WSAA DAMS

INFORMATION PACK ONE

WATER SERVICES
ASSOCIATION OF AUSTRALIA

CONTENTS

CUSTOMER DRIVEN, ENRICHING LIFE

The Water Services Association of Australia publishes this series of information packs on behalf of the Australian urban water industry to present the current situation on key issues of relevance to the industry.

The urban water industry is striving to achieve four outcomes by the year 2030. By working together with a common goal WSAA members intend to be:

> **The most efficient trusted and valued service providers in Australia**

> **A compelling voice in national policy making**

> **A valued partner in urban and land use planning to enrich communities**

As well as taking a strong role in the:

> **Stewardship of the urban water cycle**

The urban water industry is committed to ensuring customers and communities have the water they need to live their lives. To achieve this we support a diversified portfolio of water sources accepting that some water sources have multiple roles.

ABOUT WATER SERVICES ASSOCIATION OF AUSTRALIA (WSAA)

WSAA is the industry body that supports the Australian urban water industry. Its members and associate members provide water and sewage services to approximately 16 million Australians and many of Australia's largest industrial and commercial enterprises. WSAA is always willing to innovate and seek new and smarter ways of doing things and prides itself on making decisions that are based on sound knowledge and research.

SUMMARY POINTS

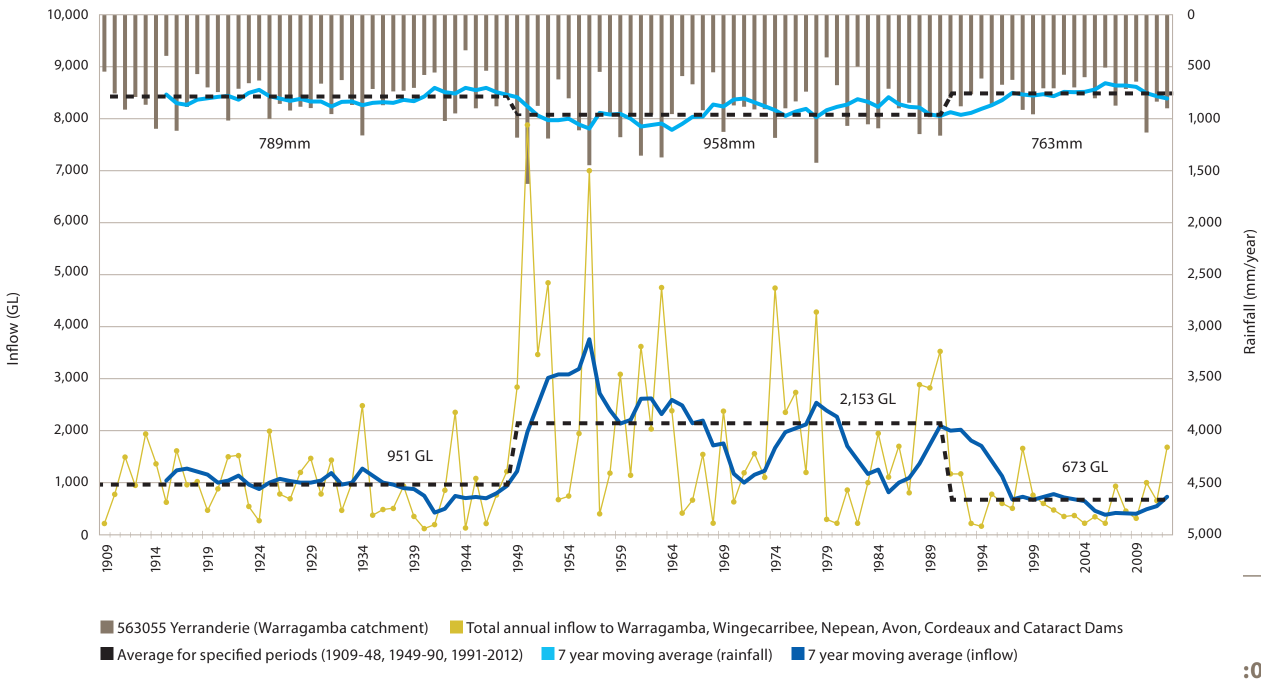
- Over the long term, dams can provide the cheapest source of bulk water for the urban environment, and dam water is easier to treat than other sources, such as seawater desalination. However, their construction can involve significant costs, and environmental impacts.
- The changing climate is affecting the role of dams in public water supply. Long-term forecasts are for less rain in southern Australia which challenges water quality and quantity management in existing dams.
- Most dams are built for water supply but a small number like Brisbane's Wivenhoe Dam are built both for water storage and flood mitigation. Recent record floods resulted in high damage bills, so good dam management that protects life and property, is a high priority.
- Dams are part of a wider ecosystem and are integral to communities use for recreation, tourism and agriculture. Collaboration, particularly with land use planners, is needed to ensure better decision-making that protects drinking water quality and quantity.
- Dams are assets that need to be on the balance sheet. The ecosystem services provided by dams for public water supply can top over a billion dollars, as is estimated to be the case for Melbourne's closed catchments.
- Dams do not just store surface water, in parts of Australia dams store water from various sources such as seawater desalination and groundwater.
- Australia is still building dams for public water supply, such as the recent enlargement of Cotter Dam in ACT. Utilities are quantifying all costs and benefits, testing climate and demand-related scenarios, and exploring all options with communities and government early in the planning to ensure the most optimal solution for water supply.

DAMS IN AUSTRALIA

Surface water dams have long dominated Australia's urban water system. The first two – Yan Yean outside Melbourne and Lake Parramatta, Sydney – were completed in 1857. Dam building continued steadily, accelerating after WW II. Today, there are 500 large (more than 15m high) dams. The Sydney Catchment Authority has 20 supply dams and weirs that hold more water per head of population than any other city in the world. Other metropolitan areas such as Melbourne and South East Queensland (SEQ) store dam water providing for up to seven years of secure supply based on historical inflows. Dams smooth out seasonal, annual and multi-year drought variations in inflow, to distribute water supply according to daily demands. The capacity of dams to sustain supply is dictated by local site conditions and stream flow conditions that are affected by climate and weather. This leads to the characterisation of dams as a 'climate-dependent water source'.

Dams generally provide the cheapest source of bulk water for the urban environment. Dams are typically

Fig. 1 **TOTAL ANNUAL CATCHMENT INFLOW TO SCA'S HAWKESBURY – NEPEAN DAMS AND RAINFALL AT YERRANDERIE**



Note: Graph does not include inflows to Woronora Dam and Shoalhaven transfers

gravity-fed and are easier to treat than other sources, such as seawater desalination. For a long time dams have met demand for water. Occasional imbalances have been managed by temporary water restrictions. However, the role of dams in public water supply and flood mitigation has been brought under the 'political' microscope by the long term drying trend in the south of Western Australia, by the Millennium Drought (1997-2009), and by the record floods on the east coast/southeast of Australia (2010/11).

In rural and regional Australia dams have played a big part in building rural and regional prosperity. Many towns around Australia are dependent on dams for their water supplies.

The building and management of dams has reflected how regularly Australia suffers from droughts and floods. However, this is now being challenged by changing climate conditions and some of the surrounding uncertainties, particularly the severity and timing of extreme weather events.

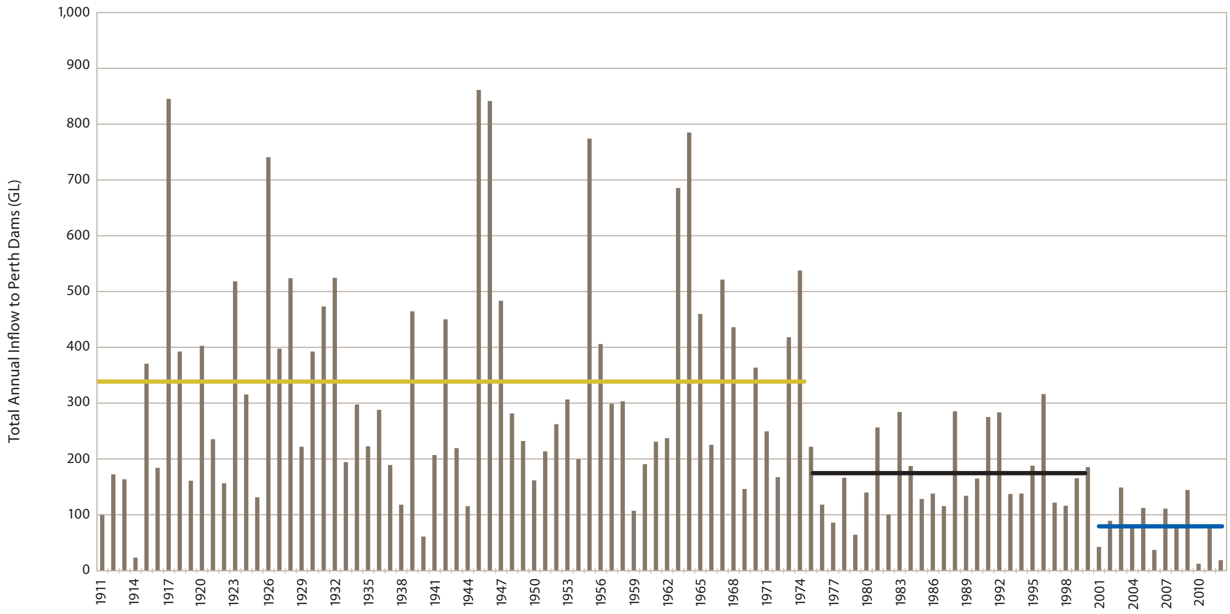
Climate risk – not enough rain

The water supply risk includes early projections of up to 10% less rainfall across southern Australia by 2030 and 20% by 2050. They also include more extreme events including drought, floods and bushfires (CSIRO & BOM 2007, 2011). This is crucial for public water supply in Australia's most populous areas.

The south west of Australia has experienced a step change in its rainfall and stream flow patterns (Figure 2). The long-term drying trend evident from the mid-1970s currently places this area and the city of Perth in a position where it is unlikely that any new dams will ever be built.

In Victoria during the Millennium Drought, stream flow reductions into dams were four times greater than the decline in rainfall (CSIRO 2010). This occurred not only because of a general decline in annual rainfall, but because reductions in autumn changes meant catchments were drier at the start of winter, resulting in less efficient winter runoff from catchment areas.

Fig. 2 YEARLY STREAMFLOW FOR MAJOR SURFACE WATER SOURCES – IWSS



This highlights the complex relationship between climate, weather, rainfall and stream flow into dams. The Millennium Drought reduced national GDP by almost 1% and the net welfare costs of mandatory restrictions (invoked during the drought) amounted to several hundred million dollars per jurisdiction per year (PC 2011).

For further details, refer to WSAA's paper 'Climate Change Adaptation in the Australian Urban Water Industry' (WSAA 2012).

Climate risk – too much rain

The proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe (IPCC, 2012). A 1-in-20 year maximum daily rainfall event is likely to become a 1-in-5 to 1-in-15 year event by the end of the 21st century in many regions (IPCC, 2012). According to the Climate Commission 'across Australia, it is more likely than not that heavy rainfall events will become more frequent as the temperature increases. The tendency for increase in intensity may be stronger for the larger, rarer events (current 1-in-20 year events) (Rafter and Abbs, 2009) particularly at the sub-daily timescale' (Westra et al., 2013).

Average inflows into Australia's major dams

Despite record rainfall on the east coast since the Millennium Drought broke, the Climate Commission states that only about one-third of the rainfall debt was paid back with the 2010 and 2011 floods. (Steffen, Hughes & Karoly, 2013).

Table 1 includes information on total dam capacity in Australia's major cities and the average inflows into those dams over time. It includes the reduction in inflows experienced during the Millennium Drought on the east coast, and the long-term drying trend in the southwest of Australia (Perth).

Table. 1 **DAM CAPACITY AND AVERAGE INFLOWS**

Location	Total dam capacity (GL)	Average inflows/yr (GL)
Adelaide	197 (Mount Lofty Ranges dams)	**Mount Lofty Ranges dams** 1892-1990 (177) 1997-2007 (113)
	South Australians also rely heavily on the River Murray for public water supply	**River Murray** 1891-2007 (11,100) 1996-2007 (5,700)
Brisbane	2,220 (12 dams including Wivenhoe) Wivenhoe Dam – 1150	**Wivenhoe Dam** 1984-2001 (572) 2001-2009 (100)
Melbourne	1,294 (Upper Yarra, Thomson, Maroondah and O'Shannassy dams)	**Upper Yarra, Thomson, Maroondah and O'Shannassy dams** Pre-1996 (615) 1997-2009 (376)
Sydney	2,581 (20 dams including Warragamba and Upper Nepean)	**Warragamba and Upper Nepean dams** 1909-1948 (951) 1948-1990 (2153) 1991-2012 (673)
Perth	581 (11 dams)	1911-1974 (338) 1975-2000 (177) 2001-2005 (93) 2006-2012 (66)
Canberra	205 (4 dams)	Pre-1996 (202) 1997-2009 (95)

DAMS AND FLOOD MITIGATION

Dams provide attenuation on flood flows even when at capacity because of the large surface area, the ability to store water, and the constrained rate of outflow through spillways or other release.

At the end of 2010 Queensland had experienced its second wettest year on record experiencing double the mean rainfall. In Victoria the rainfall was 30% higher than average (Steffen, Hughes & Karoly, 2013). The wet season and summer rainfall in 2010/11 for both these states resulted in significant flooding.

However, because of the flood mitigation effects of Wivenhoe Dam, the flood peak in Brisbane in 2011 (4.46m) was fortunately not as high as the record 1974 peak (5.45m).

Nevertheless the impact flooded 14,000 properties, with 1,970 people evacuated (Steffen, Hughes & Karoly, 2013). The Queensland floods also left a damage bill of $2b to local government infrastructure and another $4b to public infrastructure, as well as $2.4b in insurance payouts to date (Insurance Council of Australia 2013).

Wivenhoe Dam – Brisbane

This was built on the Brisbane River in 1984 to supply water, and provide for flood mitigation. It is able to hold back 1,450 GL above its normal capacity, as a flood mitigation measure. Again, it contributed to reducing the impact of the 2011 floods on Brisbane.

Despite this, the Queensland Government announced a Commission of Inquiry into the management of Wivenhoe during those floods. The final report recommended that dam operators should temporarily reduce the Wivenhoe Dam level to 75 per cent of its normal capacity if the Bureau of Meteorology makes another strong warning about an extremely heavy wet season.

In making this decision the Minister for Water seeks advice in November each year from the Bureau of Meteorology and the Department of Energy and Water Supply. Previous and current seasonal outlooks, current dams levels, water security, and dam operations are considered, to determine the extent to which lowering the dams is likely to mitigate the impacts of a potential flood.

Warragamba Dam – Sydney

Built following a record drought in the 1930s, it is one of the largest domestic water supply dams in the world. Originally the dam had one spillway controlled by gates.

When new flood estimation methodologies indicated that the dam could experience floods much greater than originally anticipated, the dam wall was raised five metres and strengthened by post tension anchors. The second stage, completed in 2002, involved building an auxilliary spillway for management of floodwaters during rare or extreme conditions (1:750 year events and greater).

The operation of the main spillway gates in 2012 (in response to high rainfall – but not a major flood event) sparked significant interest, as the dam had not spilt for 14 years. In response to the recent spill from Warragamba Dam and the experience in Brisbane, the NSW Government has commenced a detailed review of the flood management arrangements for the Hawkesbury-Nepean Valley. Options include raising the Warragamba Dam wall to provide some flood mitigation. A flood of the rarity of the 2011 Brisbane floods would leave a significant damage bill. The review will also consider whether the use of alternative operating procedures at Warragamba Dam might assist in mitigating flood impacts downstream. The Government expects to receive findings of the review by the end of 2013.

CASE STUDY ONE – THE GREATER SYDNEY SURFACE WATER STORAGE SYSTEM STORAGE SY

This system supplies Sydney, the Blue Mountains, the Illawarra, the Southern Highlands, the Shoalhaven and Goulburn (supplementary supply), and has a total capacity of about 2582 GL. Despite the average stream flows since 1991 being at their lowest ever, the severe drought years since 1991 have not been as bad in Sydney as those severe drought years during WWII (Figure 1). The following principles guide the design and management of the system.

> Water supply storages (dams) act as buffers against highly variable surface water supplies fed from rainwater. In other words, Sydney's dams have the capacity to hold 5.4 years of water supply to take us through prolonged drought periods.

> The Sydney Catchment Authority's water supply system eliminates the likelihood of running out of water, and minimises the frequency and duration of water restrictions.

> Evidence shows that there are reasonable inflows to Sydney's dams even during extended drought periods. For example, during the depths of the last drought (2001-2007), the inflows reduced to 372 GL in 2004. This was still around 70% of Sydney's demand in that year.

> To protect the water supply from running dry in drought periods, production from the seawater desalination plant occurs when dam levels reach 70%, and at 50% water restrictions are invoked. The reductions in demand achieved by these initiatives and smaller scale alternative water supplies like recycled water, combined with the catchment inflows that occur even during drought, ensure a secure and reliable water supply.

DAMS AND DRINKING WATER QUALITY

In addition to storing water, dams provide detention times that improve water quality in a number of important respects. This includes natural processes where pathogens die off, and particulate matter settles out. Dams also attenuate fluctuations in water quality, which reduces water quality risks.

Dam storage can also introduce water quality risks associated with cyanobacterial (blue green algae) blooms and the release of iron and manganese from sediments. Manipulating water in the dam and undertaking catchment management activities to reduce nutrient runoff can reduce this risk. Dams are either part of open catchments or closed catchments.

Open catchments

Open catchments such as those in SEQ are areas where land use is mixed. While used to harvest water these catchments also include other valuable activities such as farming and recreation. Water from storages in an open catchment undergoes treatment through sophisticated filtration and disinfection systems, given the higher levels of sedimentation and pollutants. Good land management is the first, and best, way to improve the quality of water stored and released from dams. In open catchments, improving the biodiversity of the catchment and working towards more sustainable land use is the key. In most jurisdictions, this occurs through:

> land use planning and vegetation clearing controls

> devising and using assessment tools for new developments (eg the neutral or beneficial effect test)

> catchment management activities such as tree planting, stream rehabilitation and soil conservation

> community education activities.

Closed catchments

Closed catchments such as those for most of Melbourne's supplies do not allow public access. The native forest filters rainwater that flows across the land and into rivers and creeks that supply the reservoir. As a result, the quality of the water is very high and requires minimal treatment. Closed catchments provide the highest level of protection to drinking water supplies. Melbourne Water for example estimates the water quality benefits of ecosystem services provided by closed catchments is:

> Capital $1.1b

> Operating $110m plus fixed costs, or around $60m/yr

CASE STUDY TWO – **BARWON WATER REGIONAL WATER CORPORATION**

Barwon Water, Australia's largest regional water corporation delivers services to 285,000 residents. This can rise to 510,000 residents over the holiday periods. Most of these people receive water from one of 12 major dams. Barwon Water's recent Water Supply Demand Strategy (2012-2062) identifies that, with the permanent water savings plan combined with the occasional use of temporary water restrictions, the dams supplying the coastal townships of Aireys Inlet, Apollo Bay and Lorne (all popular holiday destinations) will deliver water security for the next 50 years. This is provided the new storage for Apollo Bay is completed in 2014.

COST OF DAMS

Over the years, dams have provided a relatively cheap supply of water. Approximately $0.30-$0.90/kL for raw water through to treated dam water; delivered via a gravity fed system.

The relative difference in costs between dams and seawater desalination ($1.50-$5/kL) is magnified because most large dams were built, and partially paid for, many years ago. Current water users have been receiving cheap water from the old infrastructure paid for by older generations, but are now paying for the current 'spike' in new infrastructure costs. These costs to some extent will equalise over time.

However, for new dams there can be significant costs. Environmental and social impacts associated with their construction add to the financial cost. As this will vary depending on the location and other factors it is difficult to provide an estimate of these financial costs to compare to the financial cost of constructing a seawater desalination plant.

The cost to build a large dam or a seawater desalination plant in today's dollars is significant. An informed decision must include a good understanding of the factors affecting future demand, like population growth. It must take into account changing development patterns, appliance efficiency and customer behaviour. It must combine these with climate scenario modelling, and environmental flow requirements.

INDUSTRY RESPONSE TO CLIMATE UNCERTAINTY

Engaging with customers and communities

Dams are major regional infrastructure. This means that existing and potential dams attract many stakeholders, often with competing interests. Balancing these interests across the environmental, social, economic and cultural values attributed to dams, is complex. The industry is also aware of the need to engage with regional planners and a broad network of stakeholders. The work completed by ACTEW in the lead up to a decision to enlarge Cotter Dam illustrates this (see case study 4).

Adaptive planning

Adaptive planning is the industry's way of managing risk associated with variables that influence demand for water. A number of utilities have created approaches incorporating:

> the identification of flexible portfolios of water supply and water efficiency options. These may be at the site scale (eg household rainwater tanks), the local scale (eg third pipe recycled water schemes), and at the city/regional scale (eg large scale seawater desalination plants)

> scenario planning, combined with risk assessment

> development of severe drought contingency plans.

For further details please refer to WSAA's paper on 'Urban Water Security' (2013).

CASE STUDY THREE – THE NEUTRAL OR BENEFICIAL EFFECT TEST (SYDNEY CATCHMENT AUTHORITY)

In Sydney's drinking water catchments, councils cannot approve development applications unless they are satisfied that the development would have a neutral or beneficial effect on water quality. Where the councils are not satisfied, they are required to refer the application to the SCA seeking concurrence. This requirement is set out in the legal document 'Drinking Water Catchments Regional Environmental Plan No. 1'. The outcomes from the SCA's assessment become conditions of concurrence that are included in council conditions of development consent. The REP is also responsible for:

> developing rectification action plans

> setting water quality objectives in line with the NSW Government's priorities for water quality protection

> introducing strategic land and water capability assessments which identify appropriate types and intensity of land use that will not adversely affect water quality.

Using dams to store desalinated or recycled water

Dams can also play a role as storages for climate independent sources of water like seawater desalination and recycled water. Dams in Perth are regularly used to balance storage for sources ranging from surface and groundwater to desalination, before distribution to customers in periods of greater demand. In some other cities dams may also be used to store desalinated water when the plants are operating. In Melbourne, Cardinia Reservoir will be used to store water from the Wonthaggi seawater desalination plant. Australia does not currently replenish its dams with highly treated sewage. Other parts of the world do. In Singapore approximately 11 million litres of recycled water is added every day to a reservoir, then further treated as part of Singapore's normal drinking water treatment system. This source meets 30 per cent of the nation's water needs.

Developing technologies to decrease evaporation from dams

The dams that are more vulnerable to climate change will be the larger shallower ones in areas where high evaporation rates are most likely to increase. Even now, annual loss of water from storages through evaporation can exceed 40 per cent of water stored over a year (Prime et al. 2012). The volume of water lost through evaporation from dams in South East Queensland is roughly equal to that supplied through the distribution system, 300GL according to the Urban Water Security Research Alliance (Yao X et al. 2010). By contrast, Sydney's evaporation rate is approximately 100 GL/yr (or 20% of volume supplied), by virtue of the deep storages and low surface area to volume ratios.

Developing new technologies to reduce evaporation is important. Food grade polymer modules that float on a dam have been trialed in the northwest of Victoria with great success – 88% reduction in evaporation, with positive effects on water quality with lower temperatures maintained (GWMWater 2011).

Valuing ecosystem services

As stated earlier catchment ecosystems provide important 'natural' infrastructure for water quality and supply, and protection against water-related hazards. A multiple barrier approach recognises this. Valuing ecosystem services can help WSAA members deliver on their goals, but a key shift needs to occur beyond just the 'valuation'. Catchment ecosystem values need to be integrated into utility and regulatory decision-making processes.

This means counting catchments as corporate assets. It means factoring the value of ecosystem services into the investment appraisals and cost-benefit analysis applied to water investments.

CASE STUDY FOUR – ENLARGEMENT OF COTTER DAM – CANBERRA (ACTEW)

The proposal to enlarge the Cotter Dam is part of a suite of initiatives to secure the ACT's water supply. These initiatives were chosen after four years of investigations including the ACT Government's 'Think water, act water – a strategy for sustainable water resources management', and ACTEW's Future Water Options project.

Enlarging the Cotter Dam has expanded its capacity from 4GL to 78GL. This inundated 231ha of land, most of it a former pine forest destroyed by fires. A further 38ha was cleared for construction and ancillary works. The Cotter Dam project proved to be the most appropriate option because it:

> provides the greatest net economic benefit to the community – several hundred million dollars. The dam delivers amounts of water similar to those projected for the large Tennent Dam option, but with less risk, in a quicker timeframe, and at half the capital cost (only $363m)

> has low environmental impacts

> makes use of existing infrastructure (pump station at Lower Cotter and the Mount Stromlo WTP)

> draws water from a more reliable catchment than the Tennent or Googong catchments

> catches much of the overflow from storm events that the current dams in the Cotter system cannot store.

The dam enlargement is the biggest project of its type in Canberra for 35 years. About 2,800 people have worked on the dam, some from as far as England. The Cotter Recreation Precinct includes the popular picnic and recreation areas of Cotter Avenue, Cotter Campground, Cotter Bend, Casuarina Sands and the immediately surrounding forest areas. The Canberra community places a high value on the recreation opportunities within the Cotter Precinct. The project has included upgrading recreational facilities and providing new recreation experiences. One, the new Cotter Dam Discovery Trail, educates the community about Canberra's water history, and has provided unique viewing and educational opportunities of the construction of the dam.

To demonstrate the broad economic values attributed to natural assets, Melbourne Water recently attempted to quantify the other benefits associated with Cardinia Reservoir (a catchment area and man-made receiving body for water from Silvan Dam and the Wonthaggi seawater desalination plant), as well as the adjoining recreation area, and the Cardinia Creek. In total the value of those natural assets is estimated to be about $173m.

Protecting rivers – the role of environmental flows

Rivers, streams and wetlands need certain amounts of water at certain times to support healthy aquatic ecosystems. In rivers with dams, or those used for irrigation or disposal of treated sewage, this normal flow is changed. To compensate, water may be released from dams at certain times to allow rivers to function normally. Water may also be protected from abstraction – where water is removed from a river for irrigation or some other purpose (ACT Govt). Every state in Australia has laws and/or guidelines governing abstraction rates from rivers as well as the amount of water needed in reserve to protect the natural flow of our rivers.

For example in the ACT, environmental flow volumes required by regulation change in response to whether or not the ACT is under water restrictions due to drought. In 2012 a total of 374GL or environmental flows came from the dams on the Cotter and Queanbeyan rivers, and from the Lower Molonglo water treatment plant in the ACT. Due to good rainfall in these catchments in 2012 all of the dams overspilled and released more water that the regulated environmental releases.

CASE STUDY FIVE – **ECOSYSTEM VALUATION IN THE BLUE LAKE CATCHMENT, MOUNT GAMBIER SOUTH AUSTRALIA**

SA Water is responsible for the quality and availability of reticulated water distributed to its customers. One of the key water sources in South Australia's south east is Blue Lake, primarily fed by groundwater (an unconfined aquifer). As well as providing most of the domestic, commercial and industrial water for the City of Mount Gambier, the area is an important recreational destination, attracting around 400,000 visitors a year. The catchment for the groundwater aquifers that feed Blue Lake (the "Capture Zone") covers an area of 28,610 hectares, and is comprised of a mosaic of grazing land (around 60% of the catchment), urban settlements, plantation forestry and irrigated farms.

Several government agencies cooperate in the management of the Blue Lake Catchment to preserve its various water and ecosystem services. Overall, common goals include:

> Maintaining or improving water quality (drinking water provision; touristic attraction due to vibrant blue lake water colour in summer)

> Avoiding/mitigating further lake level decline

Natural ecosystems in the Blue Lake Catchment can deliver important water quality and supply services according to a broad evaluation of the Blue Lake Catchment completed in 2009 (SA Water and University of South Australia 2009). Four catchment management options were assessed against the identified ecosystem services covering water quality and quantity as well as other values linked to the human wellbeing and economic processes in the region. The results of the valuation exercise indicated potential order-of-magnitude estimates of economic gains achievable by the tested management options.

	Catchment ecosystem management options			
	Drainage well management	**Water-sensitive urban design and mini-wetlands**	**Natural and constructed wetlands**	**Rainwater harvesting**
Water service values	Reduced risk of water supply contamination	More efficient stormwater capture and re-use	Water replenishment and purification	Water capture and use
Other ecosystem service values		Recreation, amenity and aesthetic	Recreation, amenity, aesthetic, biodiversity, carbon store, fuel and other products from reed crop	
Net Present Value(approx)	$5 million	$1 million	$10 million	$20 million

CASE STUDY SIX – PROVIDING ENVIRONMENTAL FLOWS TO AREAS DOWNSTREAM OF SYDNEY'S DAMS

The Sydney Catchment Authority had been releasing environmental flows from its dams since 1999 to supplement low flows in the rivers downstream of its dams. The SCA spent $80m between 2006 and 2011 to rectify the adverse downstream environmental impacts of its dams. Over this period it installed new environmental flow release works at five dams and 10 weirs. It also installed fishways at one dam and 11 weirs. New environmental flows which mimic the full variability of river flows commenced from the SCA's dams on the Nepean River in 2011 and on the Shoalhaven and Woronora rivers in 2009. These flows required substantial retrofitting of release infrastructure to make the full range of environmental flow releases. In 2011-12, 440GL of water was released from the SCA's dams as environmental flows, compared to 418GL provided to supply. The SCA has installed new fishways at dams and weirs to overcome the significant barriers that dams present to the movement and migration of fish. Extensive monitoring and evaluation programs are in place to assess the effectiveness of these works and releases.

CONCLUSION

Building dams may over the long term provide low cost supplies. Initial construction costs, however, are high. Dams can have significant local environmental impacts, including changes to flow regimes in rivers, reduced downstream environmental flows and submergence of land, as well as dislocation of communities. Other options such as seawater desalination, recycled water, rainwater and stormwater harvesting may secure water needs.

To manage climate, population growth, economic and technological uncertainties, it is critical to identify, assess and regularly review various portfolios of supply augmentation and demand management options for a system. However, every urban water system is unique. Good, robust collaborative planning between the industry, regulators and communities is also required. In some locations, dams will be the appropriate solution to meet future water supply needs. Australia has not stopped building dams for public water supply as this paper shows through the example of the recent enlargement of Cotter Dam. However, the long-term drying trend in southwestern Australia (evident from the mid-1970s) currently places this area and the city of Perth in a position where it is unlikely that any new dams will ever be built to meet Perth's public water supply needs.

Building new dams is one option for managing Australia's future water needs. Against a backdrop of changing climate conditions and growing populations, increasing focus on Integrated Water Cycle Management and a portfolio approach to managing water supply and demand, means that dams will continue to play a principal role in meeting water needs.

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