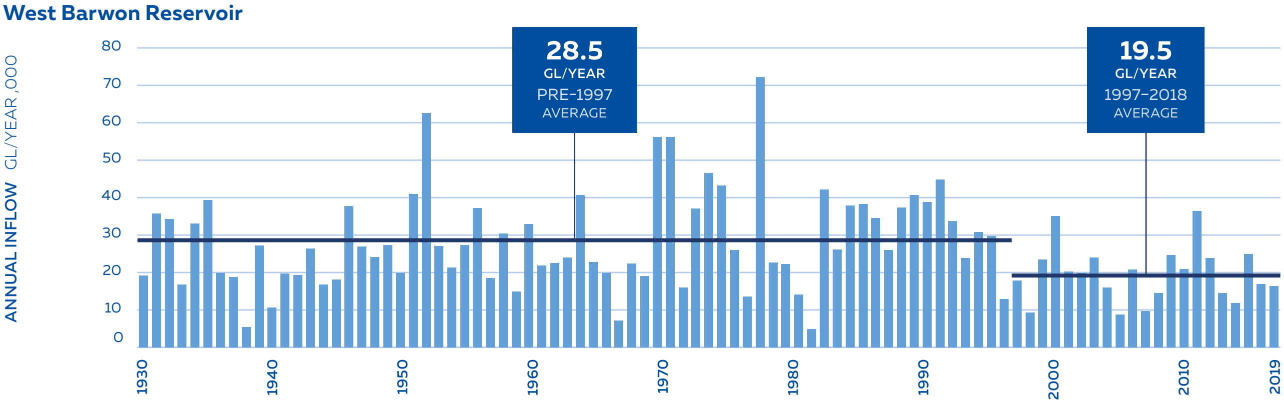
Melbourne MAIN WATER STORAGES



Perth



West Barwon Reservoir



Sources Melbourne Water data; Water Corporation data; Barwon Water data.

CASE STUDY 1 WATER CORPORATION

Perth water supplies

In Perth, streamflows have decreased dramatically due to lower winter rainfall and hotter summers. Since the 1970s May to July rainfall in the south west of Western Australia has reduced by around 20 per cent (BOM and CSIRO, 2018). The amount of streamflows to Perth dams generated from each millimetre of rainfall continues to decline (Water Corporation, 2020a).

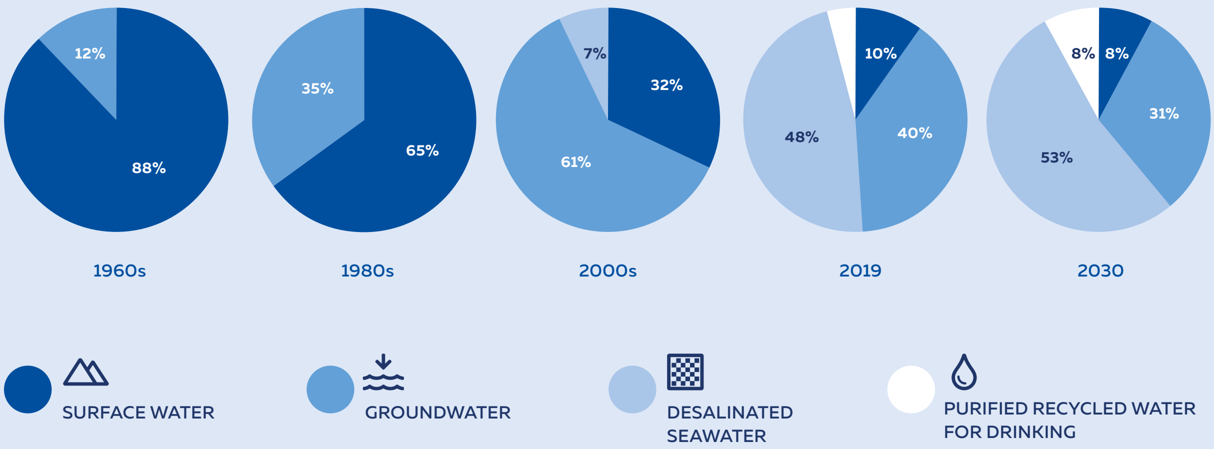
Given this, Water Corporation is responding and adapting to climate change to secure water supplies for Perth, by continually working towards the long-term targets outlined in Water Forever, first published in 2009.

The plan adopts a three-pronged approach, which includes:

- Working with the community to reduce water use to help defer the need for investment in further new climate independent sources
- Developing new water sources
- Increasing the amount of water recycled.

Perth's water supply portfolio has shifted to rainfall independent sources over several decades (Figure 5) and is now comprised of a combination of diverse sources, including seawater desalination, purified recycled water for drinking (groundwater augmentation), groundwater and dams (Water Corporation, 2020b).

FIGURE 4 Water supply sources in Perth 1960s – 2030s (Water Corporation, 2020b)



Rainfall independence for water security

The Australian water industry needs to continue moving towards a diversified portfolio of water supply options to secure water supplies for our rapidly growing cities and regional centres in the face of climate change and drought.

Australia's weather and climate continues to change in response to a warming global climate. Australia is projected to experience increases in sea and air temperatures, with more hot days and fewer cool extremes.

Increased temperatures are exacerbated by the large amounts of paved surfaces in urban environments resulting in the urban heat island effect. Providing water and land for green infrastructure, including parks and open space, supports cool, healthy environments reducing heat in the urban landscape, providing resilience to chronic and acute heat events and improving air quality.

To optimise the use and investment in a diverse portfolio of water supply sources, we need multiple-rainfall dependent and independent sources to balance security, cost and other network constraints, while meeting customers' and communities' diverse and evolving expectations for water, wastewater and stormwater services. Balancing supply and demand efficiently requires us to consider a diverse range of water supply sources.

We have developed the rainfall independence spectrum to show in general terms the dependence of urban water supply options on rainfall, where an option either:

- Directly relies on rainfall
- Indirectly relies on rainfall
- Does not rely on rainfall.

We consider that rainwater tanks, stormwater reuse and surface water options directly rely on rainfall, and that seawater desalination does not rely on rainfall. However, in many cases, the level of dependence of a water supply on rainfall is context specific.

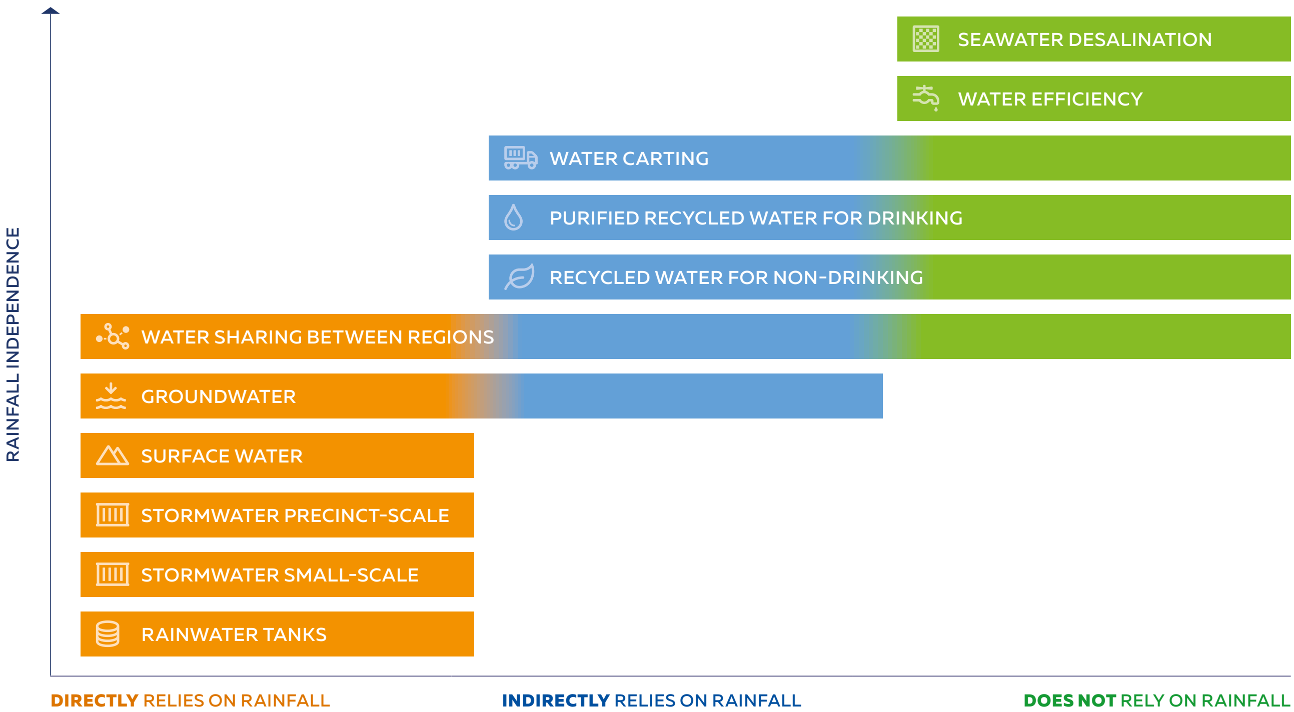
Some groundwater aquifers are connected to surface water supplies and are recharged with rainfall events ('directly relies on rainfall'), other deeper groundwater sources are not connected to surface water and there is a much longer period between rainfall events and water recharging the aquifer ('indirectly relies on rainfall').

In a community where drinking water is sourced primarily from surface water the recycled water is indirectly reliant on rainfall, however where drinking water is sourced primarily from seawater desalination the recycled water does not rely on rainfall.

In water sharing between regions, the source of water shared could be surface water (directly relies on rainfall), groundwater (either directly or indirectly relies on rainfall), recycled water (either indirectly or not reliant on rainfall) or desalinated water (does not rely on rainfall).

Water carting can transport different sources of water, and as there is flexibility in the direction and distance traveled, is considered either indirectly reliant on rainfall or not reliant on rainfall.

FIGURE 5 Rainfall independence spectrum



Understanding all the options on the table

WSAA is working to improve the data available to water utilities, customers and stakeholders on long-term urban water supply options in Australia. This report supports WSAA's initiative by providing a comprehensive, directly comparable, and contemporary levelised cost dataset for long-term water supply options in Australia and is designed to stimulate discussion about the relative cost-effectiveness of supply options.

This report also compares the wider considerations of different water supply options, including their rainfall independence, energy use, as well as social and environmental impacts and benefits.

For this project, WSAA and Marsden Jacob Associates compiled a dataset of approximately 330 water supply projects from across Australia.

The majority of the projects are implementable or currently considered options, ranging from operational projects to those that are in design or options development and assessment phases. While comprehensive the projects do not necessarily represent all existing water supply projects or options.

While not a source of water, using water wisely (including water efficiency measures, demand management and leakage management) will always be part of the water security equation in Australia and we have considered water efficiency projects as an option in this report.

WATER SUPPLY OPTIONS CONSIDERED ARE:

- Groundwater
- Rainwater tanks
- Purified recycled water for drinking
- Recycled water for non-drinking
- Seawater desalination
- Stormwater harvesting and reuse
- Surface water
- Water carting
- Water sharing between regions
- Water efficiency

What are the advantages of different water supply options?

Different water supply options have different benefits, and these will differ depending on the city or community and how the project interacts with the surrounding environment.

In addition to supplying water to cities and communities, benefits may include:

- Improving the resilience of the water supply portfolio by reducing dependence on rainfall
- Avoiding infrastructure costs
- Preserving or improving liveability, including supporting water-enabled green and blue infrastructure
- Preserving or improving waterways and biodiversity
- Avoiding flood damage
- Avoiding urban heat impacts
- Avoiding greenhouse gas emissions
- Contributing to sustainable use of resources and the circular economy
- Technological advancement.

For example, several recycled water projects in our dataset include indirect benefits of avoiding large scale infrastructure upgrades. In making a decision about going ahead with a recycled water option, including avoided costs particularly for wastewater infrastructure, made the recycling projects viable options compared with other options including seawater desalination, despite having marginally higher financial levelised costs.

Several precinct-scale stormwater harvesting and reuse projects are viable based on the benefits to downstream waterways by reducing nitrogen releases through stormwater treatment. These projects also deliver benefits by avoiding drinking water augmentations by reusing the harvested water for irrigation.

Water efficiency projects provide an effective way to reduce the demand of water and combined with reducing leakage, can delay the requirement for new water supply options. In many metropolitan areas, water efficiency projects over the last 15 years has resulted in substantial reduction in per person water use. We must continue to consider water efficiency options in our water supply planning, however we are unlikely to meet the significant water supply challenges by implementing water efficiency alone.

More detail on the wider considerations for each water supply option, including advantages of each option, is included in the water supply option summaries from page 20 onwards.

What are the costs of different water supply options?

This report examines the broad role each option can play in the water supply mix including the indicative costs of each option, noting that most options are more expensive than the dams built many years ago and paid for by previous generations.

Median levelised costs estimated for each water supply option in our dataset ranges from $0.40 per kilolitre for water efficiency projects to $20 per kilolitre for water carting (Figure 6 Costs of water supply options included in WSAA study $/kL 2019-20). Aside from small-scale stormwater, rainwater tanks and water carting, median levelised costs for other water supply options are below $5 per kilolitre.

Surface water remain the lowest cost options and dams are an important part of our water supply portfolio. However, these options are high risk investments as they rely on rainfall and are less resilient to climate change than other options.

Our analysis found the cost of water from purified recycled water for drinking is comparable to water from seawater desalination. Community support can be a particular challenge for purified recycled water, however by engaging openly and transparently with communities this can be overcome. For more information about how to approach this conversation, see WSAA's recent All options on the table: lessons from the journey of others report (WSAA, 2019). The cost of recycled water for non-drinking is relatively high, because while this option includes lower cost projects that use recycled water for agriculture and industrial processes, it also includes higher cost projects including where pipework is duplicated to provide recycled water to households.

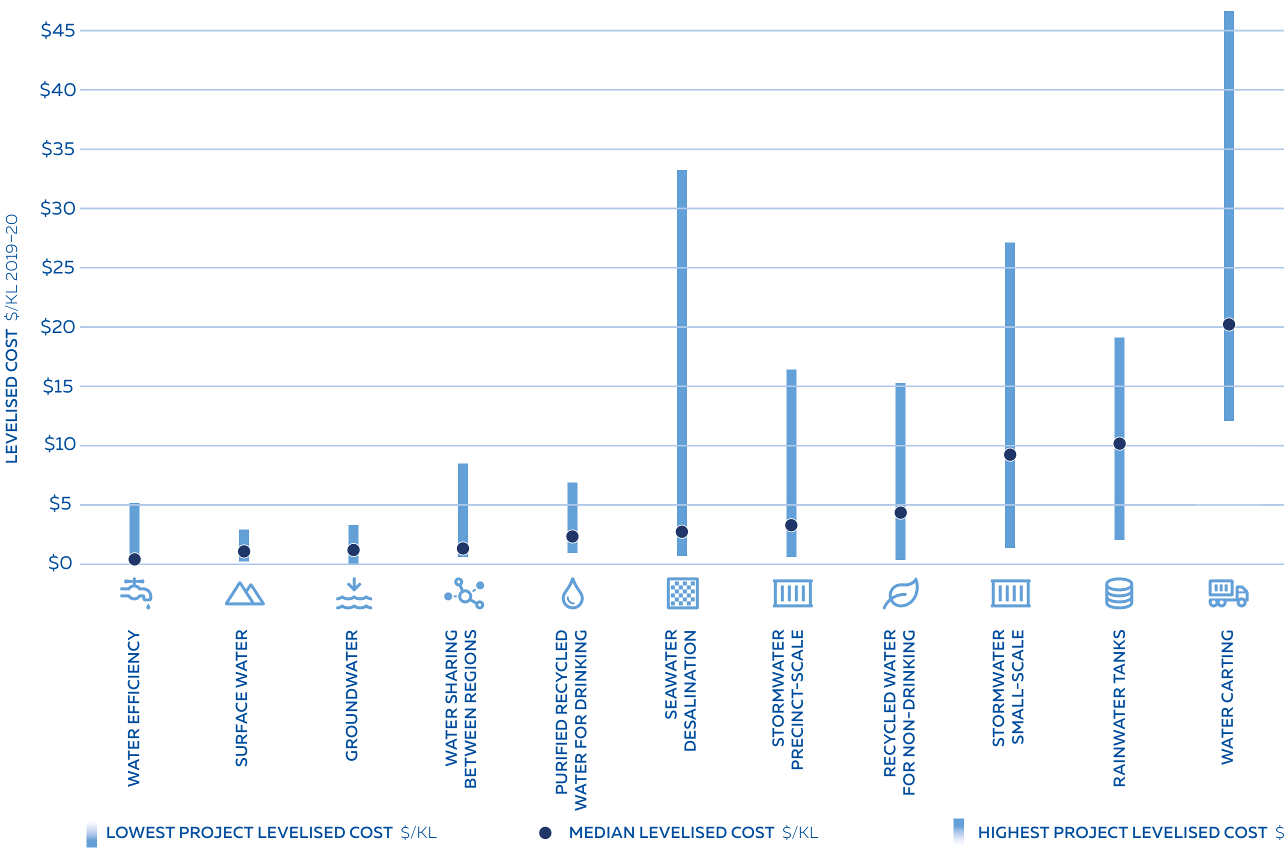
Recycled water for non-drinking and stormwater options had high costs compared to other options. These decentralised approaches to providing water supply can offer social, environmental and liveability benefits at a local level, and these are becoming increasingly important to customers and the wider community.

However, as identified by the Productivity Commission in 2018 it can be difficult to measure and value some of the benefits beyond water supply and therefore can be difficult to justify based on typical business cases. These options are more likely to be realised with the inclusion of robust willingness to pay studies, and/or a framework to encourage co-funding from other sectors such as health or local government.

Several projects included in the dataset are emergency responses to drought, including some of the seawater desalination projects (high cost and low yield) and the water carting options. These options provide emergency water supply to communities during drought, and indicate the importance of diverse and climate resilient sources.

Managing energy use and greenhouse gas emissions is an ongoing challenge for the water industry. Energy use contributes costs to water supply projects and is an important consideration when evaluating options. More information on energy use for water supply options is available at Energy use and greenhouse gas emissions, page 17.

FIGURE 6 Costs of water supply options included in WSAA study $/KL 2019-20



How much water do these options supply?

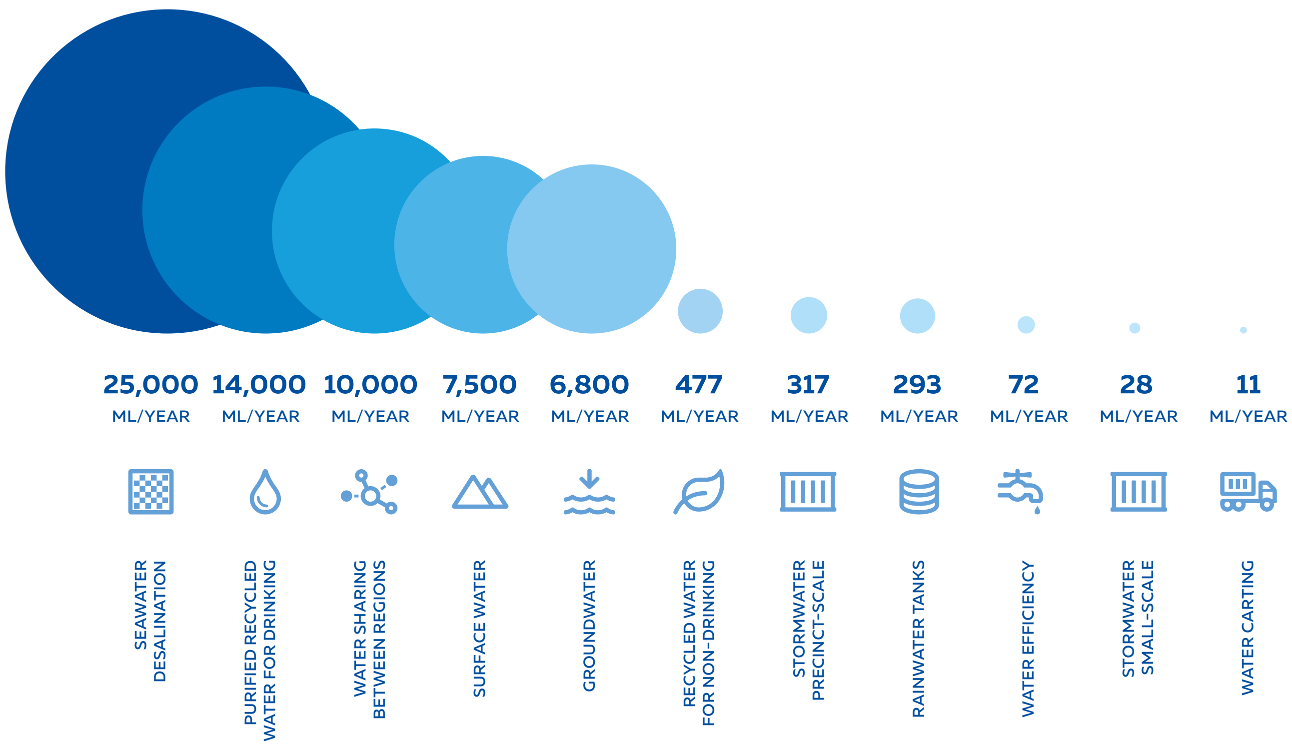
There is a significant range in yields across the water supply options included in the dataset. Median annual yields range from 30 megalitres for small-scale stormwater projects, to 25,000 megalitres for seawater desalination projects.

The highest yields are from large scale centralised options including seawater desalination, purified recycled water for drinking, water sharing between regions, surface water, and groundwater. While decentralised options including recycled water for non-drinking, stormwater reuse and rainwater tanks had low annual yields, these projects have the ability to contribute to the urban water supply portfolio. Decentralised options contribute to water supply resilience and water security particularly during periods of high demand (eg, hot, dry summer days) and can defer or delay the need to invest in large decentralised water supply options.

Aside from water efficiency projects, our analysis shows levelised costs tend to remain below $4 per kilolitre for supply options with higher median yields. Levelised costs tend to increase for water supply options with yields below 600 megalitres per annum, potentially suggesting economies of scale above the 600 megalitres per annum supply range.

Water supply options contribute to water security whether they yield drinking or non-drinking water. Options in the study that yield drinking water include: drinking water quality water, including groundwater, purified recycled water for drinking, seawater desalination, surface water, water carting and water sharing between regions. Other options yield water for non-drinking purposes, including rainwater tanks, recycled water for non-drinking and stormwater harvesting and reuse.

FIGURE 7 Median yield of water supply options included in WSAA study ML/YEAR = MILLION LITRES PER YEAR



Yield is the average annual demand for water that can be sustainably managed over the long term. Yield is not static. It changes over time as inflows, infrastructure, demographics, the system design criteria and the operating rules for the system change.

How should we use the information in this report?

This report provides a comprehensive, directly comparable, and contemporary levelised cost dataset for long-term water supply options as well as a discussion of wider considerations, including benefits and impacts of water supply options for use in options development.

In developing water supply options, cities and communities should consider all of the options available – 'all options on the table' – and measure them against the same criteria including costs, contribution to water security, energy use and greenhouse gas emissions and local constraints.

The evidence base in this report should not be used as direct input in water supply option business case assessments. A business case assessment of water supply options requires detailed assessment of location-specific factors not reflected in the levelised costs. These factors include climate variability, demand, local-specific economic, social and environmental costs and benefits, and the level of community acceptance.

FIGURE 8 How to use the information in this report

✓ Options development	✗ Decision making
Levelised costs Comparative costs	Project specific costs
Contribution to water security	Project specific benefits
Energy use and greenhouse gas emissions Local constraints	Community acceptance

For this study, we have measured levelised costs so that estimates are directly comparable. The levelised costs in this report have been developed by considering the total direct life cycle cost to deliver the proposed yield.

This means the levelised costs for a surface water option includes the capital costs to construct the dam or weir, any additional water treatment infrastructure, and any additional network infrastructure to deliver water to the community, as well the cost to operate the water supply option over its asset life.

Costs included in analysis	
Typically, the bulk of costs is physical infrastructure	
Water, wastewater, drainage and waterway infrastructure	
O&M expenses	Capital expenditure
Direct costs – scheme specific	
Costs for lifecycle of project	

Costs not included in analysis
Indirect costs – broader system
External costs and benefits

In the case of seawater desalination options, the levelised cost includes capital and operating costs related to the desalination plant, and any pipelines or other infrastructure to connect to network infrastructure to deliver water to the community. For recycled water, levelised costs include the capital and operating costs for any additional water treatment infrastructure, and the infrastructure to deliver recycled water to customers.

However, only direct costs related to the water supply option are included. Indirect costs to the broader system are not included, nor are the external costs and benefits costed. As already discussed, in making decisions about water supply options, direct, indirect and external costs and benefits should be evaluated in a business case.

More information about the method we used to develop the dataset and determine the levelised costs is available at The dataset, page 61.

Why are we using levelised costs?

Levelised costs are a standard way to measure the costs that go into producing a kilolitre of water supply. Levelised cost provides a useful measure to easily compare water supply or conservation options of varying scales and timeframes, on an equivalent basis. It is a measure of lifecycle costs for a project, not just the upfront costs.

Energy use and greenhouse gas emissions

Managing energy use and greenhouse gas emissions is an ongoing challenge for the water industry. Energy use contributes costs to water supply projects and is an important consideration when considering and evaluating options. Water supply options should be designed to optimise both operational energy use and embodied energy. This will generally result in lower costs and a reduction in greenhouse gas emissions.

Energy use for water supply options

Energy use for water supply varies significantly across Australia, depending on local conditions including water use, topography, water sources and water treatment.

The intensity of energy consumption depends on the specific technologies and activities applied. High energy intensity technologies and activities include:

- Membrane technologies used in desalination and recycled water
- Filtration processes used in drinking and recycled water treatment
- Pumping for access to source water or to transport water.

High energy intensity represents an ongoing operational cost, and the source of energy also influences cost.

In many cases water utilities use renewable energy to power energy intensive water supply options such as seawater desalination. Some water utilities have invested in their own renewable energy supplies such as mini-hydro generating plants, gas-cogeneration and solar. Using renewable energy allows water utilities to reduce greenhouse gas emissions. Water utilities also use carbon offsets to offset the greenhouse gas emissions generated by their energy use.

In addition, generally water efficiency programs reduce the energy use, particularly those programs that include installing water efficient appliances on hot water taps and showers.

TABLE 1 Energy use for water supply options

WATER SUPPLY SOURCE	TYPICAL ENERGY USE (KWH/KL)	REFERENCE
Groundwater including water treatment	0.2 – 2.5	Beca Consultants (2015)
		Plappally and Lienhard (2012)
Rainwater tanks	0.59 – 4.9	ISF (2013)
		Tjandraatmadja et al (2012)
		Retamal et al (2009)
Purified recycled water for drinking	1.3 – 3.8	Lam et al (2017)
		ISF (2013)
Recycled water for non-drinking	0.5 – 8.0	ISF (2013)
Seawater desalination	3.3 – 8.5	Lam et al (2017)
		ISF (2013)
		Cook et al (2012)
		Plappally and Lienhard (2012)
Stormwater harvesting and reuse	Limited data available[1]	
Surface water including water treatment	0.1 – 1.0	Lam et al (2017)
		Biswas and Yek (2016)
		ISF (2013)
		Plappally and Lienhard (2012)
		WSAA data
Water carting	Limited data available[2]	
Water sharing between regions	0.01 – 3.3	Lam et al (2017)
		Plappally and Lienhard (2012)

1 Similar to recycled water for non-drinking options, stormwater harvesting and reuse options have variable energy use
2 Water carting energy use arises primarily from fuel use by the truck carting the water. The distance travelled influences the energy (fuel) use

Embodied energy in water supply options

Embodied energy is the amount of energy used to manufacture a material or product and is important to consider in a holistic analysis of energy consumption in urban water supply options.

The embodied energy impact of water supply options is influenced by (Kenway et al, 2008):

Amount of materials used

The more materials used the higher the embodied energy.

Type of materials used

Recycled materials generally have a lower overall embodied energy.

Durability of the materials and systems

More durable materials and systems have a longer life expectancy, less repair and replacement leads to lower embodied energy over the life of the system.

Maintenance of the materials and systems

Appropriate maintenance can extend the life of the system, reducing embodied energy over its life cycle.

Greenhouse gas emissions

Generation of energy from fossil fuels generates greenhouse gas emissions, and using energy from these sources to power water supply options contributes to greenhouse gas emissions and climate change.

Across Australia energy is generated from different sources and this makes providing detailed analysis of greenhouse gas emissions arising from different water sources difficult to estimate. For example, while most of Australia relies on non-renewable fossil fuels, with coal, gas and oil generating about 85 per cent of Australian electricity, electricity generation in Tasmania is dominated by hydroelectricity, which supplies around 80 per cent of the state's power (DEE, 2018), and the Australian Capital Territory uses 100% renewable electricity (ACT Government, 2019).

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Groundwater

Groundwater can offer a reliable supply of water, even in times of drought. Our analysis found groundwater is a relatively low-cost water supply option and environmental impacts can be managed, however not all communities have freshwater groundwater sources available to them.

PROJECTS CONSIDERED	19
ESTIMATED ASSET AGE RANGE (YEARS)	30 – 130
$/KILOLITRE	0.10 – 7.00
MEGALITRES/YEAR	800 – 17,500

What does this option include?

Groundwater projects involve wells to extract the water from groundwater aquifers and associated infrastructure to treat and transport the water. The projects included in the dataset all use freshwater groundwater sources.

Groundwater is water that is beneath the earth's surface and can be found in fractured rock or layers of sand and gravel called aquifers.

Aquifers provide natural underground reservoirs that can offer a reliable supply of water, even in times of drought. Water is pumped out of the ground through wells and treated for drinking water supply.

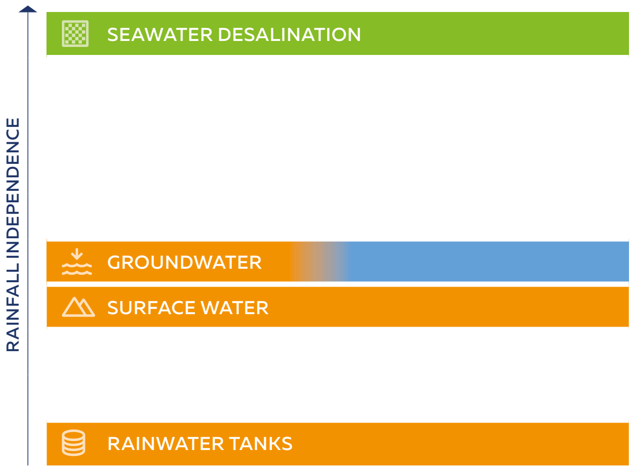
All naturally occurring freshwater groundwater originally came from rainfall, though this may have occurred a very long time ago.

In addition to freshwater groundwater, saline groundwater is a potential water source if the salt water can be reduced so that it is fit for purpose. Desalination of saline groundwater is an option similar to seawater desalination, where a process called reverse osmosis is commonly used and the saltwater is pushed through a membrane (a barrier with tiny holes) to remove the salt and mineral content.

What is the contribution to water security?

Shallow fresh groundwater resources are connected to surface waters and are both affected by drought and climate change. Deep groundwater reserves are more resilient to changes in rainfall and refilling of deep aquifers can take many years, however water quality tends to be lower, increasing the cost of treatment.

Groundwater aquifers are also at risk of being depleted due to over-withdrawal and salt water intrusion. Over-use may not be detected for several decades because of slow renewal and movement of the resource.



What are the wider considerations?

Aquifers can become underground reservoirs by pumping fresh water into it when surplus water is available. This process is known as aquifer storage and recovery.

When household bores are in place for non-drinking water in an urban water system (eg, in Perth, or the eastern suburbs of Sydney), groundwater reduces the peak demand and overall demand. Potentially delaying or deferring the need to implement higher capital cost water supply investments.

Groundwater resources are strongly connected to surface water supplies, and many of Australia's ecosystems, plants, and animals depend upon groundwater. Harvesting groundwater can have relatively low environmental impacts provided it is carefully managed.

The sustainable extraction limit of an aquifer is usually less than the rate of annual recharge, or renewal. Pumping aquifers causes groundwater levels to fall, which can affect ecosystems and river discharge, and increase salinity potentially making it unsuitable as a fresh water supply.

What is the energy use?

For operation and water treatment the energy use for freshwater groundwater options is 0.2 – 2.5 kWh/kL (Beca Consultants, 2015; Plappally and Lienhard, 2012).

Energy demand for groundwater options is from pumping and water treatment. The method of pumping depends on the source of the water and the distance to the community supplied with water.

Similar to surface water options, the amount of energy used in pumping water will depend on the topology of the area, the distance pumped and the source of the water. Groundwater options generally require more energy than surface water due to the need to lift water from its source.

Freshwater groundwater options require relatively lower energy use compared to other water supply options.

Desalination of groundwater (not included in this study) is a more costly option than using fresh groundwater, largely due to the energy required to desalination.

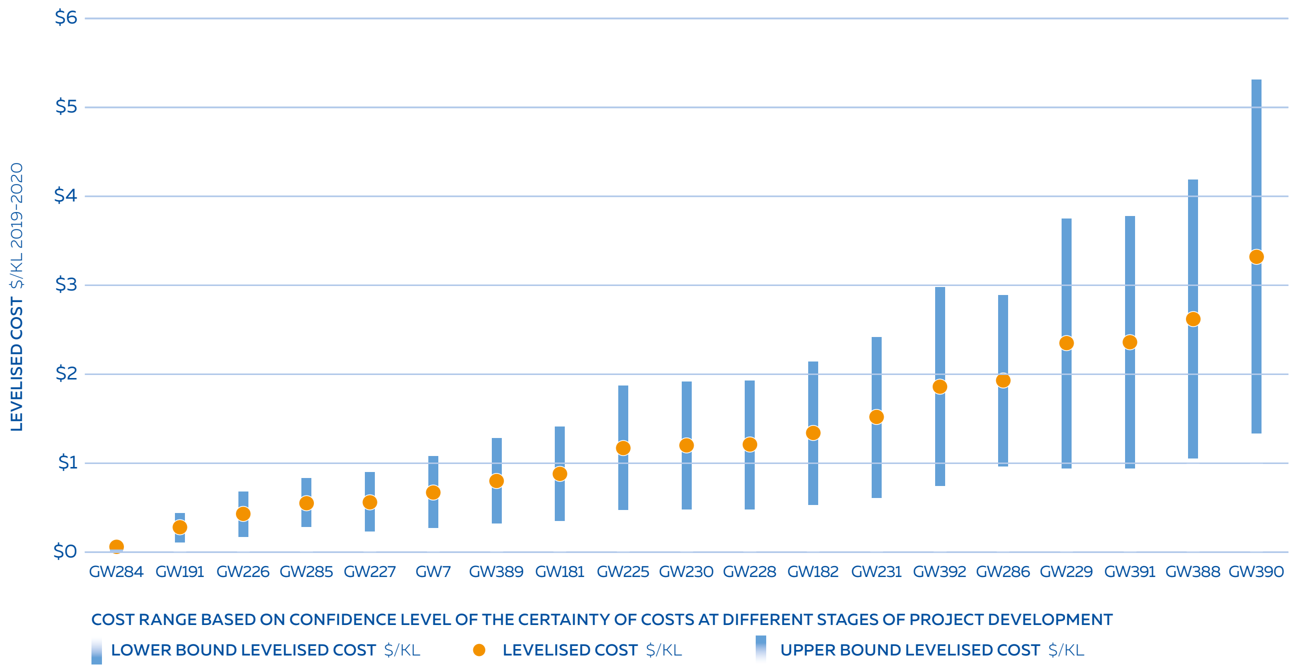
What are the costs?

The levelised costs of groundwater projects range from around $0.10 per kilolitre up to $7 per kilolitre. The levelised cost for 11 out of 14 projects is less than $2 per kilolitre.

Key attributes of the estimates include:

- Costs included for groundwater projects include drilling wells, storing raw water, constructing pipelines and booster pump stations and associated operating and maintenance costs. The relevance of these costs varies from project to project.
- The median annual yield across projects is 6,800 megalitres per annum, ranging from around 800 megalitres per annum up to 17,500 megalitres per annum. Groundwater project yields are dependent on rainfall and have been adjusted to reflect likely annual yields where available.
- Most projects were at planning stage with a +/- 60 per cent confidence interval around cost estimates. These wide confidence intervals mean the levelised costs should be interpreted with some caution.
- The higher cost projects are not associated with relatively low annual yields.

FIGURE 9 Levelised costs of groundwater options $/KL 2019–2020



CASE STUDY 2 PARKES SHIRE COUNCIL

New bore Lachlan River Lower Alluvial Aquifer

A new bore on the Lachlan River Lower Alluvial Aquifer was drilled and cased to a depth of 120 metres by Parkes Shire Council in 2015. The project included 2.5km of interconnecting pipework to supply pumped groundwater to Parkes' major raw water pump station. Water from the bore field is pumped 35km to the Parkes Water Treatment Plant.

The trunk infrastructure is undersized based on growth in instantaneous demand. Due to this restriction, terminal storage has been increased to provide peak needs, as such, interruptions to supply from the borefield reduce the available storage. The new bore provides increased security of supply by providing redundancy and increasing the resilience of water supply in Parkes Shire.

Parkes Shire continues to operate within existing licences and entitlements. The project improved the sustainability of the Lachlan River Lower Alluvial Aquifer as a groundwater resource by spreading the draw down load across a larger geographic area.

Growth in demand in Parkes Shire has mainly been due to large industrial customers and associated residential growth. Increased supply resilience and climate independence has led to no restriction of supply thus no economic impact on industrial and commercial users.

The project was designed with the future in mind, with the ability to harvest surface river water for groundwater artificial recharge should regulatory barriers be overcome, to provide additional rainfall independence for the Parkes Shire water supply portfolio.

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Rainwater tanks

Rainwater tanks in urban communities can provide multiple benefits including reduced demand on drinking water supplies, greener gardens and reduced stormwater runoff. Our analysis shows rainwater tanks are a relatively high cost option. Rainwater tanks are dependent on rainfall, and are therefore less reliable in drought years, however they have a place in the mix of urban water supply options.

PROJECTS CONSIDERED	9
ESTIMATED ASSET AGE RANGE (YEARS)	20
$/KILOLITRE	2 – 19
MEGALITRES/YEAR	480 – 7,350

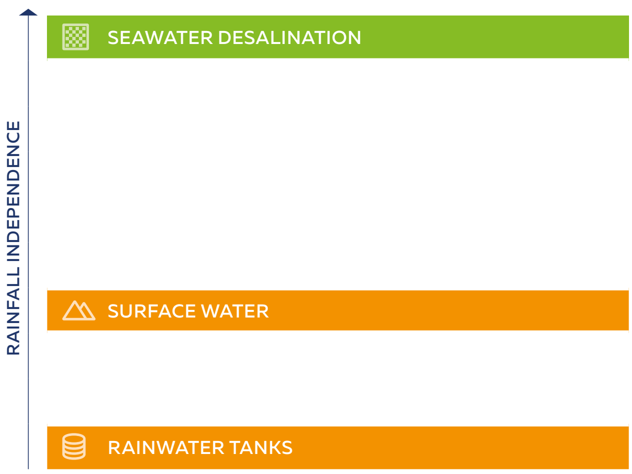
What does this option include?

For households where a rainwater tank is installed, when it rains the roof of the house becomes the water catchment area. The gutters on the roof funnel rainwater into the pipes, which connect the gutters to the water tank. The water is then transported via pipes to the water tank installed above or below the ground. Water is then generally pumped from the tank to the household's pipes.

In urban areas water sourced from rainwater tanks is generally connected to toilets, laundry and outdoor taps.

Rainwater tank projects in this study refer to water utility programs that supply rainwater tanks to households.

What is the contribution to water security?



Rainwater tanks are reliant on rainfall. Because rainfall is not regular or constant in intensity, studies show that in a drought year a tank that is connected to the garden, toilet and laundry will be empty for some of the time (Mukheiber et al, 2012; Melbourne Water, 2017).

The reliability of rainwater tanks is linked to roof size and tank size. For a relatively small roof size (100 m2), 100% reliability cannot be achieved even with a very large tank (10,000 L). However, some studies have found that for a relatively large roof size (200 m2), approximately 90% reliability can be achieved with a tank size of 10,000 L and 100% reliability is achievable except in a dry year (Imteaz et al, 2012).

Reliability is also improved when there is more even distribution of rainfall across the year. If there is low or no rainfall for several months of the year (such as in Perth) tanks may be empty during the time of greatest demand for garden watering.

While rainwater tanks are generally allocated an asset age range of up to 20 years, a recent study for Hunter Water (Williams, 2015) indicated that about 40% of tank systems that were four or more years old had failed or had a failure fixed. The most common source of failure was the pump followed by the switching device. Householders are required to maintain rainwater tanks and pumps to maintain their functionality.

Rainwater tanks can reduce the peak demand and overall demand for drinking water in an urban water system. Potentially delaying or deferring the need to implement higher capital cost water supply investments.

What are the wider considerations?

Using residential rainwater tanks as distributed storages capturing and storing rainwater, can provide flood mitigation benefits in many catchments, even for significant flooding in some catchments that occurs once every hundred years on average. Larger benefits are generally seen in smaller, steeper catchments and for more frequent flooding events (Melbourne Water, 2017).

There is a high level of acceptance and interest in rainwater tanks within urban communities often due to a view that it 'makes sense' not to waste rainwater. There are ongoing opportunities to use rainwater tanks as a way to engage with customers and communities about the urban water cycle.

Rainwater tanks provide customers with an opportunity to reduce water bills. Rainwater tanks also allow customers to use water during drought and restrictions, this can provide opportunities for customers to maintain local green infrastructure and achieve liveability benefits.

Several studies have confirmed that the largest rainwater substitution can be achieved with households that are connected to multiple indoor end-uses (Burns et al, 2015).

What is the energy use?

The energy use for rainwater tanks is typically 0.59 – 4.9 kWh/kL (ISF, 2013; Tjandraatmadja et al, 2012; Retamal et al, 2009).

Energy demand for household rainwater tanks is from pumping and other electrical equipment (Mukheibir et al, 2013). A recent study demonstrated that systems that use cheaper fixed-speed pressure pumps to provide water to toilets and washing machines have a much higher energy intensity than those systems that supply to high flow end-uses like outdoor irrigation (Retamal et al, 2019). There is high variability of energy use based on rainwater tank system set-up (Moglia et al 2014).

At the household scale, rainwater harvesting systems generally have lower energy intensity than recycled water options (eg, household greywater systems) (ISF, 2013).

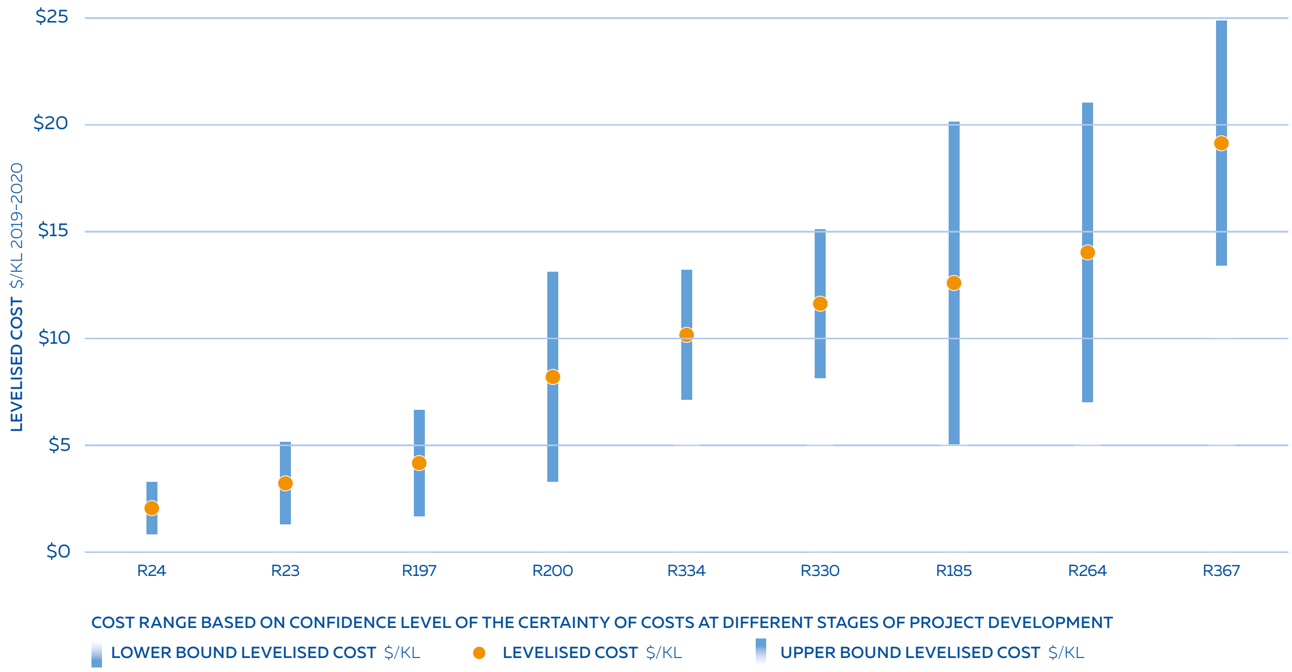
What are the costs?

The levelised cost of household rainwater tank projects ranges from around $2 to $19 per kilolitre.

Key attributes of the estimates include:

- Project costs generally include the supply of rainwater tanks to households and businesses for the collection of rainwater and connections to supply back to the household for non-drinking uses.
- Annual yields were not provided for all projects, though the range from those with data ranged from 480 to 7,350ML per annum. Rainwater tank project yields are dependent on rainfall.
- All project costs are either at a concept design or at a planning stage therefore the cost range is +/- 60 per cent.
- For some of these projects, our dataset does not contain details of the costs of expected yield of the projects, only an estimate of the levelised cost from the project's proponent. This makes it difficult to explain the significant range of levelised costs. However, given they are small-scale projects they are likely to be highly site-specific.

FIGURE 10 Levelised costs of rainwater tank options $/KL 2019–2020



CASE STUDY 3 **MELBOURNE WATER**

Tapping into the benefits of rainwater tanks

In Melbourne rainwater tanks have become a popular alternative to traditional water supply for watering gardens and keeping public spaces green. More recently water utilities have begun to realise the benefits that rainwater tanks can provide for the wider urban water system.

Over the past few years, Melbourne Water has worked with its customers and stakeholders on several projects that have assessed the ability of rainwater tanks to provide multiple benefits for customers and Melbourne's water systems.

Benefits from these projects have included lower water bills, reduced demand on drinking water supplies and greener gardens. Rainwater tanks were shown to help prevent urban flooding, and limit erosion damage and pollution to urban waterways through reducing and slowing down stormwater run-off. The benefit to urban water ways is best when paired with infiltration.

Melbourne Water has found a high level of interest from residents in installing or supporting rainwater tanks, but they have also discovered barriers to widespread adoption.

These include costs to individual residents, ensuring the right expertise for site visits, and physical constraints. Melbourne Water has also found that approaches for local government to engage with their community on reducing residential stormwater runoff are not well understood, and challenges were also found when work fell outside existing planning instruments.

Some key steps in the implementation stage or rainwater tank projects can assist with overcoming barriers. These include; that planning controls can work to help achieve benefits of tanks, market-based instruments can help determine best cost-effective works between public and private land and direct funding tanks on private land is justified in certain circumstances.

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Purified recycled water for drinking

Purified recycled water treated to meet the Australian Drinking Water Guidelines is safe for drinking. Our analysis found the cost of water from purified recycled water for drinking is comparable to water from seawater desalination. Community support can be a particular challenge for purified recycled water, however by engaging openly and transparently with communities this can be overcome.

PROJECTS CONSIDERED	31
ESTIMATED ASSET AGE RANGE (YEARS)	20 – 50
$/KILOLITRE	0.90 - 6.90
MEGALITRES/YEAR	100 – 81,000

What does this option include?

Purified recycled water sourced from wastewater and stormwater treated to meet the Australian Drinking Water Guidelines through multiple levels of treatment and disinfection.

The process relies on advanced water treatment, such as ultrafiltration, reverse osmosis, chlorination and ultraviolet disinfection. This removes chemicals and micro-organisms to ensure the water is safe to drink.

Purified recycled water is used to augment drinking water supplies via different configurations:

Groundwater augmentation

Purified recycled water is used to recharge groundwater aquifers which store and naturally further filter the water before being extracted, treated again and provided to the community through the water supply network.

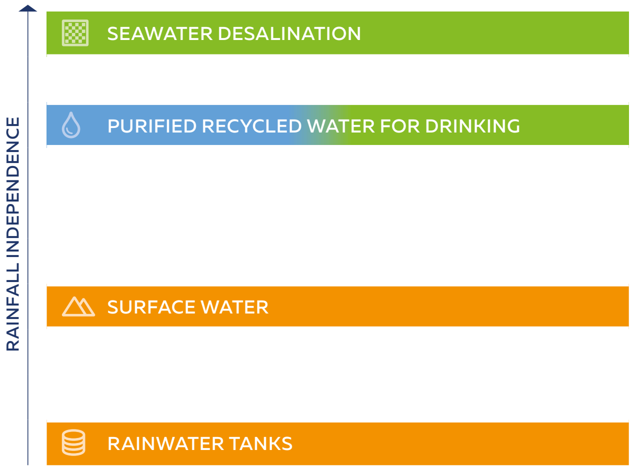
Reservoir augmentation

Purified recycled water is added to a waterway (eg, river) or reservoirs and mixes with surface water before being treated again and provided to the community through the water supply network.

Treated water augmentation

Purified recycled water is added directly to the existing water supply network.

What is the contribution to water security?



Purified recycled water for drinking is a relatively reliable water supply option. While indirectly reliant on rainfall where the drinking water source is surface water or groundwater, recycled water provides diversification to the water supply portfolio increasing water security.

Existing water supplies can be supplemented by using purified recycled water for drinking which has a higher level of rainfall independence than surface water and groundwater options and provides a climate resilient drinking water source.

What are the wider considerations?

Recycling wastewater and stormwater avoids discharge into the ocean or rivers, reducing nutrients and other pollutants released to waterways. Instead nutrients can be recovered and used beneficially.

Any treatment train involving reverse osmosis will produce a brine which can be discharged safely to ocean, but in most cases not to inland waterways. There is also a need to consider discharges within the wastewater catchment (eg, industries, hospitals) and these may need increased focus (monitoring) or pretreatment to maintain safe drinking water quality.

Community support can be a particular challenge for purified recycled water, more because of the 'yuck factor' than any technical aspects. Community education and engagement for purified recycled water has evolved significantly over recent decades; and WSAA's recent All options on the table – Lessons from the journey of others report explores how many cities in the USA and other parts of the world have achieved community acceptance for purified recycled water (WSAA, 2019).

What is the energy use?

For operation and water treatment the energy use is estimated to be 1.3 – 3.8 kWh/kL (Lam et al, 2017; ISF, 2013).

Due to advanced treatment requirements and associated infrastructure recycled water options generally have higher energy requirements than surface water options, although less than desalination options.

What are the costs?

The levelised costs for projects we assessed ranges from $0.90 per kilolitre to $6.90 per kilolitre. The median levelised cost is $2.34 per kilolitre.

Key attributes of the estimates include:

- The yields from the sample set of projects include projects with yield in the range of 100 megalitres to 81,100 megalitres per annum with a median yield of 10,000 megalitres per annum. Recycled water for drinking project yields are indirectly dependent on climate conditions
- Most project costs are either at a concept design or at a planning stage therefore the cost range is +/- 60 per cent. There is a small number of projects for which actual costs were provided.
- There is a range in levelised costs across each of the treatment process and augmentation types. Groundwater augmentation projects in the dataset are the most consistent in terms of levelised costs, with most around $2.00 per kilolitre.

FIGURE 11 Levelised costs of purified recycled water for drinking options $/KL 2019–2020

CASE STUDY 4 WATER CORPORATION

Perth Groundwater Replenishment Scheme

Perth's groundwater replenishment scheme recharges aquifers with purified recycled water, making Water Corporation the only Australian utility to implement and use purified recycled water from wastewater for drinking.

Their journey is a result of two decades of work in securing the trust of regulators, bipartisan Government support and community acceptance.

Perth's rainfall has reduced significantly over 40 years, impacting stream flows and groundwater supplies. A 12% reduction since 1990 has resulted in a 50% reduction in stream flows into Perth's reservoirs.

Secondary treated wastewater from Beenyup Wastewater Treatment Plant is diverted to Beenyup Advanced Water Recycling Plant, where it is further treated to drinking water quality, instead of going to an ocean outfall. The recycled water is recharged into the confined Leederville and Yarragadee aquifers. Before building the project, Water Corporation conducted a trial from 2010-2012, to prove and showcase the technology. At the start of the Leederville trial, it was estimated that the water would take around 30 years to reach the first drinking water abstraction bore. Monitoring data suggests that with a full-scale scheme, recharging up to 14GL/year into both aquifers, the water could reach the first abstraction bores in ten to twenty years.

The "yuck factor" was seen as a potential barrier. Water Corporation built trust with a face-to-face approach rather than a costly marketing campaign.

As well as the Groundwater Replenishment Trial, their approach included:

- Community member engagement with the project team
- Proactive media engagement
- Community advisory panel
- Tracking community sentiment
- School and university programs
- Clear language and terminology
- Transparency
- Educating key influencers
- Creation of a visitor centre.

After obtaining state government approval, Water Corporation successfully commissioned the full-scale scheme (Stage 1) in 2017, and are currently building Stage 2.

FIGURE 12 Water Corporation's approach to securing a climate resilient water supply

References

ISF (Institute for Sustainable Futures) (2013). Saving water and spending energy?; Building Industry Capability to Make Recycled Water Investment Decisions. Prepared by the Institute for Sustainable Futures, University of Technology, Sydney for the Australian Water Recycling Centre of Excellence.

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Recycled water for non-drinking

Recycled water for non-drinking purposes reduces the demand on the drinking water system and avoids discharge of wastewater to the environment. Our analysis found that recycled water for non-drinking was relatively high cost as a water supply option, however when other benefits are considered it can be a viable option in water supply portfolio.

PROJECTS CONSIDERED	51
ESTIMATED ASSET AGE RANGE (YEARS)	35 – 50
$/KILOLITRE	0.40 - 15.00
MEGALITRES/YEAR	86 – 26,000

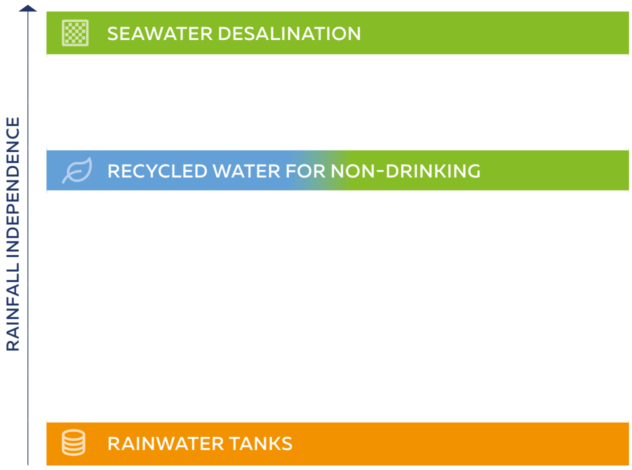
What does this option include?

Recycled water sourced from wastewater treatment plants and sewer mining for non-drinking purposes including irrigation of food crops, public open spaces and backyards, toilet flushing, clothes washing, industrial processes, water features and dust suppression. It includes projects with a single irrigation customer, multiple industrial customers or a precinct scale third pipe residential scheme.

Recycled water can be treated to be suitable for different non-drinking end uses. The higher the level of exposure for customers the higher the level of treatment required. Recycled water used for washing machines, toilet flushing, watering lawns and gardens and ponds and water features end uses, also referred to in some parts of Australia as 'Class A' recycled water, has a higher quality than water used for irrigating public spaces and sporting fields, dust suppression and irrigation for agriculture.

The treatment process for high exposure end uses relies on advanced water treatment, including UV disinfection or chlorination to ensure water quality requirements are met.

What is the contribution to water security?



Recycled water for non-drinking is a relatively reliable water supply option, and provides increased water security.

While indirectly reliant on rainfall where the drinking water source is surface water or groundwater, recycled water provides diversification into the water supply portfolio increasing water security, particularly during drought.

Recycled water for non-drinking options can reduce the peak demand and overall demand for drinking water in an urban water system. Potentially delaying or deferring the need to implement higher capital cost water supply investments.

What are the wider considerations?

Recycling wastewater and stormwater avoids discharge into the ocean or rivers, reducing nutrients and other pollutants released to waterways. Instead nutrients can be recovered and used beneficially.

The demand for recycled water can vary depending on weather (eg, lower use for outdoor irrigation during wetter periods), which can make the option less cost effective. This also means that this form of recycling rarely defers future investment in wastewater treatment and disposal, as a secure disposal route is needed during wetter periods when wastewater flows are generally highest.

Recycled water for non-drinking provides an opportunity to deliver water-enabled green and blue infrastructure for liveability outcomes at all times, and particularly during drought.

There are opportunities to increase agricultural production and to create local food bowl regions through a secure recycled water for non-drinking supply.

What is the energy use?

Depending on the existing level of water treatment at wastewater plants and the levels of treatment required for reuse, the energy required to recycle water for non-drinking will vary and can range from 0.5 to 8.0 kWh/kL (ISF, 2013).

Due to advanced treatment requirements and associated infrastructure recycled water options generally have higher energy requirements than surface water options, although less than desalination options. In general, recycled water for non-drinking will have a lower energy use than recycled water for drinking.

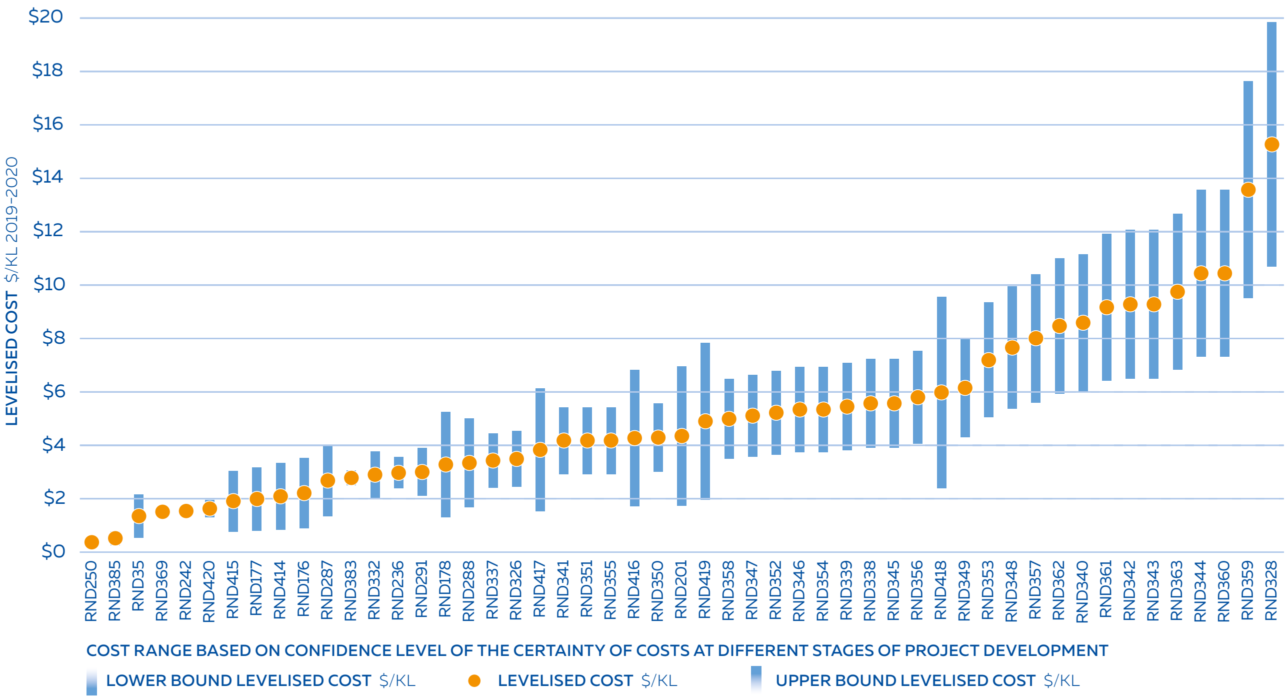
What are the costs?

The levelised cost of the projects ranged from $0.40 to $15 per kilolitre. The cost of recycled water for non-drinking is relatively high cost, because while this option includes lower cost projects that use recycled water for agriculture and industrial processes, it also includes higher cost projects including where pipework is duplicated to provide recycled water to households. The median levelised cost was $4.35 per kilolitre.

Key attributes of the estimates include:

- Project costs generally include the wastewater treatment processes to recycled water standards and network reticulation costs to supply recycled water to individual houses and businesses in new growth areas.
- There is a significant range in annual yields for the recycled water projects included, ranging from 86 megalitres to 26,000 megalitres per annum with a median yield of 477 megalitres. Recycled water for non-drinking project yields are indirectly dependent on climate conditions (which influence demand) and have been adjusted to reflect likely annual yields where available.
- Most project costs are either at a concept design or at a planning stage therefore the cost range is +/- 60 per cent. There is a small number of projects for which actual costs were provided.
- Projects with yields greater than 500 megalitres per annum on average tended to have lower levelised costs compared with those projects with yields less than 500 megalitres per annum. This suggest some economies of scale can be achieved with recycled water for non-drinking projects.
- From the information available, projects for agricultural or industrial end uses had lower costs, generally less than $5 per kilolitre, with many projects below $2 per kilolitre.

FIGURE 13 Levelised costs of recycled water for non-drinking options $/KL 2019–2020



CASE STUDY 5 **SA WATER**

Northern Adelaide Irrigation Scheme

Across Australia water utilities contribute to food security, by applying a circular economy approach to their operations using recycled water for irrigation and intensive horticulture.

This provides significant opportunity and impact for local food bowl regions in close proximity to metropolitan areas, with multiple benefits including creation of jobs, increased agricultural productions, water security and improved environmental outcomes by reducing discharge of nutrients to receiving waters.

One example is the Northern Adelaide Irrigation Scheme which supplies recycled water to the Northern Adelaide Plains food production area, creating 3,700 jobs in and around Adelaide's northern suburbs and adding more than $500 million per year to the South Australian economy.

SA Water invested $155.6 million to deliver recycled water from the Bolivar Wastewater Treatment Plant to greenhouses and other food production processes north of the Gawler River. The upgrades increase its production of recycled irrigation water to 60 per cent, enabling 12 billion litres per year of high quality, climate-independent recycled water for the scheme.

The total cost of this project was offset through partial funding from the National Water Infrastructure Development Fund ($45.6 million) and further revenue to be collected from new recycled water customers.

Reference

ISF (Institute for Sustainable Futures) (2013). Saving water and spending energy?; Building Industry Capability to Make Recycled Water Investment Decisions. Prepared by the Institute for Sustainable Futures, University of Technology, Sydney for the Australian Water Recycling Centre of Excellence.

CASE STUDY 6 **BARWON WATER**

Black Rock Recycled Water Plant

The Black Rock Recycled Water Plant, completed in 2013, supplies Class A recycled water via a 'purple pipe' scheme to the Armstrong Creek and Torquay North Urban Growth Areas. When fully developed, the mandated scheme will supply approximately 25,000 homes around 2.5GL of recycled water per annum.

Recycled water via purple pipe was the only option considered at the time, however when looking back it does compare favourably to the alternative of desalination water ($4.50/kL vs $4.64/kL). Its use aligned with the strategic direction of both Barwon Water and the local councils (City of Greater Geelong and Surf Coast Shire) as well as meeting a need to diversify resources in a time of drought and climate uncertainty. The project demonstrated environmental leadership to the community and was an important step forward for integrated water management and improving water security in the region.

The provision of Class A recycled water provides a climate independent water supply to these growth areas, reducing demand on potable resources while creating a more diverse portfolio of options for future use.

Since the original business case was prepared in 2009 the project costs increased significantly. At the same time, projected demand reduced by half from 5GL/a to 2.5GL/a. The reduced demand is due to the trend of large houses on smaller house blocks, less discretionary watering, limited active open space watering and no passive open space watering.

The overall cost effectiveness of the scheme was impacted by:

- The high salinity of the source wastewater. This required the use of expensive-to-operate salt removal treatment technology to ensure that the recycled water salinity is suitable for sustainable garden watering.
- Improvements in residential water efficiency that reduced the demand for recycled water.
- High upfront infrastructure investment and a long and slow demand take-up.

The whole of community cost for the recycled water scheme to Armstrong Creek and Torquay North is $331M. The levelised cost has gone up significantly from the business case in 2009 and now sits at around $8.61/kL. This revised levelised cost is much higher than that of water supply options such as seawater desalination.

Seawater desalination

Seawater desalination provides a rainfall-independent source of water and is an effective way to secure water supplies against the effects of climate change, population growth and drought. Our analysis found seawater desalination was a medium cost option. Seawater desalination uses large amounts of energy which contribute to its operating costs as well as generating greenhouse gas emissions where fossil fuels are used.

PROJECTS CONSIDERED	28
ESTIMATED ASSET AGE RANGE (YEARS)	35 – 50
$/KILOLITRE	0.70 – 33.24
MEGALITRES/YEAR	3,650 – 109,000

What does this option include?

Desalination projects include new desalination plants as well as augmentations of existing plants, and the associated infrastructure for each project (including pipelines and brine outfalls).

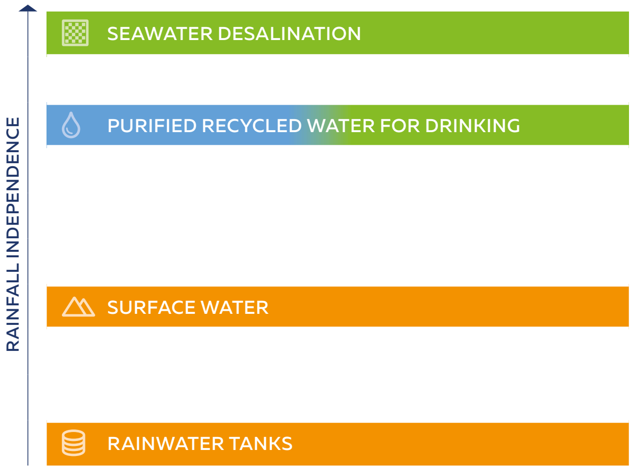
Desalination is the process of removing salts from saline or brackish water to create freshwater suitable for drinking.

A process called reverse osmosis is commonly used, where the saltwater is pushed through a membrane (a barrier with tiny holes) to remove the salt and mineral content. This is an energy intensive process.

The size of a desalination plant can range from a small unit the size of a shipping container to large plants which can provide hundreds of millions of litres of water a day. This study included small and large options, including several small-scale emergency drought response options.

What is the contribution to water security?

Seawater desalination provides a reliable source of water that is not dependent on rainfall. It offers flexibility as a desalination plant can be turned off, or its production capacity reduced, when other water sources are available.



What are the wider considerations?

The direct environmental impact of a desalination plant can be managed through careful design and operation. High energy use will result in greenhouse gas emissions if energy is sourced from fossil fuels.

Seawater desalination plants discharge large volumes of hypersaline brine directly into the ocean, raising concerns about potential impacts to marine life. However, Australian studies have shown minimal impact subject to brine discharge outfalls being designed and located with careful assessment to achieve low impacts (Clark et al, 2018; Seqwater, 2018).

Innovation in desalination to increase the efficiency of the process and therefore increase the production of drinking water from seawater may in the future further reduce the costs and energy use of seawater desalination.

Seawater desalination is not available to cities and communities away from the coast.

What is the energy use?

For operation and water treatment the energy use is 3.3–8.5kWh/kL (Lam et al, 2017; ISF, 2013; Cook et al, 2012; Plappally and Lienhard, 2012).

Desalination has higher energy use compared to other water supply options.

Producing drinking water from seawater desalination can use ten times as much energy as obtaining water from surface water and groundwater. The highest energy demand in desalination plants comes from the reverse osmosis process.

In Australia, the majority of large-scale seawater desalination plants are either powered by renewable energy supplies or have their energy related emissions offset.

What are the costs?

Desalination has high upfront costs related to membrane treatment and energy infrastructure. Ongoing operational costs are also relatively high due to high energy use.

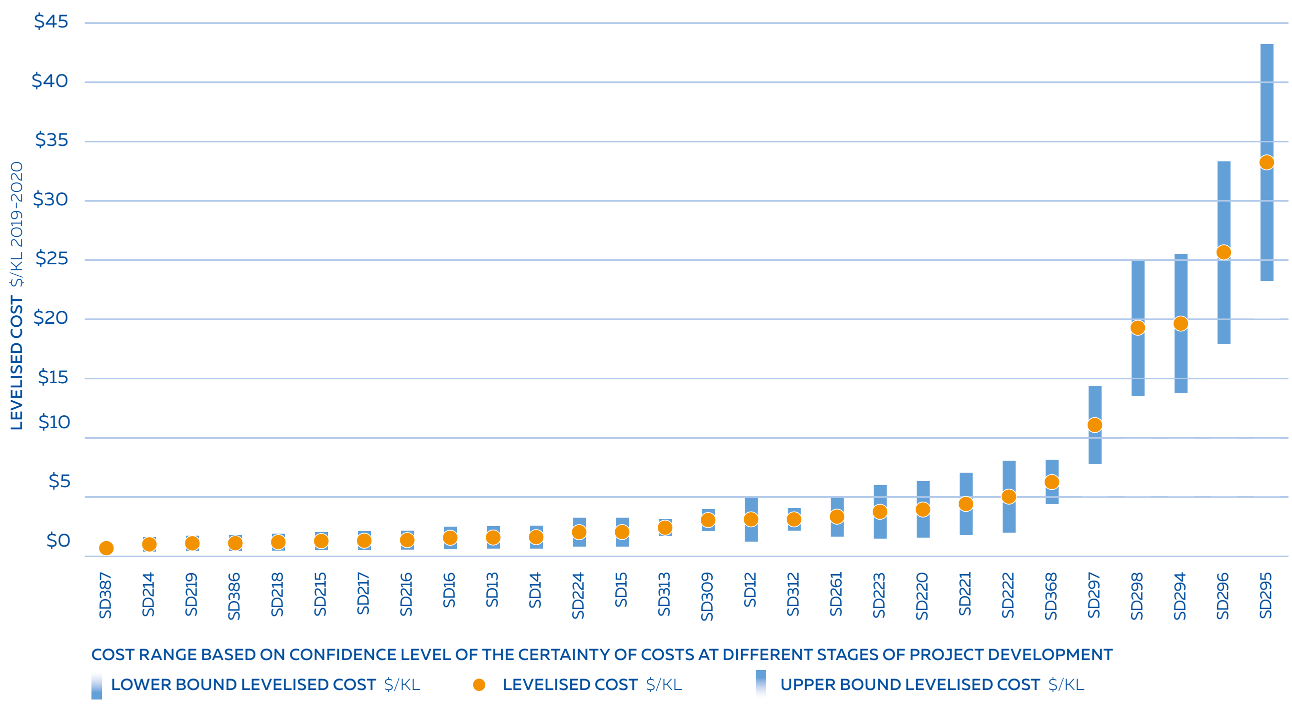
The levelised cost of seawater desalination projects is summarised in Figure 14 Levelised costs of desalination options $/kL 2019–2020, page 38.

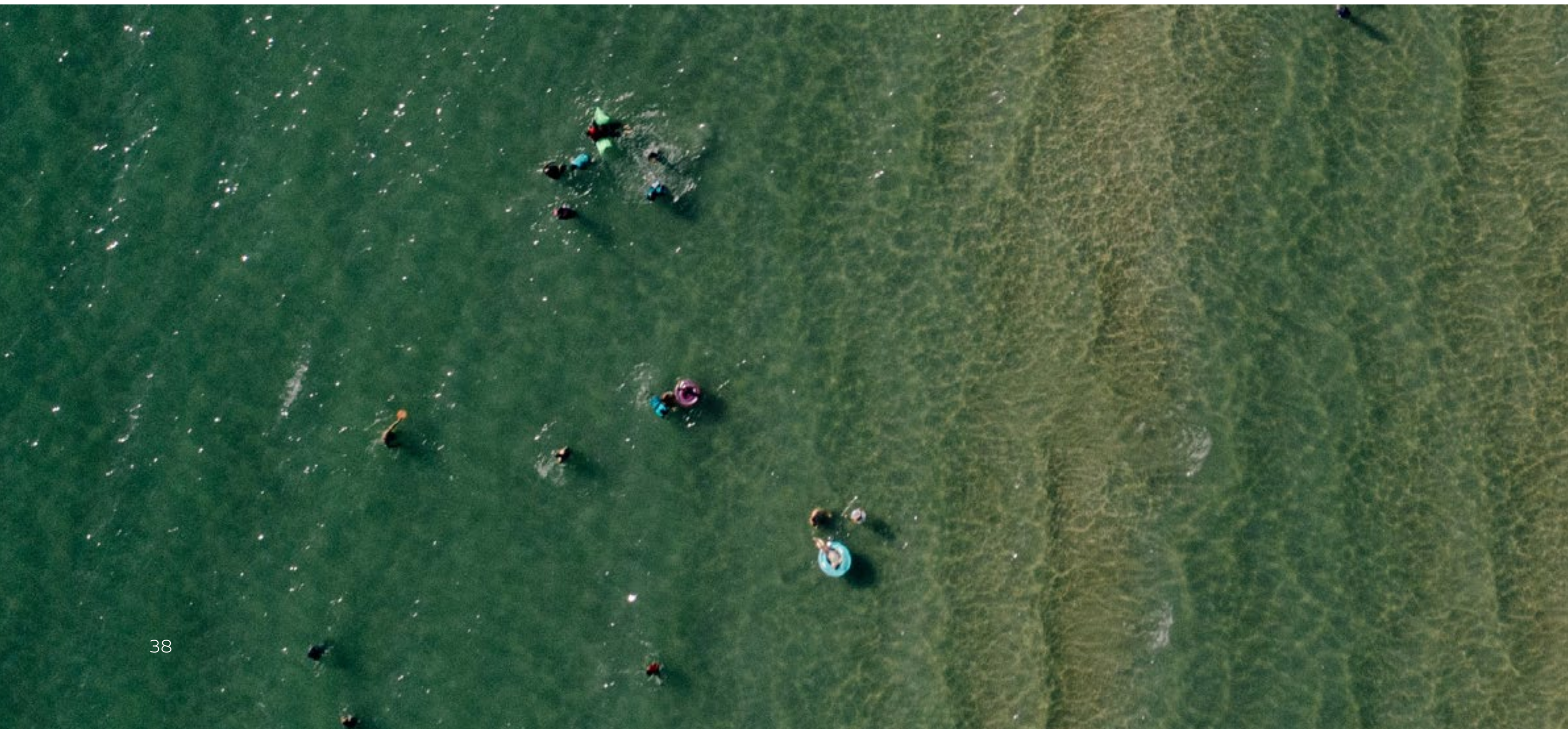
The levelised cost of seawater desalination projects generally range from around $2.00 to $6.00 range, though 5 of the 28 projects were greater than $10.00 per kilolitre these projects were developed in response to water scarcity in drought.

Key attributes of the estimates include:

- Costs included for seawater desalination projects include plant capital and operating costs, and connection infrastructure. Project data provided includes a mix of construction costs for new desalination plants and extensions of existing plants
- The median annual yield is 25,000 megalitres per annum, and the range 3,650 to 109,000 megalitres per annum. Seawater desalination project yields are independent of climate conditions
- More than half the projects were based on detailed cost estimates with a +/- 10 per cent confidence interval, indicating good data quality. The remaining projects were in various stages of planning with wider confidence intervals applied to cost estimates.
- Lower cost projects tended to relate to plant expansions, requiring less supply infrastructure relative to building a new seawater desalination plant. Projects with an annual yield greater than 50,000 megalitres per annum were generally in the bottom half of the levelised cost estimates.

FIGURE 14 Levelised costs of desalination options $/KL 2019–2020





CASE STUDY 7 **PERTH, GOLD COAST, SYDNEY, MELBOURNE, ADELAIDE**

Flexibility and diversity, desalination in Australia

Seawater desalination can provide flexibility and diversity to a city's urban water supplies, making it more resilient towards a changing climate and growing population. Desalination plants operate independent of rainfall and can be implemented on a scale that can make a significant difference to the overall supply reliability of a city. Since the Millennium Drought most major coastal cities in Australia have invested in desalination plants to improve their water security.

In Melbourne, Sydney, Adelaide and south east Queensland, seawater desalination plants provide critical back up during dry periods, and can be placed in standby during wetter months or years. Most recently Kurnell Desalination Plant was switched on to supply water to Sydney after dam levels dropped below 60 per cent. Desalination was also able to provide a critical back up supply in Brisbane during extreme rain events in 2011 and 2013 that affected the water quality in local dams.

In Perth, long term reduction in rainfall has had a significant impact on dam inflows. Perth's two desalination plants, the Perth Seawater Desalination Plant and the Southern Seawater Desalination Plant, now act as a base load provider of water making up to 48% of the water supply for the city. New seawater desalination plants are an option for Perth's water supply in the future with the Water Corporation looking at changes in rainfall, the drying climate and population growth to determine timing.

References

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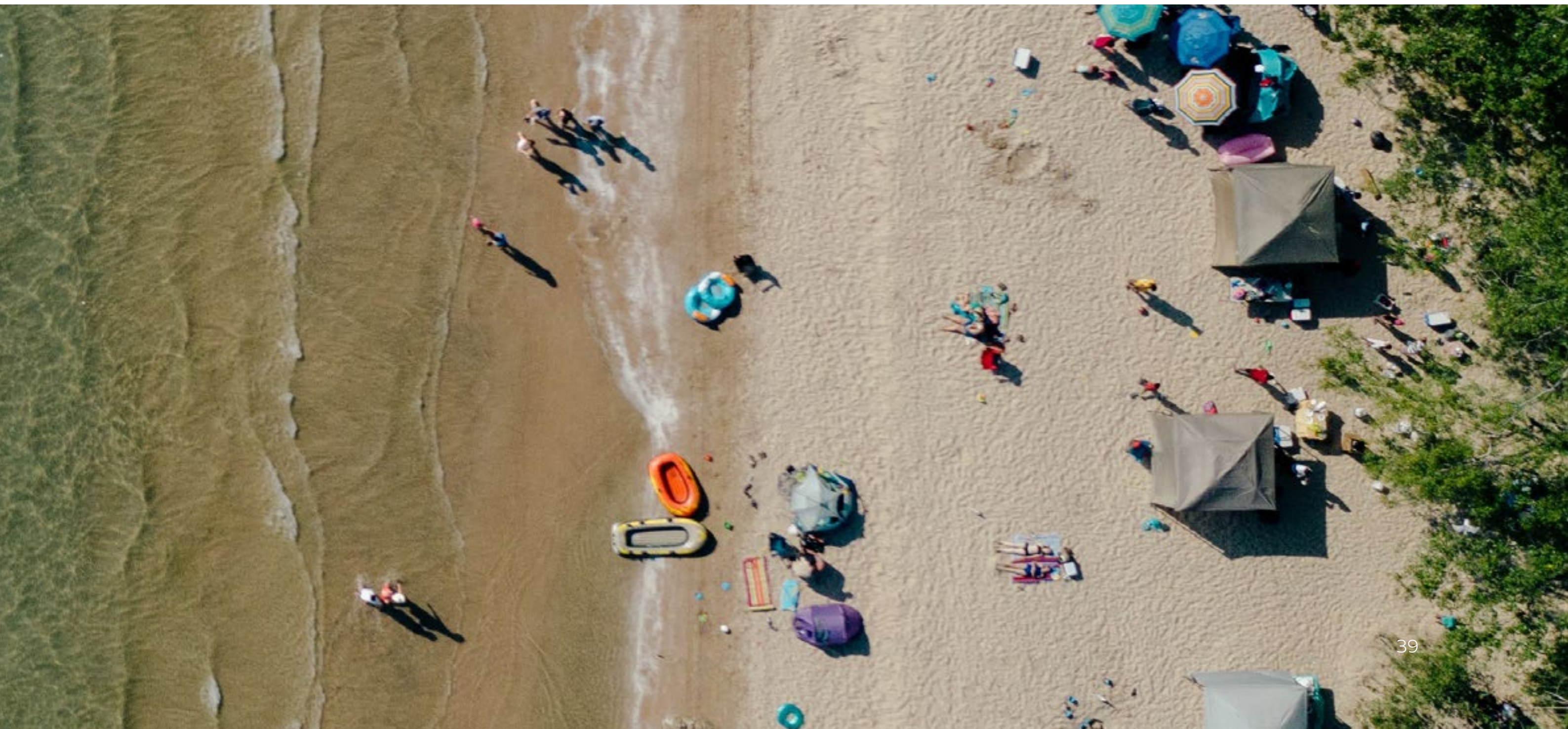


Stormwater harvesting and reuse

Stormwater schemes provide multiple benefits to communities, including improving public amenity and providing health benefits through the provision of green and blue infrastructure, as well as local environmental benefits and reduced local flooding. Our analysis shows stormwater projects are relatively high cost and suggest economies of scale can be achieved with decentralised stormwater harvesting.

Precinct-scale	
PROJECTS CONSIDERED	23
ESTIMATED ASSET AGE RANGE (YEARS)	25 – 50
$/KILOLITRE	0.60 - 16.00
MEGALITRES/YEAR	80 – 3,000

Small-scale	
PROJECTS CONSIDERED	56
ESTIMATED ASSET AGE RANGE (YEARS)	25 – 50
$/KILOLITRE	1.30 - 33.00
MEGALITRES/YEAR	3 – 189

What does this option include?

Stormwater harvesting involves collecting, storing and treating stormwater from urban areas and it can then be reused as recycled water – typically for the irrigation of local parks, playing fields or golf courses. Stormwater is collected from car parks and roads, gardens and open space and footpaths via stormwater drains or creeks.

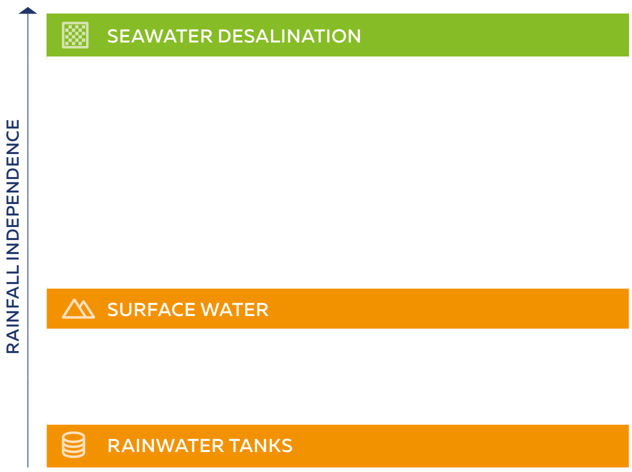
Stormwater harvesting and reuse schemes can be large or small. A stormwater harvesting scheme consists of:

- An extraction point where stormwater is captured or diverted from a drain, creek or pond.
- A network of pipes or open channels to transport stormwater from the connection point to the storage site.
- A reservoir or storage tank where stormwater is temporarily collected for treatment and use.
- A treatment system, which could include a wetland s that produces recycled water that is suitable for and safe for its permitted end use.
- A network of pipes for distributing the recycled water.
- A system to manage by-products produced in the stormwater harvesting facility.

What is the contribution to water security?

Stormwater harvesting and reuse schemes are reliant on rainfall.

Recycled water for non-drinking options can reduce the peak demand and overall demand for drinking water in an urban water system. Potentially delaying or deferring the need to implement higher capital cost water supply investments.



What are the wider considerations?

Stormwater schemes can provide multiple benefits to communities, including improving public amenity and providing health benefits through the provision of green and blue infrastructure.

Increased storm flows from hard surfaces, sediment and other stormwater pollutants (e.g. litter, nutrients, organic matter, bacteria, heavy metals, oil and grease) can damage aquatic habitats, cause bed and bank erosion, loss of native vegetation, and increase the frequency of flash flooding. Stormwater harvesting can improve environmental health by re-establishing a more natural water cycle or flow regime and through reducing waterway pollution.

Stormwater harvesting increases the opportunities for sustainable water management which is an important consideration in water sensitive urban design.

In some cases, stormwater harvesting and reuse can also reduce local flooding.

What is the energy use?

There is limited specific data available on the energy use of stormwater harvesting and reuse. However, as with wastewater, the energy demand of stormwater recycling is highly variable and dependent on a number of factors including: the quality of the incoming stormwater, the treatment required, and the end use.

Many stormwater recycling systems have low (or zero) energy demand as they are passive systems such as wetlands and raingardens (Beca Consultants, 2017). However, water transfer for reuse requires typically pumping and energy use. One of the challenges for the operation of wetlands and raingardens is the need for ongoing maintenance to ensure they are functioning as intended.

What are the costs?

The cost effectiveness of stormwater schemes is generally low due to the water treatment requirements and storage requirements relative to the volume of water produced.

We have separated out precinct-scale and small-scale stormwater schemes for our cost analysis.

Costs of precinct-scale stormwater

These projects generally included larger-scale stormwater projects for irrigation purposes.

The levelised cost of precinct-scale stormwater harvesting projects varies between $0.60 to $16 per kilolitre, with 18 of the 23 projects less than $5.00 per kilolitre.

Key attributes of the estimates include:

- Project costs generally included stormwater treatment processes and any supply connections.
- Yields across the projects range from 80 megalitres to 3,000 megalitres per annum with a median yield of 375 megalitres per annum. Precinct-scale stormwater project yields are dependent on rainfall and have been adjusted to reflect likely annual yields where available.
- All project costs are at planning stage with a +/- 60 per cent confidence interval around cost estimates. The levelised costs should be interpreted with some caution as a result.
- While projects with yields greater than 1,000ML per year projects have levelised costs at the lower end from $0.60 to $2.50 per kilolitre, there was not a strong link between yields and levelised costs for those projects with yields below 1,000 megalitres per annum.

Costs of small-scale stormwater

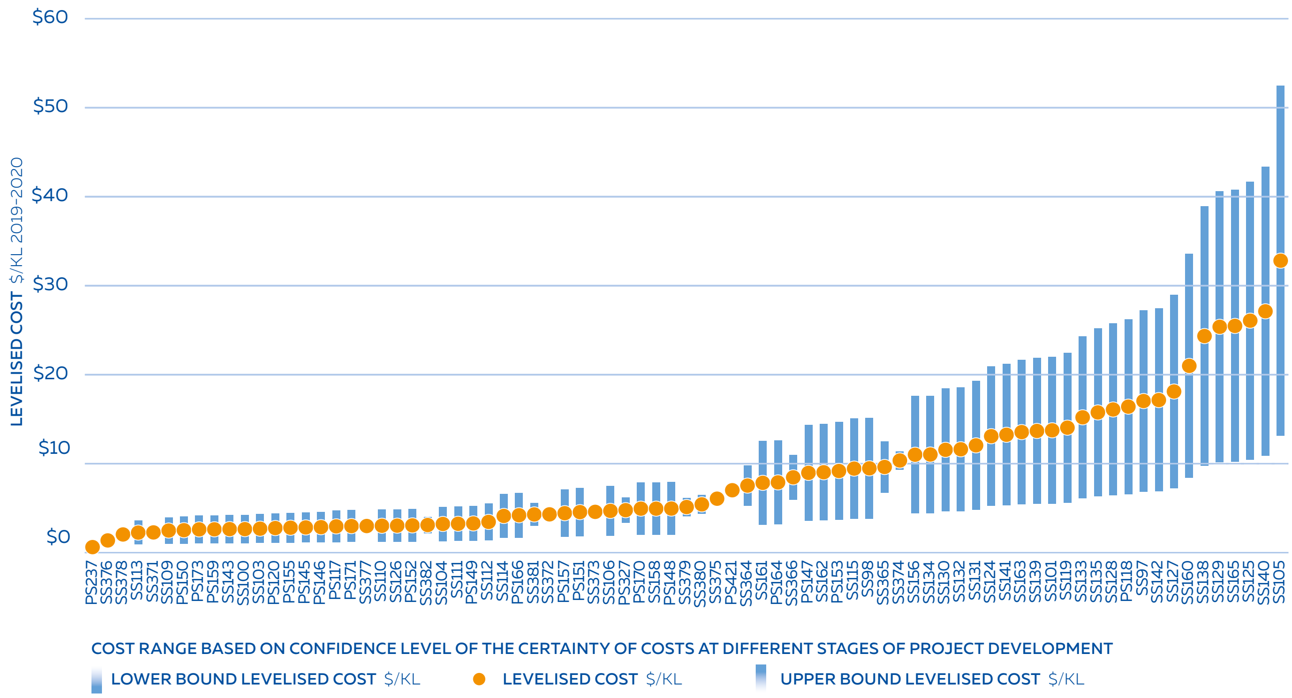
Projects are generally for the irrigation of parks, gardens and sporting ovals.

The levelised cost of small-scale stormwater harvesting projects varies between $1.30 to $33 per kilolitre.

Key attributes of the estimates include:

- Project costs generally include stormwater treatment costs and supply infrastructure.
- Yields across small-scale stormwater projects range from 3ML to 189ML per annum with a median yield of 28ML per annum. Small-scale stormwater project yields are dependent on rainfall and have been adjusted to reflect likely annual yields where available
- The levelised cost for projects with annual yields above 80ML generally ranged from $2.50 to $11, whereas the levelised cost for projects with yields less than 80ML per annum ranged $11 to $33 per kilolitre. This demonstrates that levelised costs for larger small-scale projects costs are consistent with the precinct-scale projects, whereas as the project yields decreases the levelised cost tends to increase, suggesting economies of scale can be achieved with stormwater harvesting projects.
- All project costs are at a planning stage therefore the cost range is +/- 60 per cent.

FIGURE 15 Levelised costs of stormwater options– all stormwater harvesting $/KL 2019-2020



CASE STUDY 8 **SOUTH EAST WATER**

Aquarevo

Aquarevo is a collaboration between South East Water and Villawood Properties to deliver a unique residential development. Built on a former wastewater treatment plant site, Aquarevo was created out of an opportunity to implement and advance innovative water and energy saving technology in a real-world residential urban setting.

It's predicted that by 2050 12 per cent of Melbourne's water supply will need to come from alternative water sources due to population growth and climate change. Each home at Aquarevo is plumbed with three types of water: drinking, recycled and rainwater. The integrated approach to water and sewerage services will cut each home's demand for mains drinking water by 70 per cent.

Each property is fitted with a 2,400 litre (2,000 litre capacity) rainwater tank, to capture water from the roof. After filtration, ultra violet and heat treatment, this water is used in the home as a rain to hot system, to supply hot water in showers, baths, laundry and washing machines.

South East Water's TankTalk® technology is connected to each rain tank which receives weather forecasts from the Bureau of Meteorology and then releases water to storm water drains from the tanks before predicted heavy rainfall, to create more storage capacity for fresh rainfall and to mitigate localised flooding. The estate will also feature largely stormwater-fed wetlands that are connected to water bodies, helping to reduce peak stormwater runoff by 25 per cent.

To supply rainwater as a source of non-drinking water, Aquarevo faced challenges from existing regulation, policy, statutory requirements and required a great level of consultation with government, council and relevant authorities. Extensive risk and mitigation strategies were carried out and monitoring will continue over the next few years to influence future thinking and possible regulatory change.

There was also a risk that customers wouldn't accept the initiatives and that builders wouldn't come on board with the changes. But Aquarevo has been well-received and the first residents have already moved into their new homes.

References

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Surface water

Surface water is an important part of our existing water supply portfolio. Dams and reservoirs store water for future use, however these options are often high-risk investments as they are reliant on rainfall and less resilient to climate change than other options. While our analysis found surface water options are relatively inexpensive to operate in the long term, dams are expensive to build and have significant environmental and social impacts.

PROJECTS CONSIDERED	31
ESTIMATED ASSET AGE RANGE (YEARS)	30 – 130
$/KILOLITRE	0.25 - 2.94
MEGALITRES/YEAR	2,000 – 36,500

What does this option include?

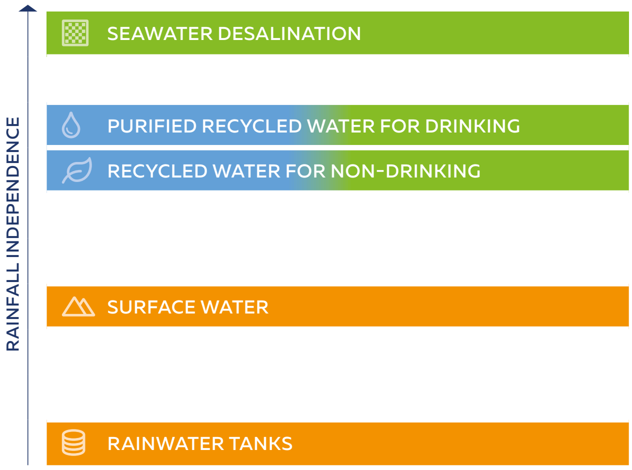
Surface water projects include construction of dams and weirs, upgrading dams and construction of off-river storages to add capacity to the drinking water system. As well as associated infrastructure including upgrading water treatment plants and infrastructure required to transport water.

Dams are built to control and store water. A dam wall creates a reservoir in which water can be stored. Stored water is then treated before being provided to the community through the water supply network.

A dam can be located 'on river', where it fills directly from river flows, or 'off-river' where water is transferred to it from other sources, such as a nearby river or dam.

A weir is a small barrier that is built across a river to raise the water level slightly on the upstream side, allowing water to pool while still allowing water to flow steadily over the weir itself. Weirs allow regulation of our surface water system and can be used to divert water to storage.

What is the contribution to water security?



Rainfall independence is important for water supply security. Surface water options are directly dependent on rainfall and are therefore high-risk options as our climate gets hotter and drier.

Existing dams provide an important store of water during drought. As storages deplete, they provide lead-time to plan and implement other drought response actions, such as a desalination or recycled water plant, to ensure communities do not run out of water during a severe drought.

What are the wider considerations?

Dams provide the opportunity to reduce flooding by storing large volumes of water and then controlling the rate of outflow to downstream rivers through spillways and other release structures.

Dams can provide positive social outcomes by providing economic stimulus to an area during construction and through increased tourism and recreation once in operation.

In some cases, hydroelectricity can be generated from surface water options. Hydroelectricity is electrical energy generated when water rotates a turbine shaft, and in Australia is most commonly generated from water stored in dams and then discharged from the dam through water turbines.

In recent decades there have very few new dams constructed in Australia largely due to their reliance on rainfall, impact on the environment and negative community views.

The environmental and social impacts of a dam are associated with the surrounding land that may be inundated and alteration of river flows downstream of the dam. Not only a water source, rivers are ecosystems that provide habitats for flora and fauna, and changes to a river's flow and water quality usually causes irreversible impacts. The size of these impacts is related to the size of the dam and whether it is located on-river or off-river.

Dams have a potential impact on Aboriginal cultural heritage, by inundating important sites and impacting access to ancestral lands.

What is the energy use?

For operation and water treatment the energy use is 0.1 – 1.0 kWh/kL (Lam et al, 2017; Biswas and Tek, 2016; ISF, 2013; Plappally and Lienhard, 2012; WSAA data).

Surface water options require relatively lower energy use compared to other water supply options.

Energy demand for surface water options is from pumping and water treatment. The method of pumping depends on the source of the water and the distance to the community supplied. The amount of energy used in pumping water will depend on the topology of the area, the distance pumped and the source of the water.

What are the costs?

Dams have a relatively large upfront cost due to the scale of infrastructure required. The ongoing costs to operate a dam once built are relatively low if the dam is located near the community receiving the supply. However, if a large pipeline is required to transfer water from one region to another, the costs increase significantly (see Water sharing between regions, page 52).

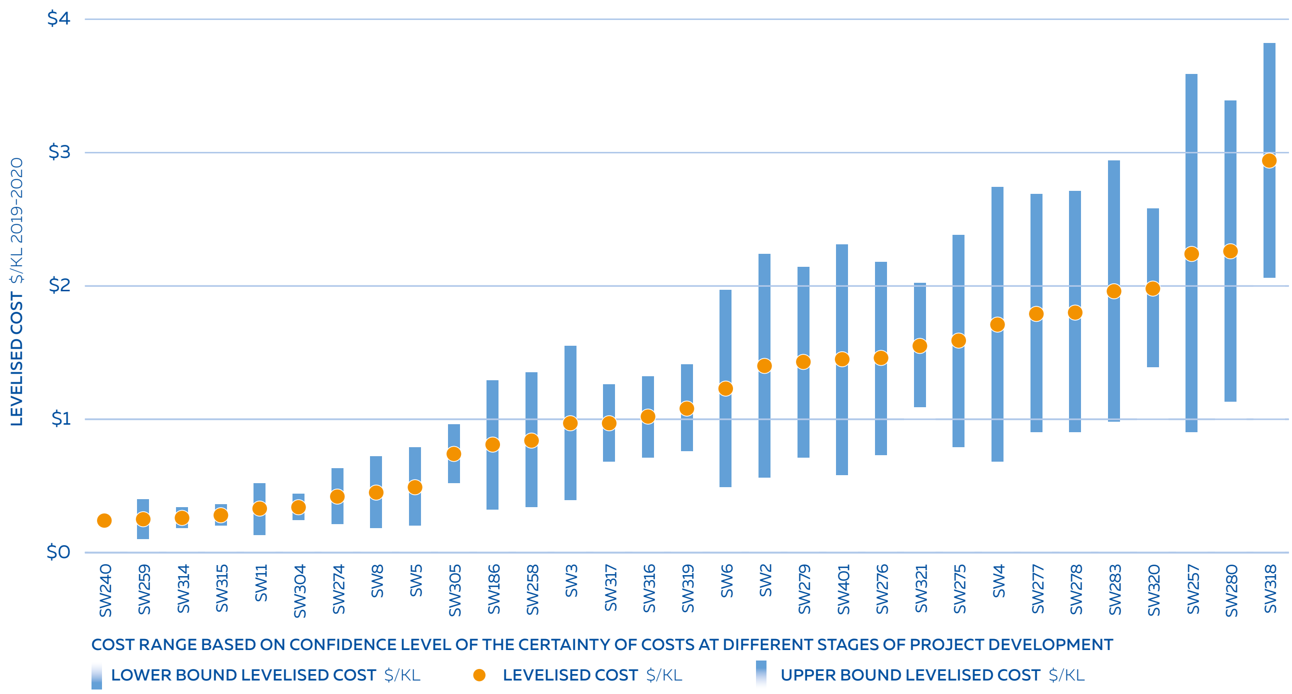
More than 80% of Australia's current water supply is sourced from surface water, many of the existing sources of supply are more than 30 years old, and some are over 100 years old. Most of the lower cost opportunities for surface water have already been taken and are in operation. Therefore, it is likely that the projects in this dataset are more costly than existing options.

The levelised costs surface water projects range from $0.25 up to $2.94 per kilolitre.

Key attributes of the estimates include:

- Costs include dam/storage construction or augmentation costs, operating and maintenance costs, constructing pipelines and booster pump stations, and water treatment plant upgrades. The costs included varies depending on the nature of the project.
- The median annual yield across projects is 7,500 megalitres per annum, ranging from around 2,000 megalitres per annum up to 36,500 megalitres per annum. Surface water yields are dependent on rainfall and have been adjusted to reflect likely annual yields where available.
- One project in the dataset was an actual/reported cost and the remainder were mostly in the planning or concept design stage, meaning there was at least a +/- 30 per cent confidence interval applied to costs.
- A key driver of the results is the extent to which downstream infrastructure was required to integrate the project into the water distribution system. For example, dam upgrades require less infrastructure compared to construction of a new dam which also needs a pipeline to the water treatment plant and pump stations. Higher cost projects tended to require more associated infrastructure. Most of the projects with higher levelised costs had below median annual yields. This suggests some economies of scale.

FIGURE 16 Levelised costs of surface water options $/KL 2019-20



CASE STUDY 9 ICON WATER

Cotter Dam Enlargement

The enlargement of the Cotter Dam, completed in 2013 and filled in 2016, plays a key role in helping secure the water supply for the ACT and surrounding region in the future, allowing Icon Water to deal with frequent, longer and more severe droughts without having to endure regular high-level water restrictions for extended periods. Environmental and cultural impacts had to be carefully considered and addressed.

Enlarging the Cotter Dam involved building a new 80 metre high dam approximately 100 metres downstream of the existing Cotter Dam, as well as two substantial earth embankment dams adjacent to the main dam. The enlarged dam has a capacity of 76 gigalitres, nearly 20 times its original size, and the new reservoir increased the ACT Water storage capacity by 35%. The construction cost of the Enlarged Cotter Dam was $410.5 million.

Aboriginal people have lived in and managed the Cotter lands and waters for more than 25,000 years and there is extensive archaeological evidence of Aboriginal artefacts, rock shelters, ochre quarries and ceremonial sites scattered throughout the Cotter catchment. Icon Water has a comprehensive heritage program to ensure the Cotter's history is recorded for present and future generations.

During construction sensitive areas were identified and fenced off for protection. Approximately 4,000 artefacts were recovered from land to be inundated and returned to country with a ceremony with the local First Nations People.

The protection of the endangered Macquarie Perch is considered the project's greatest environmental achievement, building the world's first freshwater rock reef, a 7 kilometre weaving wall of giant boulders, carefully placed one-by-one into position to create a safe environment for the local species, protecting the fish population from marauding cormorants and downstream Epizootic Haematopoietic Necrosis (EHN) Virus.

Through optimised design materials choices the project achieved a significant reduction in the lifecycle environmental impact of materials use reducing embodied carbon emissions by 23% (37,000 tCO_2e). This was primarily achieved through increasing fly ash content in concrete and sourcing aggregates from on site. Carbon emissions from construction and operation of the enlarged Dam were and continue to be offset to meet project conditions of development approval.

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Water carting

Water carting is generally a last resort option for water supply to communities. Relatively small volumes of water are transported by truck at high cost as a short-term supply option. Our analysis showed levelised costs generally increase with increasing water carting distance.

WATER CARTING EXAMPLES	13
$/KILOLITRE	13 – 47
MEGALITRES/YEAR	1 – 8,000

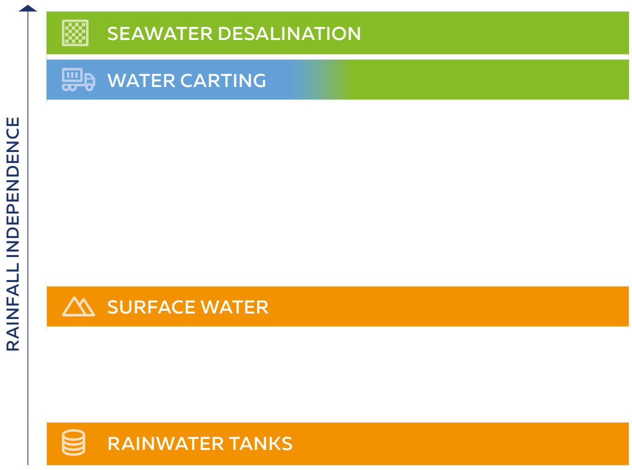
What does this option include?

Projects generally include the cartage of small volumes of water when areas are in short supply, and are usually as a short-term supply option. Water carting projects provide a drinking water supply in areas where other water supplies are insufficient or temporarily unsuitable. They can be used as emergency responses to drought and water scarcity.

Water carters take drinking water from a supply that meets the Australian Drinking Water Guidelines, usually town drinking water supplies or directly from a bulk water supplier at the point of treatment. Water carts and water trucks are specialised water carrying vehicles used to transport water.

Water carting projects can include transporting water within a catchment or between catchments. In some cases water can be transported over hundreds of kilometres.

What is the contribution to water security?



Water carting can provide reliable drinking water supply in relatively small volumes. Water can be supplied from any drinking water source.

However, where water scarcity affects a region water carting can struggle to meet demand with delays to supply for even small volumes.

In a portfolio of options approach to water supply for large communities, water carting would generally only be included as a last resort option.

Water carting can in some cases be the most cost-effective option for small, generally more remote communities, where an existing supply has failed due to either climate uncertainty or unacceptable water quality risks and the development of an alternative source has a high unit cost.

What is the energy use?

Water carting relies on trucks to transport water. Generally, water carting trucks use diesel fuel as an energy source.

Fuel use varies with the type, size, age and condition of the water carting truck and the distance the truck is transporting water.

There is limited specific information available about fuel use for water carting options, however fuel costs are included in the costs charged per kilolitre for carting water.

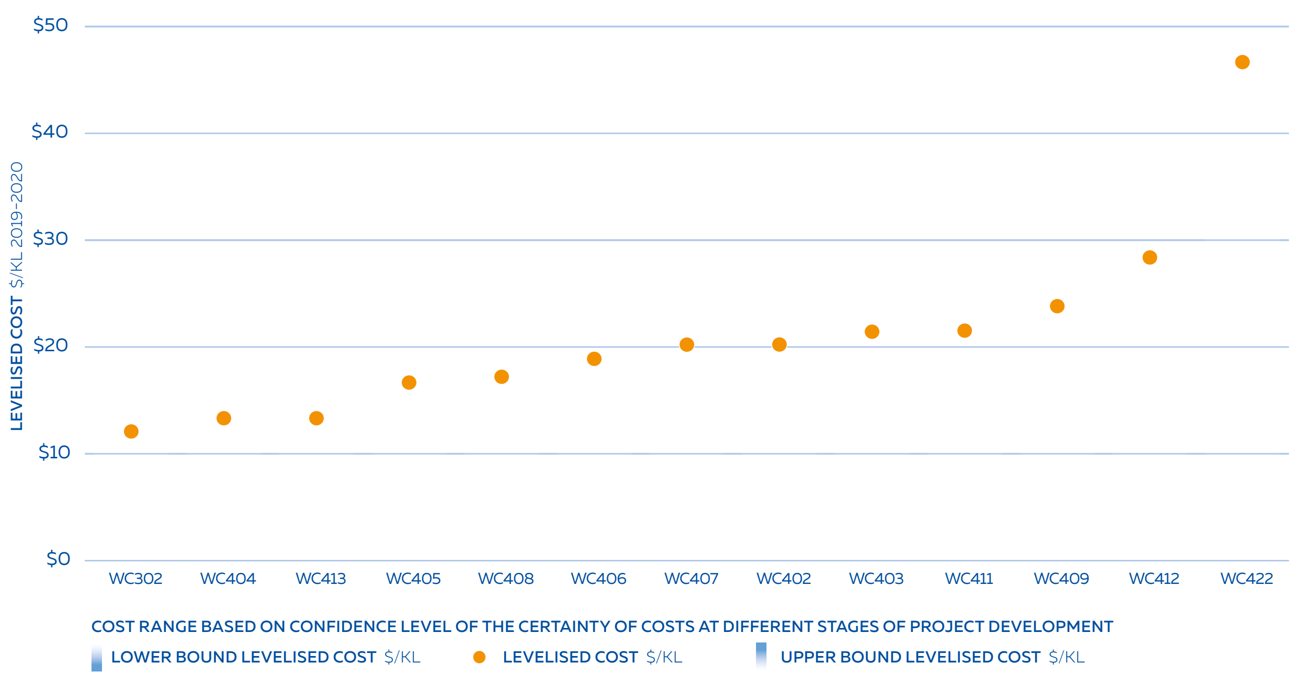
What are the costs?

Projects ranged from $13 to $28 per kilolitre, aside from one project at $47 per kilolitre. Levelised costs tend to be in a similar range.

Key attributes of the estimates include:

- There is a significant range in annual yields for the water carting projects, ranging from 1ML to 8,000ML per annum, with a median yield of 11ML per annum. In most cases the data provided was based on monthly supply agreements. Water carting project yields are based on actual volumes delivered
- All water carting costs are actual operating costs incurred by water businesses.
- Levelised costs generally increase with increasing water carting distance.

FIGURE 17 Levelised costs of water carting options $/KL 2019-2020



CASE STUDY 10 **SEQWATER**

Planning for off-grid communities in South East Queensland

In South East Queensland, 'off-grid communities' are urban communities supplied by a water source that is not directly connected to the South East Queensland Water Grid (see case study 29 South East Queensland Water Grid, page 54).

All 16 off-grid communities have their own water supply source. The sources include surface water (dams, weirs or run-of-river supply) and groundwater. The way the water supply system is operated can increase the water security of off-grid communities. During normal times, the operation is simply to refill the local distribution reservoir every day from the nominated supply source. As demands increase over time or climatic conditions change, the water treatment plant for the off-grid community will operate for additional hours throughout the day.

When demand exceeds the supply capability due to drought, the local distribution reservoir ensures that demand can be met in the short term.

As the distribution reservoir levels drop or the supply conditions reduce, operation is changed as per the community's Drought Response Plan and alternative or contingency supplies are introduced. Contingencies include carting water from the South East Queensland Water Grid as required for 16 of the off-grid communities.

In Water for Life South East Queensland's Water Security Program 2016-2046, Seqwater provides clear and transparent information about demand, supply, system operation, level of service and drought response for each off-grid community. Including information where water carting is part of the emergency operation for drought response.

CASE STUDY 11 **GENERATING WATER AT HOME**

Innovative and future water supply options

In addition to rainwater tanks and onsite bores, there are other technologies and processes that provide opportunities for water to be generated, or reused, by households.

Technologies and processes include:

- Greywater diversion devices: divert washing machine and shower wastewater for non-drinking end uses (e.g. watering the garden)
- Greywater treatment systems: treating and reusing washing machine, shower and kitchen wastewater for non-drinking end uses (again, typically for uses external to the house)
- Black water recycling technologies: treating and reusing household wastewater for all sources including toilets, for non-drinking end uses
- Atmospheric water technologies: extract water from humid air by condensation (cooling the air to below its dew point), or by exposing the air to desiccants or pressurising the air.

Currently, at a household scale, most recycled water options are relatively high cost, typically produce insufficient quantities to make the household fully self-sufficient with respect to water consumption, and have a high energy intensity, particularly where treatment is required. However, investment in research and development for low-cost energy-efficient technologies means these options are an opportunity for the future.

As with all water supply options, we must ensure that both public health and the environment are protected. When considering options to generate water at a household level, residents should refer to the their local health regulator for advice.

Household water generation may become a positive disruptor for urban water supply in the future, similar to small-scale photovoltaics (solar panels) to the energy industry – where solar panels are on 20 per cent of Australian roofs and generate 3.4 per cent of Australia's electricity – particularly if the quantities of water generated allow for a level of self-sufficiency.

Water sharing between regions

Water sharing between regions via pipeline interconnectors allows water supply in a region to be optimised by moving water between catchments and transferring water from communities with more water to those with less. Our analysis shows water sharing between regions are generally relatively low-cost options, with some exceptions.

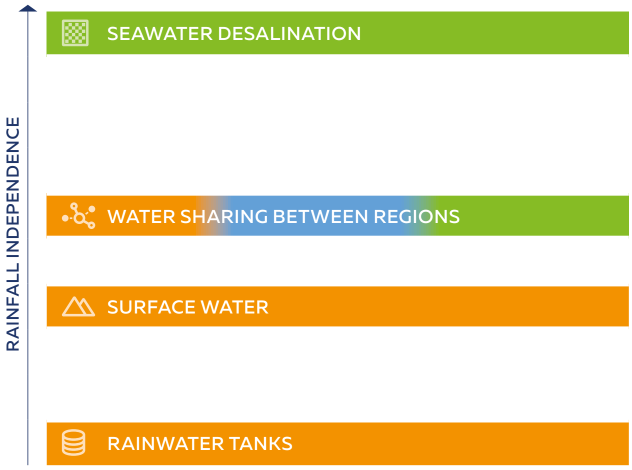
PROJECTS CONSIDERED	10
ESTIMATED ASSET AGE RANGE (YEARS)	35 – 80
$/KILOLITRE	0.60 - 2.60
MEGALITRES/YEAR	7,000 – 100,000

What does this option include?

Water sharing between regions via pipeline connects two or more major water sources and transports water from one catchment to another.

Pipeline interconnectors are used in Australia to move water from rivers, dams, groundwater and desalination plants. Projects provided for this dataset include water sourced from surface water only.

What is the contribution to water security?



Generally pipeline interconnectors increase the reliability of a community's water supply.

The reliability depends on the rainfall distribution across the connected regions and whether or not the connection can take advantage of the complementary strengths and weaknesses in the two systems.

Connecting a region with small storage and high yielding catchments to a region with large storage and low yielding catchments, for example, can be mutually beneficial to both regions.

What are the wider considerations?

Sharing water between regions can maintain the economic and social outcomes in those regions, and particularly in the region receiving water. However, community views on sharing water between regions are not always positive and should be considered in options analysis.

Construction of pipeline interconnectors can provide positive social outcomes by providing economic stimulus to an area during construction. However, there are also environmental impacts arising from construction including impacts on flora and fauna, waterways and lands.

What is the energy use?

The energy use water sharing between catchments (operating pipeline interconnectors) is 0.01 – 3.3 kWh/kL (Lam et al, 2017; Plappally and Lienhard, 2012).

Sharing water between regions require relatively lower energy use compared to other water supply options. Where pipelines are able to operate under gravity (without pumping) energy use is very low.

Energy demand for water sharing between regions options is primarily from pumping. The amount of energy used in pumping water will depend on the topology of the pipeline route, the distance pumped and the source of the water.

What are the costs?

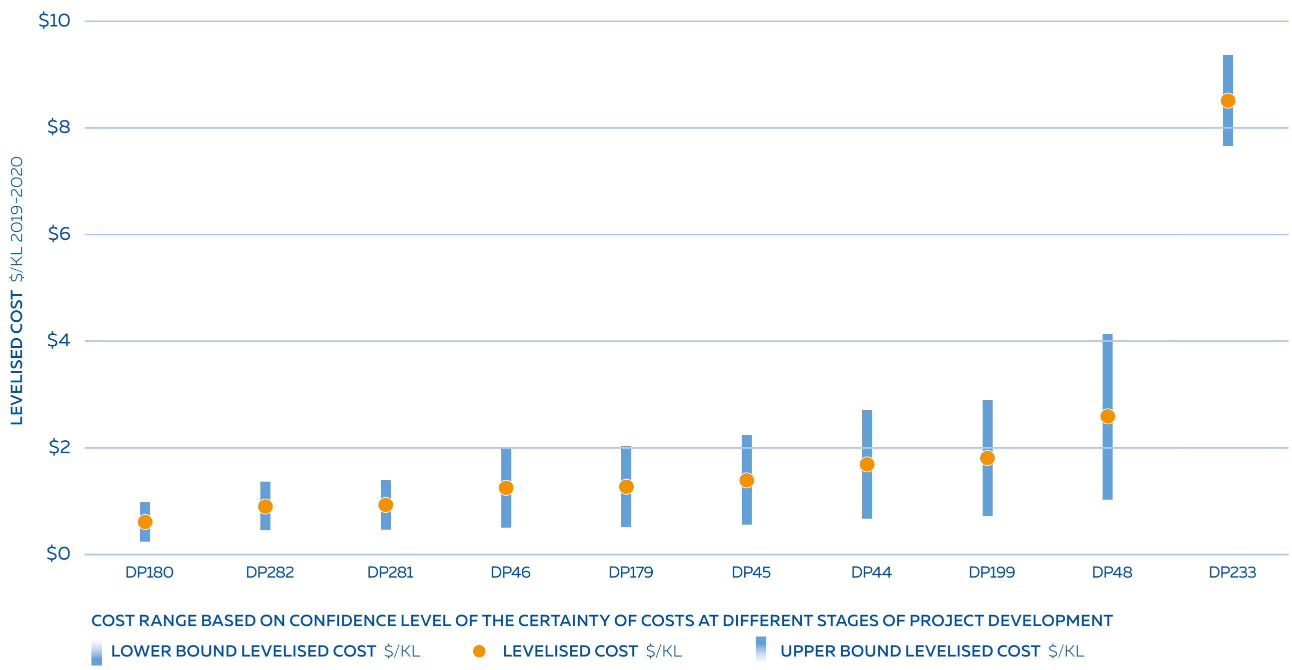
Costs to construct can be moderately high depending on the distances involved between regions, length of pipework, terrain, the method of construction and associated storage requirements.

All projects ranged from $0.60 to $2.60 per kilolitre, aside from one project with a levelised cost of $8.50 per kilolitre.

Key attributes of the estimates include:

- There is a significant range in annual yields for the pipeline projects, ranging from 7,000ML to 100,000 per annum. Pipeline project yields are dependent on rainfall and have been adjusted to reflect likely annual yields where available.
- Most pipeline project costs are either at a concept design or at a planning stage therefore the cost range is +/- 60 per cent.
- Levelised costs tend to be in similar range and are not necessarily impacted by volume.
- Pipeline interconnectors that connect adjacent catchment areas are likely to have lower levelised costs than those that are moving water from larger distances.

FIGURE 18 Levelised costs of water sharing between regions options $/KL 2019–2020



CASE STUDY 12 SEQWATER

South East Queensland Water Grid

The South East Queensland (SEQ) Water Grid allows Seqwater to move treated drinking water around the South East Queensland region. This is especially important when patchy rainfall leaves some areas with full dams and other parts of the region with lower dam levels.

The Water Grid can supplement but not completely replace local water supplies.

The SEQ Water Grid is a bulk water supply network of:

- 12 dams
- 36 conventional water treatment plants
- 3 purified recycled water treatment plants
- 1 desalination plant
- 28 bulk water reservoirs
- 22 pump stations
- More than 600km of bulk drinking water supply pipelines.

The SEQ Water Grid was constructed in response to the water supply crisis in South East Queensland during the Millennium Drought (2001–2009), with additional communities added to the Water Grid since it was first constructed. The SEQ Water Grid boosts the yield of the system by about 85,000 million litres a year, and helps delay the need for additional water supply infrastructure.

CASE STUDY 13 **ORANGE CITY COUNCIL AND PARTNERS**

Central West NSW regional water supply connections

Water sharing between regions via pipeline interconnectors allows water supply in a region to be optimised by moving water between catchments and transferring water from communities with more water to those with less.

Orange to Molong (via Molong Dam), Cumnock and Yeoval Pipeline

Project managed by Cabonne Council and Orange City Council (completed early 2017).

In western NSW, the township of Molong's main water supply is Molong Creek Dam. This project involved the construction of a 16km raw water pipeline from Orange to Molong Creek Dam capable of transferring up to 1 million litres per day.

The existing raw water main from Molong Creek Dam to Molong is then utilised to transfer raw water to Molong when the storage is low. Water is then treated at the Molong Water Treatment Plant (WTP) and transferred via a 49km drinking water main to the townships of Cumnock and Yeoval.

Cabonne Council and the NSW State Government committed $16 million to this project.

Orange to Carcoar Water Treatment Plant Pipeline (via Millthorpe and Blayney)

Project managed by Orange City Council in association with Central Tablelands Water (completed February 2018).

Funded by Orange City Council, Central Tablelands Water and NSW State Government, this $26.3 million project involved the construction of a 60km bi-directional drinking water pipeline between Orange WTP and Carcoar WTP via Blayney (including the townships of Spring Hill and Millthorpe). The pipeline can transfer up to 9 million litres per day of drinking water in both directions.

Macquarie River to Orange Pipeline

Project managed by Orange City Council (completed in early 2015 at a total cost of $38.7 million)

This project delivers up to 12 million litres per day of raw water from the Macquarie River to Orange WTP. The project involved the construction of three transfer pump stations and a 39km pipeline

Cowra to Central Tablelands Water Emergency Connection

Project Managed by Orange City Council with various components contract managed by Central Tablelands Water and Cowra Shire Council (currently under construction).

This $5.5 million NSW State Government funded project involves works to enable an existing one directional pipeline between Carcoar WTP and Cowra WTP to allow drinking water to be transferred in two directions (i.e. Carcoar WTP to Cowra WTP and Cowra WTP to Carcoar WTP). The project involves the upgrading of Inlet Screens and offtake pumps on the Lachlan River at Cowra, the construction of a Pump Station at Woodstock and a Reservoir at Carcoar WTP. The pipeline is capable of transferring up to 3.5 million litres per day in either direction.

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Water efficiency

Using water wisely will always be part of the water security equation in Australia. With many established programs across the country, water utilities continue to help customers reduce their water use. The benefits for customers and the community are many including reduced water and energy costs and deferring the need for large-scale water supply infrastructure.

PROJECTS CONSIDERED	46
ESTIMATED ASSET AGE RANGE (YEARS)	5 - 50
$/KILOLITRE	0.00 – 5.17
MEGALITRES/YEAR	0.01 – 3,690

What does this option include?

Projects range from the supply of water efficient appliances, leak repairs, and behaviour change.

Water efficiency reduces water demand through programs that aim to increase water efficiency and change behaviour.

What is the contribution to water security?

Water efficiency is an important part of water security. By reducing demand for water supply, investment in water efficiency options can maintain water supplies and delay or defer the need for investment in new water supplies.

During the Millennium Drought water efficiency initiatives across Australia were very successful with large decreases in per person water usage. In Sydney for example water usage dropped 30 per cent and in some cities even more.

These efforts continue across the country and include initiatives like Smart Approved WaterMark, the one stop shop for water efficiency certification, advice and solutions in Australia. smartwatermark.org

Smart Approved WaterMark

What are the wider considerations?

Customer research by WSAA and water utilities around the country shows that water efficiency remains an important issue for customers and many want their water utility to support them to do more.

What is the energy use?

Generally water efficiency programs reduce energy use, particularly those programs that include installing water efficient appliances on hot water taps and showers.

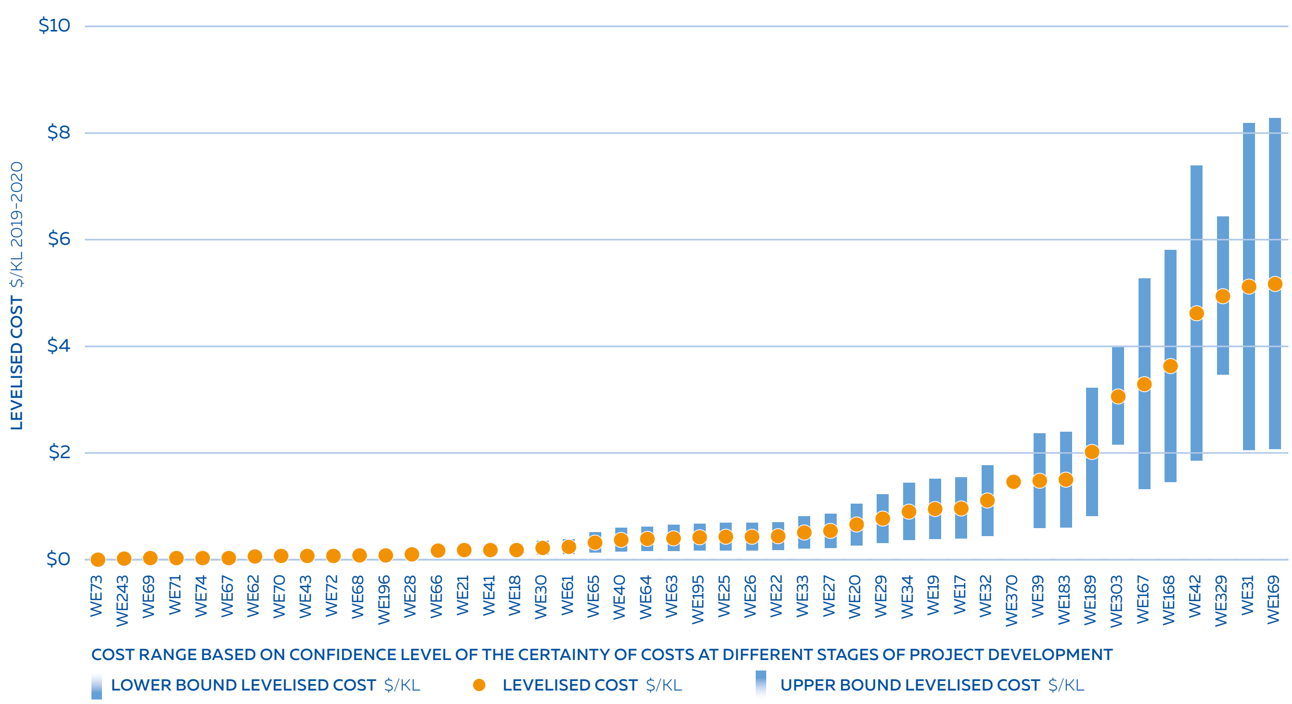
What are the costs?

By their nature, water efficiency projects occur because they are cost-effective for achieving small water savings. As a result, their levelised costs tend to be relatively low. Over 70 per cent of the projects we assessed have a levelised cost of less than $1 per kilolitre. The remaining 30 per cent have levelised costs less than $5.50 per kilolitre.

Key attributes of the estimates include:

- Project costs generally include the supply of the water-efficient appliance or costs associated with a demand management program.
- Water savings from water efficiency projects range from 0.01ML to 3,690ML per annum, though the median yield for these projects is 72ML per annum. Water efficiency projects related to outdoor water savings are dependent on climate conditions.
- Range in data quality – most project costs are either at a concept design or at a planning stage therefore the cost range is +/- 60 per cent. There is a small number of projects which actual costs were provided.
- Levelised costs did not tend to change with higher yields. Yields for most projects are less than 300ML per annum.

FIGURE 19 Levelised costs of water efficiency options $/KL 2019-2020



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CASE STUDY 14 SYDNEY WATER

Strata block retrofit program

WaterFix® Strata delivers large scale, cost-effective water savings to inefficient residential strata-managed buildings. Sydney Water's plumbing service was originally established in April 1999 and over 500,000 properties have received the WaterFix® service. Recently this service has been adapted to suit strata buildings.

Research shows that over 87 per cent of water use in apartment buildings occurs within each apartment, mostly from showers. Sydney Water has achieved water savings of up to 30 per cent for buildings after they have used the WaterFix® Strata service (depending on the building's level of water efficiency). It is estimated the service delivers the best results on buildings using over 450 litres of water per bedroom each day.

The building's possible water savings are estimated by using water efficiency benchmarking tools, identifying the number of bedrooms and reviewing the building's water use history.

Sydney Water works with the strata manager and inspects a sample of units in the building. Once the decision to proceed has been made each apartment owner has an appointment to repair leaks, install water efficient devices and leaks in common areas are fixed. Around 12 blocks of units have received the WaterFix® Strata service with average water savings of 30 per cent.

In 2018-19 Sydney Water invested $354,000 in WaterFix Strata to deliver new water savings of 188 megalitres per year. The current value of the accumulated savings (to August 2020) from the program is $1.26 million or 539 megalitres. Sydney Water is planning to continue to invest in the program which it estimates has a levelised cost of -$0.003/kL (i.e., benefit of 0.3 cents per kilolitre).

Leakage

According to the Bureau of Meteorology, non-revenue water losses average at around 10 per cent of the utilities' system input across Australia.

Given this figure is among the lowest levels in the world, reducing it further may not always be cost effective. However, with a drive towards customer centricity, water utilities are more aware of improving customer experience through addressing the impacts of leakage.

In simple terms, leakage is the component of water that does not make it to the customer and is "lost" somewhere in the system. Leakage can be categorised into three categories:

- Reported bursts visible at the surface and reported by the public or utility staff
- Unreported bursts not visible at the surface, and usually picked up through investigation or leak detection surveys
- Background leakage small leaks that cannot be detected, which over time may gradually worsen until they can be detected.

Water utilities across Australia use different strategies to reduce leakage including:

Pressure management

Reduction of excess average and maximum pressures.

Active leakage control

Monitoring of flows in metered areas to identify leaks and repair before they become a greater issue.

Pipeline and assets management

Material selection, installation, maintenance, rehabilitation and replacement, and is commonly associated with renewals.

Speed and quality of repairs

Repairs done quickly and to a suitable standard.

When employed simultaneously these strategies positively influence each other. Technological advances mean that utilities can better monitor network systems and pro-actively manage against leaks and bursts. Any decisions and investment should always consider customer expectations and requirements.

CASE STUDY 15 **WANNON WATER**

Warrnambool Roof Water Harvesting

In a first in Australia, Wannon Water's Warrnambool Roof Water Harvesting Initiative is a leading example of integrated water management. The project 'taps' a new water catchment by capturing water from roofs that would otherwise be lost in run-off, supporting more liveable and sustainable cities.

Roof Water Harvesting refers to rain water being collected from rooftops in new residential or industrial subdivisions and transported through pipes to an existing raw water storage. The water is then treated at the water treatment plant and becomes part of the drinking water supply.

The Warrnambool Roof Water Harvesting Initiative began in 2011 with the pilot applied to 250 lots across two subdivisions. It has progressively expanded and now includes industrial sheds at the Gateway Business Park in Horne Road.

In an average year, the system harvests all the annual water needs of the properties it is connected to.

This system is progressively being expanded as development occurs in Warrnambool's main north-east growth corridor over the next 30 years.

The roofs of some 3,000 new homes will eventually form an urban catchment that is expected to contribute 471 million litres of water each year into the Brierly Basin and then treated at the Warrnambool Water Treatment Plant for urban drinking water.

There are a number of non-financial benefits of the roof water harvesting project such as:

- Lower energy use and associated greenhouse gas generation
- Reducing the impact of the significant increase in runoff from large impervious surfaces associated with residential development – Russell's Creek is limited in capacity and susceptible to flooding
- Utilising a water resource that would otherwise go to waste, noting that Russell's Creek does not have any environmental values that are reduced by the interception of the roof water
- Providing the ability to implement the project progressively thereby reducing the volume of water required to be harvested from the Gellibrand River, resulting in improved environmental flows in the Gellibrand River
- Raising the consciousness within the community of the value of rainwater
- Providing a demonstration site of this concept for others to see what is possible as an augmentation option
- Replacing the need for new homeowners to install a rainwater tank that takes up valuable space on their land or introduce a maintenance requirement

The total cost of the ultimate scheme is expected to be $18 million, with the levelised cost estimated as $2.39 - $3.50.

Approach to our study

WSAA engaged Marsden Jacob Associates to undertake the data collection and analysis for this project. Marsden Jacob Associates applied a methodology based on accepted best practice for calculating levelised cost and aligned with guidelines set by water industry regulators.

This section explains the dataset and the methodology and assumptions used to calculate the levelised costs.

Data collection

For this project, WSAA and Marsden Jacob Associates developed a dataset of approximately 330 water supply projects from water agencies across Australia. The data set comprises of projects from various sources.

These include:

- New data collected from WSAA members (195 projects)
- Previous and current water supply economic analyses by Marsden Jacob Associates and information available from published reports. For past projects, we have used water supply projects after 2009 (135 projects).

We developed the database with standard fields and definitions including information on:

Nature of the project

Name, location, type of project, asset life.

Yield

Maximum capacity, likely yield, time to reach maximum yield, climate dependency, water type.

Costs

Total capital and annual operating and maintenance costs, year of cost estimates (and conversion into $2019–20).

Stage of project development

Concept design, planning, construction estimate, complete, which affects the level of confidence in the cost estimates.

Estimated asset life

We sought permission to use data that was not publicly available. To preserve the confidentiality of information provided, we have de-identified individual projects, and do not present our findings in a form that could identify specific projects.

The dataset

Categories

We classified projects into water supply option categories:

- Groundwater
- Rainwater tanks
- Purified recycled water for drinking
- Recycled water for non-drinking
- Seawater desalination
- Stormwater harvesting precinct-scale
- Stormwater harvesting small-scale
- Surface water
- Water carting
- Water sharing between regions
- Water efficiency measures
- Other projects.

Other projects include roofwater harvesting and asset upgrades and improvements, including catchment thinning and bore upgrades.

Data age

Most of the projects in the dataset are relatively recent. Around 60 per cent of projects are from 2015 or after. Around 86 per cent of the projects are from within the last 10 years. The oldest projects date from 2009.

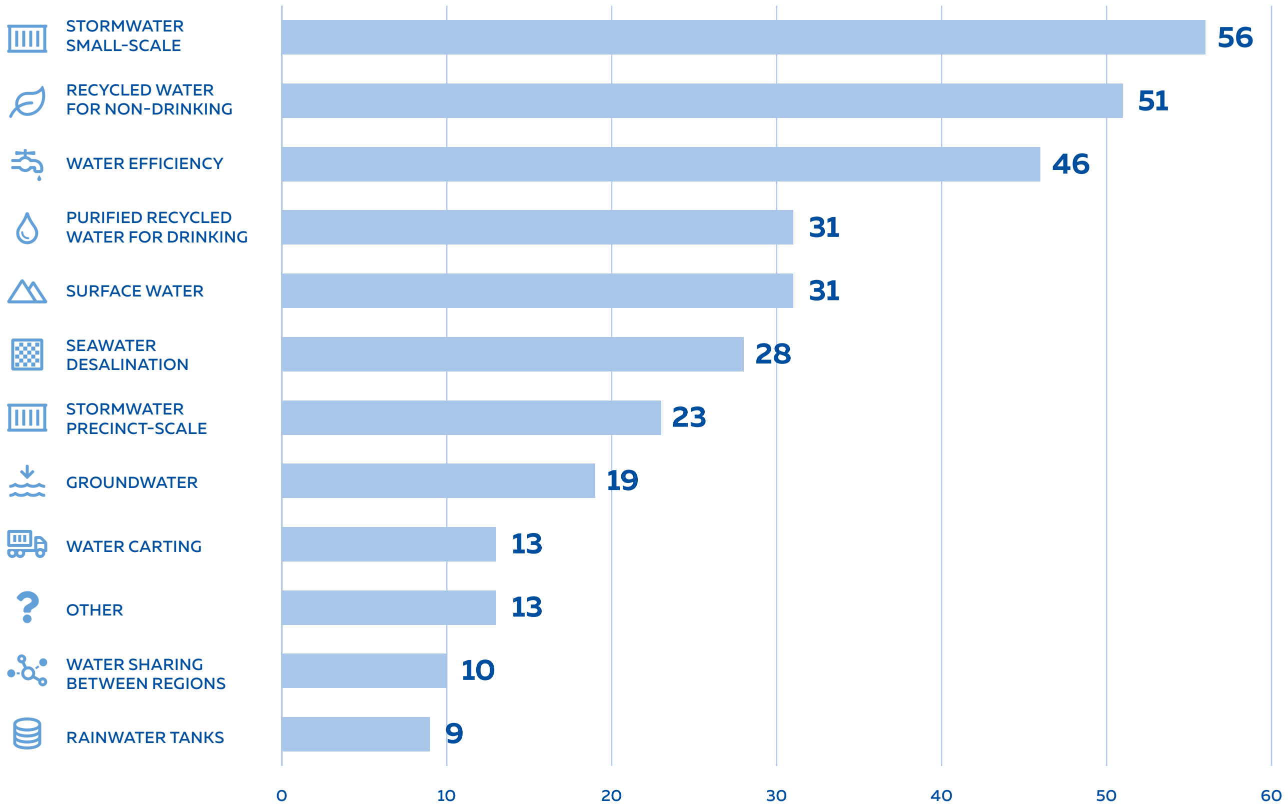
For all projects, we have escalated costs in $2019–20 using ABS Consumer Price Index data.

Confidence levels

Project costs used in the dataset have been sourced from estimates at different stages of project development. These cost estimates range from projects in early concept design through to completed projects.

The stage of project development governs the level of confidence and accuracy of the cost estimates. Where available, we have applied confidence intervals from the project documentation to develop an upper and lower bound levelised cost. Where confidence intervals were not available, we estimated intervals based on past experience. The upper and lower bound levelised cost for each project is identified within each water supply option chart.

FIGURE 20 Number of water supply projects included in data set



Asset age

We collected the estimated asset age based on information available from the project documentation. Where the information was not available, we applied an asset age consistent with other projects of that category. The levelised cost of the project is calculated for one asset lifecycle. Typical asset age by category is shown below.

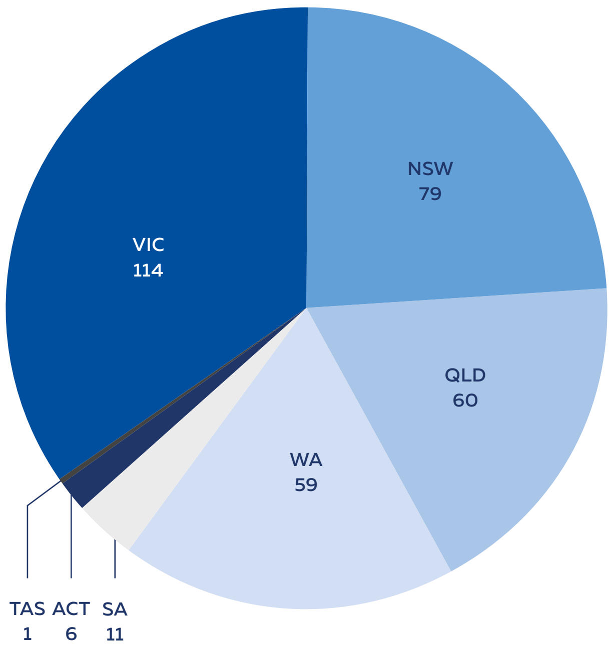
ASSET TYPE	ESTIMATE ASSET AGE RANGE (YEARS)
Groundwater	25-50
Rainwater tanks	20
Purified recycled water for drinking	20-50
Recycled water for non-drinking	35-50
Seawater desalination	35-50
Stormwater harvesting and reuse	25-50
Surface water	30-130
Water sharing between regions	35-80
Water efficiency	5-50
Others	Varied

Water carting is not an asset-based option so asset age is not included.

Location of water supply projects

Our dataset contains water supply projects from across Australia.

FIGURE 21 Location of water supply projects



Levelised cost calculation

Levelised costs are a standardised way to measure the costs that go into producing a megalitre of water supply. Levelised cost provides a useful measure to easily compare water supply or conservation options of varying scales and timeframes, on an equivalent basis. It is a measure of lifecycle costs for a project, not just the upfront costs.

Levelised costs are commonly used in the water industry. For example, Sydney Water and Hunter Water calculate levelised costs of water conservation projects as part of their Economic Level of Water Conservation (ELWC) methodology, required under their operating licences.

Under the ELWC framework, a water conservation project is assessed as economically viable where the levelised cost is less than or equal to the value of water.

In this section, we discuss how levelised cost is calculated and its components. We also outline the important assumptions we have made in our calculations.

Formula for calculating levelised costs

Equation 1 shows the standard levelised economic cost calculation. The calculation of an economic levelised cost, consistent with whole of lifecycle analysis includes the direct, indirect and externality costs and benefits attributed to the project.

In this analysis, we calculate the direct cost of project levelised costs. The levelised project cost excludes the indirect and externality components (Equation 2).

EQUATION 1 Levelised economic cost formula

$$Levelised\ economic\ cost\ \left(\frac{\$}{kL}\right) = \frac{PV(project\ costs) - PV(avoided\ and\ avoidable\ costs) - PV(externalities)}{PV(water\ yield)}$$

EQUATION 2 Levelised project cost

$$Levelised\ project\ cost\ \left(\frac{\$}{kL}\right) = \frac{PV(project\ costs)}{PV(water\ yield)}$$

Where

PV project costs

The present value of the stream of costs needed to deliver a project, including upfront capital costs and ongoing operating and maintenance costs over the life of the project. The present value is calculated over one asset lifecycle. Costs do not include project overheads.

PV avoided and avoidable costs

The present value of existing or future capital or operating costs that can be avoided as a result of the project.

PV (technical) externalities

The present value of technical (as distinct from pecuniary) costs and benefits to external parties that arise due to the project. In practice, including externalities is challenging due to a lack of robust data.

PV water yield is the present value of the annual water yield (or water savings) over one asset lifecycle. Water yield is based on project information about the expected maximum yield and the annual likely yield over the asset life.

Where the project progressively increases production or yield to reach the maximum, we have applied this gradual increase in calculating the present value of yield.

Discount rate

Is applied to convert future values into present values and represents the opportunity cost of investing in other public assets. A real discount rate of 4.5 per cent has been applied in our analysis which is consistent with of current real weighted cost of capital used for in the setting of prices across New South Wales, Victoria and South Australia.

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