Western Water Price Proposal Submission to the Essential Services Commission

Dear Environmental Services Commission (ESC),

This is a public submission from Kingspan Environmental and Peter Coombes of Urban Water Cycle Solutions in relation to the consultation process for the Western Water Price Proposal closing 28 May 2018. Please advise if this submission is inadmissible due to formatting requirements. For the purposes of this submission, Western Water is considered to operate as part of the Greater Melbourne water services system and operating characteristics of Melbourne water utilities are relevant to the operation of Western Water.

The submission is in five parts, relating to the legal responsibilities of the ESC in responding to the Western Water Price Proposal.

1. Efficient use of services by Customers
    - WIRO clause 8(b)(i) requires the ESC to have regard to the promotion of efficient use of the prescribed services by customers.
    - WI Act section 4C(c) requires the ESC to ensure regulatory decision making has regard to environmental sustainability (including water conservation)
    - WIRO Clause 11(d)(iii) requires the ESC to have regard for Western Water prices to provide signals about the efficient costs of providing prescribed water services to customers…

    The proposed two-part tariff based on a calculated Long Run Marginal Cost has been incorrectly applied. In the time scale of major water infrastructure investment, all costs are variable and apply to marginal costs which should be applied as a usage charge. Incorrect application of high fixed charges does not promote the efficient use of the prescribed services by customers. Fixed charges penalise water efficiency and send a price signal to the customer that water charges are significantly less than they are being charged; leading to greater water consumption and greater water infrastructure than is economically efficient. The attached OzWater 2018 paper presents the relevant arguments and notes the 2017 AWA submission the to the Productivity Commission which states
    High fixed charges for water services has a triple impact - it reduces community incentives to be water efficient, it falsely makes alternative water sources and efficiency less competitive and encourages complacency by water utility providers.

2. Efficiency of Regulated Entities
   - WIRO clause 8(b)(ii) requires the ESC to have regard to the promotion of efficiency in regulated entities.
   - ESC Act section 8(1) requires the ESC to promote the long-term interest of Victorian consumers

The attached 2017 AWA submission the to the Productivity Commission states

The Association submission, similar to the productivity commission's draft report has focused on economic efficiency to date however, has failed to pick up on the role of water efficiency in driving economic reform, in particular focusing on:

- *Supply-side management of water systems remains the prevalent approach to the detriment of cost efficiency*

...

- *Building an understanding of the potential for urban water use efficiency to impact network efficiency and optimisation (and associated relative costs)*

...

- *Transparent cost impact assessment of supply-side 'drought-proofing' infrastructure solutions*

The Association believes there needs to be better planning of urban water supply augmentation including strategic planning to anticipate increases in demand.

The attached Systems Analysis paper (Coombes 2018) indicates in Table 8 that Melbourne utility water operating costs increased by $273/connection or 85% in real terms from 2004 to 2016 with little or no increase in the volume of water supplied or treated. This implies a significant loss of efficiency with no apparent commentary or response from the ESC. Over the same period, Sydney Water operating costs increased by $53/connection or 15% in real terms. Figure 3 shows that over this time period Sydney has achieved water savings from rainwater harvesting and water efficient appliances of over 90GL each year, greater than the capacity of their desalination plant operating at full capacity. The paper concludes:

Systems analysis of historical demographic, water resources and economic data has revealed the benefits of distributed solutions for household water efficiency and rainwater harvesting. A policy requirement for new and renovated dwellings to meet water savings targets in Sydney has acted as an economic market mechanism to drive higher household water savings, lower water tariffs, improved household welfare and more economically efficient utility water services. These methods and insights have broader application in discovering the new economy benefits of water sensitive urban design approaches.

There are multiple case studies and peer-reviewed papers attached demonstrating that water efficiency and distributed solutions have benefits for utility efficiency and customer household bills, not least the AWA 2012 Policy Paper on the Case for Water Efficiency. The historical record suggests the ESC has not had sufficient regard for the efficient operation of Melbourne water utilities and insufficient regard for the importance of water efficiency programs for efficient operation of water utilities.

3. Impact on Competition
    - ESC Act section 8A(1)(c) requires the ESC to have regard to the degree of, and scope for, competition within the industry including countervailing market power and information asymmetries

    Water Utilities compete directly with alternative water sources such as rainwater harvesting and water efficiency which directly impact their annual revenue. The ABS Water Account 2013/14 provided estimates of the value of rainwater harvesting at $540 million across Australia. In Melbourne, in 2013/14 the value of rainwater harvesting was $45.6M worth of water that residents did not need their water utilities to provide. There is no doubt that increased rainwater harvesting reduces the revenue of water utilities. When water utilities comment on water efficiency and rainwater harvesting or other alternative water sources or fund related research they should declare a material conflict of interest. Similarly, in relation to the first point of this submission, the ESC should have regard to the impact of high fixed charges on competing, and potentially more efficient, sources of water.

4. Quality of Analysis and use of top down Averages
    - ESC Act section 8(1) requires the ESC to promote the long-term interest of Victorian consumers

    The quality of analysis carried out by water industry is crucial to the long-term interests of Victorian consumers. At the 2017 Insurance Council of Australia annual forum Geoff Summerhayes the APRA Executive Board Member spoke about a new level of analysis and risk management:

    Practice and expectations are moving beyond mere documentation of static metrics. Robust, scenario-based thinking about risks should be the new standard for risk management. Markets and investors expect to see evidence of more sophisticated analysis to identify risks and strategy for managing them. The questions investors (and regulators) will want answered are not just about "what" but "how". How do you model and identify relevant trends, opportunities and risks? How robust are your strategies given different scenarios and contingencies?

    Whether this level of analysis is cost-effective for each water utility to conduct is for others to determine but it serves as context for two important comments about the quality of analysis on which the ESC is relying

    Firstly, water services analysis continues to be characterised by separate analysis of individual elements rather than a systems approach. For example, inefficient water use, stormwater management, river health and flooding are major water management issues which appear to be outside the ambit of the price analysis but all these costs are borne by the Victorian consumer. Alternative water sources such as rainwater harvesting have the potential to reduce water utility operating costs, water utility infrastructure investment, stormwater management and flooding risks with major benefits for catchment waterways but this level of analysis is beyond that which the ESC appears to consider. An explanation (Surfaces of Big Data) of the Coombes systems analysis is attached.

Secondly, there is a significant methodological flaw with the widespread water industry use of averages for analysis. Averages conceal crucial spatial and temporal variations at the local scale that significantly alter the cumulative outcome at the urban scale. This can lead to critical misunderstanding of water security and requirement for infrastructure with strong economic consequences. A key paper on this topic is attached (Planning for Water Sensitive Communities).

5. Long Term Interests of Victorians
    - ESC Act section 8(1) requires the ESC to promote the long-term interest of Victorian consumers

    The attached legal review considers many of the issues raised in this submission and provides a perspective that the ESC has an 'excessive focus on economic interests of water monopolies at increased consumer expense'. A primary focus on the viability of the water monopolies has a twin impact, it reduces the focus on the long term interests of Victorian consumer which should be the overarching priority and it restricts the dialogue and exchange of ideas to an exchange between the ESC and the water monopolies, rather than the broader community of stakeholders. By way of example the ESC has not, to our knowledge, ever been briefed on the role of water efficiency and rainwater harvesting for economic efficiency by a stakeholder independent of the water monopolies.

THE ECONOMIC INEFFICIENCY OF FIXED CHARGES FOR WATER SERVICES AND THE IMPLICATIONS FOR EFFICIENT WATER USE

Michael Smit, Technical and Sustainability Manager, Kingspan Environmental

KEYWORDS

Fixed charges, variable charges, water efficiency

ABSTRACT

Fixed charges for water services result in households paying over $8 for each kilolitre of water they use compared to the $3.58 variable charge for water. This results in significant economic inefficiencies including disincentives for efficient water use and investing in alternative water sources.

INTRODUCTION

This paper considers the household water services bill of fixed and variable charges for water and sewerage charges based on the kilolitres of water delivered. The quantity of water delivered is the only aspect of the bill that the household manages and is related to both water and sewage charges and is therefore considered a relevant unit for cost comparison.

Using this analysis in South East Queensland indicates households that use an average amount of water pay $8.33/kilolitre for water and sewage services compared to the variable rate for water services of $3.58/kilolitre. Households that use less volume of water annually pay a higher rate for water services than those who use more, varying from $12/kilolitre to about $6/kilolitre.

Arguably this acts as a disincentive to be water efficient. Reducing the household amount of water used increases the unit cost of water received. Saving a significant amount of water by investing in water efficient appliances or a rainwater harvesting system only results in a relatively small reduction in the household water and sewage bill.

METHOD

South East Queensland households pay a combination of fixed and variable charges for water. 2017/18 Queensland Urban Utilities (QUU) water charges shown in Table 1. Queensland Urban Utilities (2018). This general relationship between variable charges and fixed charges is not uncommon for major water utilities.

The fixed and variable prices and charges for water and sewage services were incorporated into a spreadsheet showing the total household bill relative to the kilolitres used annually from 0 to 800 kilolitres. The average household use for QUU customers is 154 kilolitres/annum and this was used as a benchmark.

Analysis of the QUU Annual Report Queensland Urban Utilities (2016/2017) shows developer contributions and gifted infrastructure paid $313 million for new infrastructure for 22,187 new connections. Assuming a 50-year lifetime of the assets this equates to an additional $1.83/kl/connection. This additional fixed charge is reflected in the cost of the house and is not included in the water service charges. This cost to society appears as revenue for QUU.

Table 1: Prices, Charges and Bills

Water access charge/annum	$207
Sewerage access charge/annum	$528
Variable Charge for Water/kilolitre	$3.58 (up to 74 kilolitres/quarter)
Annual Charge for Water based on 154 kilolitres/annum	$566
Total prices and charges/average water volume used	$1301/154 kilolitres
The bill to Households for Water Services/kilolitre	**$8.33**
The bill plus developer charges to Households for Water Services/kilolitre	$10.16

Table 1 shows that the household bill is about $8/kilolitre for water and sewage services compared to a variable rate of $3.58/kilolitre for water alone.

Using this analysis we can also consider how the household bills change for low water users and high water users.

Figure 1 shows that a low water user, using 75 kilolitres/annum or half the local average water use pays over $12/kilolitre. A high water user using 300 kilolitres/annum or twice the local average pays $6/kilolitre.

Figure 2 shows that the rate paid by homeowners for combined water and sewerage services is over $18 for households using less than 50kl/annum and stabilises at about $6/kl over 250kl/annum. The higher rate for households that consume over 74kl/quarter makes almost no difference to the paid rate.

ANALYSIS

The effect of a high proportion of fixed charges significantly penalise water efficient households or, conversely, encourages households to use more water. Figure 1 shows that a low water use household pays $12 for each kilolitre used compared to a high water use household that pays $6 for each kilolitre used.

Water efficiency is penalized by this pricing structure. While a kilolitre of water costs a homeowner over $8; each kilolitre saved only saves $3.58. This disincentive for water efficiency, alternative water sources and innovation in water use creates an economic inefficiency. The result is increased water consumption and implies that we have built more water infrastructure than we need.

Water charges and sewage charges are quite different from the utility perspective. For the household, the two are closely linked. The more water the household uses the more sewage they generate. The actual relationship will vary with the proportion of outdoor uses. Water efficiency savings made reducing water used will also reduce sewage that needs to be treated. Kilolitres of water used is therefore considered a relevant unit for both water and sewage charges.

Alternative water sources such as rainwater harvesting are slightly different because they will reduce water used but not sewage generated.

DISCUSSION

Why do we have fixed charges?

Water utilities apply a complex argument where they try and distinguish between costs that vary with production (marginal costs) and then use fixed charges as a balancing item in a two-part tariff so that total costs equals total revenue. Marsden Jacobs (2004).

This argument is not correct. Over the long term lifetime of major water assets, all fixed costs become variable costs and should be included in marginal cost. Utilities make decisions that determine the cost of infrastructure, upgrades to infrastructure, costs of borrowing money and staff costs. All these are therefore variable costs reflected in the cost of producing another unit of water and should be reflected in variable charges not fixed charges. If water utilities don't apply the full cost of water infrastructure to variable water charges than households will consume more water than they would otherwise have based on the price. This will be reflected in a higher demand for water infrastructure in future because the market is not informing the customer.

Even in the short term, Coombes et al (2015) established that only 27% of the costs of operating water utilities were attributed to fixed and corporate costs but fixed charges represent 57% of the average user's bill.

Are Fixed Costs Fair?

High fixed charges are regressive, this means that low-income households who use very little water will pay a much higher rate than high-income households or other large water users. There is a specific issue around rental property where tenants only pay the variable charge for water, however, the economic reason for tenants not paying the full cost of the water they use is not clear.. .

Are Fixed Charges Efficient?

Absolutely not. Fixed charges distort the market and are therefore inefficient. Coase (1947) The AWA submission to the Productivity Commission on National Water Reform (2017) recognised that high fixed charges reduce community incentives to be water efficient, falsely make alternative water sources and efficiency less competitive and encourage complacency by water utility providers.

The accounting for gifted infrastructure from developers on new subdivisions may also be a market flaw. This represents a cost to society but is considered revenue to the utility. This could result in gold plating and an over-emphasis on centralised water infrastructure over alternative and decentralised ways of providing water services. QUU would have made a loss in 2016/17 without this revenue item.

CONCLUSION

100% variable charges would reflect the real long-term cost of water services and drive economically efficient water use and innovation.

ACKNOWLEDGEMENTS

The work and contribution to this discussion from Professor PJ Coombes.
The professional commitment of the many water utility staff I have worked with in providing a reliable and efficient service

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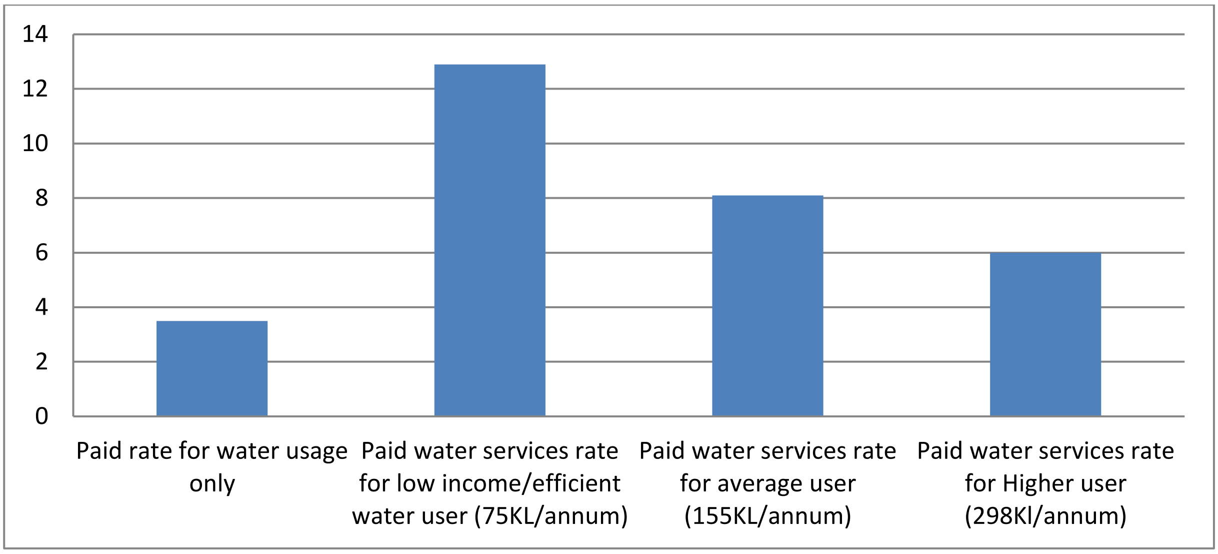

Figure 1 Paid Unit Price for Water Services, low, average and high water users

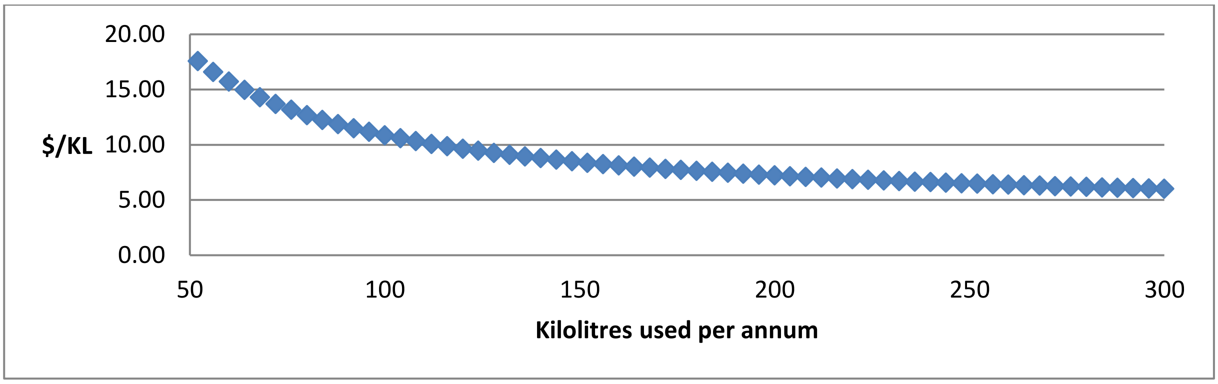

Figure 2: Paid Unit Price for Water Services

Australian Water Association Submission to Productivity Commission on Water Reform: Addendum 1

The Australian Water Association wishes to raise an addendum to its initial submission to the Productivity Commission, following further consultation with its members.

Achieving greater water efficiency

The Association, and its members, is of the view that to achieve efficient and effectives service delivery in the urban water sector, a holistic assessment of integrated water cycle management needs to be considered as this will enable the delivery of more reliable and efficient water services into the future.

The underlying principles of integrated water management have a strong focus towards achieving greater water efficiency. These include:

- Efficient use of **all** and diversified water sources
- Efficient management outcomes in the design, build and operation of water infrastructure
- Incentivising investment in water efficiency appliances and water systems

The Association believes that water efficiency remains a key contribution to the management of water demand and consumption of water within the community and therefore it must be considered holistically in planning frameworks. In particular, The Association believes:

1. Commonwealth should 'incentivise' the states through fiscal measure to ensure better implementation of holistic Integrated Water Cycle Management
2. States should be required to amend statutory planning regimes to ensure that Integrated Water Cycle Management is a requirement for all developments of over a specified threshold

The Association submission, similar to the productivity commission’s draft report has focused on economic efficiency to date however, has failed to pick up on the role of water efficiency in driving economic reform, in particular focusing on:

- Supply-side management of water systems remains the prevalent approach to the detriment of cost efficiency
- Planning agencies (e.g. state and regional land planning bodies and councils) frequently ignore water and sewer provision in strategic planning
- High fixed charges for water services has a triple impact - it reduces community incentives to be water efficient, it falsely makes alternative water sources and efficiency less competitive and encourages complacency by water utility providers
- Building an understanding of the potential for urban water use efficiency to impact network efficiency and optimisation (and associated relative costs)

- Understanding the broader impacts and future risks associated with current water utility pricing models based around increasing fixed charges

- Transparent cost impact assessment of supply-side ‘drought-proofing’ infrastructure solutions

The Association believes there needs to be better planning of urban water supply augmentation including strategic planning to anticipate increases in demand.

Consistency of investment in Research & Development and capacity building

The Association also wishes to highlight the importance of Research & Development (R&D) across The Australian water sector and the need to secure consistent levels of funding.

The Association’s submission under section 5.2 states:

“Greater national collaboration and coordination in areas such as regulatory alignment, R&D coordination, guidelines, industry certification and training and system validation has also been found to have significant potential to increase efficiencies across not only the urban water sector but other sectors contributing to livable and sustainable cities.”

While Research & Development should be considered as part of a nationally coordinated water reform agenda the Association believes that the benefits of water R&D should not be underestimated. In the urban water domain alone, current R&D expenditure has reduced from 0.5% of water utility revenue in 2010 to 0.2% of water utility revenue in 2015, in spite of $170M of research funding producing $1420M of benefits (using Commonwealth CRC model), with a benefit cost ratio of 7.9. Benchmarking studies suggest the optimal level of investment in R&D is 1.0 to 1.2% of industry revenue.

Where the Association has mentioned the value of the National Water Authority to undertake national facilitation and knowledge sharing across the sector on barriers to reform implementation, this would require greater levels of coordinated research not just in regulation but also in skills, science and technology (i.e. water recycling) to enhance the value of our Research & Development platforms. Where these knowledge gaps or barriers are found it should be within the Authority’s best interests to issue competitive Research Gants to allow for knowledge sharing.

The Association is of the view that in order to place Research & Development on a national agenda, there is a requirement for a national funding formula that supports, on a consistent basis, research and capacity building in water science, policy, and management. There is an urgent need for formation of a water R&D fund, under the National Water Authority, with co-investment by industry. The Association sees the development of a national water R&D funding formula as part of the negotiations between the Commonwealth and the States and Territories that we have advocated to create a National Water Plan. By ensuring adequate funding for water R & D Australia can maintain its reputation as a world leader in sustainable water management.

SYSTEMS ANALYSIS AND BIG DATA REVEALS BENEFIT OF NEW ECONOMY SOLUTIONS AT MULTIPLE SCALES

Peter J Coombes[1], Michael Barry[2] and Michael Smit[3]

ABSTRACT: *Historical demographic, water resources and economic "big" data was examined and included in systems analysis to reveal the benefits of distributed solutions for household water efficiency and rainwater harvesting in Australian capital city regions. A policy requirement that new and renovated dwellings to meet water savings targets in Sydney has acted as an economic market mechanism to drive higher growth in household water savings of 48,440 ML since 2007, lower water tariffs, improved household welfare and more economically efficient utility water services. The estimated annual average economic savings to households and the water utility in Sydney was $218 m - $578 m and $58m -$881 m. These methods and insights have broader application for discovering the new economy benefits of water sensitive urban design approaches. This research presents the potential for multiple scales solutions, such as WSUD, to deliver a new economy of solutions that improve the performance of utilities and mitigate impacts on households.*

KEYWORDS: Systems Analysis, Big Data, Economics, Scales, Household Welfare, Utility costs, Cities

[1] Peter J Coombes, Urban Water Cycle Solutions, Newcastle, Australia. Email peter@UWCS.com.au
[2] Michael Barry, BMT WBM, Brisbane, Australia. Email: michael.barry@bmtwbm.com.au
[3] Michael Smit, Thirsty Country. Brisbane Australia. Email: michaels42@gmail.com

1 INTRODUCTION

Cities and surrounding environments are part of a system. Urban services and outcomes should be understood and analysed as part of the system. Australian cities operate at multiple linked temporal and spatial scales, from household to region, and respond to evolving challenges and opportunities. Population growth is expanding areas, increasing densities of cities, and with greater climate variability is driving higher costs of services. In the old economy the services required by cities (such as water and energy) are mostly provided at a single centralised scale. This philosophy fosters provision of urban water services as essentially a transport industry that transfers water, wastewater and stormwater across increasingly long distances.[1]

The millennium drought revealed that decentralised approaches to increase local supply and water efficiency improved the performance of entire systems.[2] Simple strategies including household water efficiency and rainwater harvesting ensured that Australian cities did not run out of water. Solutions at multiple scales produce better overall response to variable challenges in cities. Nevertheless, centralised solutions are preferred and benefits of local strategies including water sensitive urban design (WSUD) are contested by the water industry. The Australian government's Productivity Commission, in 2011, recommended a reduced focus on water restrictions, water use efficiency and conservation in urban water system.[3] These distributed approaches were considered to be economically inefficient when compared utility water supplies. It was assumed that water efficient approaches at households had costs of $770/ML – $33,500/ML in comparison to the estimated costs of utility supply of $750/ML to $1,300/ML. In 2017, the Commission argued that water reuse, water use efficiency, water sensitive urban design and innovation has improved but it is difficult to measure and value benefits of these opportunities that may produce significant local and widespread effects on the urban water sector.[4]

An increased reliance on large scale centralised solutions such as desalination and water grids (long pipelines that connect regions and large scale supply solutions) was considered more efficient. However, the Queensland Audit Office (QOA) has established that the South East Queensland (SEQ) region inherited debt from the water grid is over $9.4 billion that corresponded with diminished economic efficiency of utility urban water supply.[5] It was assumed by the QAO that the regional water utility cannot service the debt due to decreased water use in households which reduced revenue accruing to the utility.

In contrast, Coombes et al., (2015) found that household water efficiency and rainwater harvesting reduced water use in SEQ and would decrease utility debt by over $3.5 billion in the period to 2050. Increased water use resulting from diminished household water efficiency and rainwater harvesting would drive higher utility debt and diminished household welfare from increased utility bills.[1] The economic efficiency of utility water supply was dominated by operational costs which were dependent on the volume of water demands. Similarly, the Westminster water utility in Colorado USA found that water conservation diminished the growth in water supply costs and associated household bills by 135% ($553/year). [6] Growth in household bills for utility water and sewerage services was reduced by 91% ($655/year). There are similar declines in the efficiency of water utilities with associated reductions in household welfare in North America.[7] These impacts on household welfare, dramatic increases in expenses and decline in economic efficiency of utility services are also experienced in the energy sector.[8]

The value and effect of distributed measures on households, utilities and governments is contested or uncertain. A long timeline of historical data and actions is available from Australian government agencies and water utilities that can now be used to investigate the impact of distributed solutions on the performance of urban water services. Systems analysis and forensic investigation of all available big data[9] was used to investigate the impact of household water efficiency and rainwater harvesting on water services to Australian capital city regions of South East Queensland, and Greater Sydney, Melbourne, Perth and Adelaide.

These locations were examined because they include water supply from desalination and different policies for household water efficiency and rainwater harvesting. All regions provided government incentives or subsidies to install water efficient appliances and rainwater harvesting during the Millennium drought between 2005 and

2009. The BASIX State Environmental Planning Policy was established in 2004 requiring a 40% reduction in household water use in new or renovated dwellings in Sydney. The Melbourne region was subject to the Five and Six Star housing efficiency policy that was implemented in 2005. This policy required new detached dwellings to choose either a solar hot water service or rainwater harvesting from a 50 m^2 roof connected to 2 kL rainwater tank that supplies toilet flushing. The SEQ region operated the MP4.2 and MP4.3 planning legislation, from 2008 to 2012, that required water efficient appliances and rainwater harvesting to supply clothes washers and toilets in new households.

The growth in household expenditure on utility water services, household welfare and utility water operating costs is examined to understand the economic efficiency of distributed solutions. This investigation aims to contribute to knowledge about this key question for water sensitive urban design – local actions provide whole of society benefits but what are the benefits and how do these benefits manifest across scales. This investigation also benefited from additional systems analysis of the urban water systems in each region that is reported by Barry and Coombes (2018).[10]

2 HOUSEHOLD WATER USE, WATER EFFICENT APPLIANCES AND RAINWATER HARVESTING

We examined historical household water use, and the installation of water efficient appliances and rainwater harvesting to understand the effects on urban water systems during period 2003 to 2016.

2.1 HOUSEHOLD WATER USE

Annual average household water use from 2003 to 2015 was derived from National Water Commission (NWC) [11], Bureau of Meteorology (BOM) [12] data and Utility Annual Reports by dividing total residential water use by number of connected residential properties in each year. Greater Melbourne was defined as the areas serviced by City West Water, South East Water and Yarra Valley Water. The SEQ region includes areas served by Urban Utilities, Unity Water, Gold Coast Water, Logan Water and Redlands Water. The results for Greater Sydney, Adelaide, Perth and Melbourne, and South East Queensland (SEQ) are shown in Figure 1.

Figure 1 shows that household water use in each region was reduced (SEQ 28%, Sydney 10%, Perth and Melbourne 5%) or only slightly increased in Adelaide (2%) since 2003.

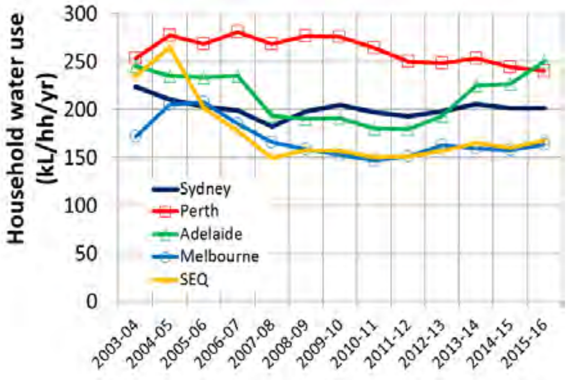

Figure 1: *Historical average annual household water use for South East Queensland (SEQ), and Greater Sydney, Perth, Adelaide and Melbourne regions from 2003 to 2016.*

These reductions or small increase in average household water use were achieved in the context of substantial growth in dwellings in each region from 29.8% for SEQ to 14.9% for Sydney. The impact of water restrictions during the drought period from 2005 to 2009 is apparent from Figure 1 as small reductions in household water use in some regions. However, the overwhelming outcome is the stabilisation or reduction in average household water use over the entire period which indicates increased efficiency of household water use.

2.2 INSTALLATION OF WATER EFFICIENT APPLIANCES AND RAINWATER HARVESTING

Installation of rainwater harvesting and water efficient appliances was investigated to understand their contribution to more efficient household water use. The national surveys of household water use and conservation for 2007, 2010 and 2013 published by Australian Bureau of Statistics (ABS) in 2013 was examined for this task.[14] Detailed spatial information underpinning this publication was obtained in 2017 and analysed with spatial demographic data from ABS (such as Community Profiles) to define the installation of rainwater harvesting and water efficient appliances throughout each region. Data from the NSW government BASIX policy [13] and from surveys of industry sales were also utilised to determine the number of rainwater harvesting installations in each year.

Examination of spatial detail underpinning the ABS 2013 publication provided amended results for

NSW, Queensland and Victoria. The dataset was also characterised by a high level of spatial variability, and revealed that capital city statistical regions in the publication do not correspond with water supply regions for each city. However, finer spatial detail in the dataset permitted a better approximation of the installation of water efficient appliances and rainwater harvesting across local government areas and within urban water supply regions. Results for installation of rainwater harvesting and connection of rainwater supplies to indoor uses in each water supply region are presented in Table 1.

Table 1: *Dwellings with rainwater harvesting and rainwater harvesting for indoor uses*

Region	Dwellings with rainwater harvesting (%)			Indoor uses in 2013 (%)
	2007	2010	2013	
Sydney	14	16.4	19.6	42
Melbourne	18.3	21.4	21.4	29
SEQ	19.8	28.8	27.9	31.7
Adelaide	38.7	27.3	34	29
Perth	9.5	7.2	9.4	32.6

The Sydney region experienced a 5.6% growth in rainwater harvesting and has a greater proportion of connection of rainwater harvesting (42%) to indoor uses. This is expected to generate greater rainwater yields. Both Melbourne (3.1%) and SEQ (8.1%) were subject to increases in rainwater harvesting, whilst Adelaide (-4.7%) experienced negative growth in rainwater harvesting. The proportion of Perth households installing rainwater harvesting was relatively static across the survey period (-0.1%). In 2013, Adelaide had the greatest proportion of dwellings with rainwater harvesting (34%) and Perth had the lowest proportion of rainwater Harvesting (9.4%).

The installation of dual flush toilets and the change in proportion of households with dual flush toilets are presented in Table 2.

Table 2: *Dwellings with dual flush toilets*

Region	Dwellings with dual flush toilets (%)			Change since 2007 (%)
	2007	2010	2013	
Sydney	66.6	81.8	85.7	19.1
Melbourne	80.2	88.7	90.8	10.6
SEQ	75.4	90.4	91.6	16.2
Adelaide	78.9	88.9	90.9	12
Perth	80.6	86.1	90.8	10.2

Table 2 shows that all regions experienced growth in the proportion of households with dual flush toilets. Sydney experienced the highest change (19.1%) and Perth had the lowest change (10.2%) in proportions of households with dual flush toilets since 2007. In 2013, SEQ had the greatest proportion of dwellings with dual flush toilets (91.6%) and Sydney had the lowest proportion of dual flush toilets (85.7%).

The installation of low flow showers and the change in proportion of households with low flow showers are presented in Table 3.

Table 3: *Dwellings with low flow showers*

Region	Dwellings with low flow showers (%)			Change since 2007 (%)
	2007	2010	2013	
Sydney	57.8	64.8	66.1	8.3
Melbourne	44.4	69.2	71.9	27.5
SEQ	49.8	76.9	79.4	29.6
Adelaide	48.7	64.2	68.9	20.4
Perth	42.4	62.1	66	23.6

Table 3 reveals that all regions experienced increased uptake of low flow showers with the highest change in SEQ (29.6%) and lowest change in Sydney (8.3%). In 2013, SEQ had the greatest proportion of dwellings with low flow showers (79.1%) and Perth had the lowest proportion of low flow showers (66%). The installation of water efficient clothes washers and the change in proportion of households with water efficient clothes washers are presented in Table 4. Note that survey data was not available for 2007.

Table 4: *Dwellings with water efficient clothes washers*

Region	Dwellings with water efficient clothes washers (%)		Change since 2010 (%)
	2010	2013	
Sydney	25.5	32	6.5
Melbourne	31	40.6	9.6
SEQ	32.1	34.4	2.3
Adelaide	34.8	44.7	9.9
Perth	32.3	43.3	11

Table 4 shows that Adelaide experienced the greatest change in dwellings with water efficient clothes washers (9.9) and SEQ had the lowest change (2.3%). In 2013, Adelaide had the greatest proportion of dwellings with water efficient clothes washers (44.7%) and Sydney had the lowest proportion (32%).

Examination of the ABS survey data of water efficient appliances and rainwater harvesting at

households revealed increased proportions of dwellings with rainwater harvesting (expect for Adelaide and Perth), dual flush toilets, low flow showers and water efficient clothes washers during the period 2007 to 2013. These results suggest an increased proportion of water efficient households in each region contributed to the stabilisation of reductions in average annual household water use over time.

3 SAVINGS FROM WATER EFFICIENT APPLIANCES AND RAINWATER HARVESTING

Each local government area, suburb in the regions has different numbers of dwellings, growth rates and climate processes which will impact on the quantum of water savings. Average water savings from rainwater harvesting and water efficient appliances for households in each city were estimated by Coombes et al., (2016)[2] as shown in Table 5.

***Table 5:** Estimated average household water savings from rainwater harvesting and water efficient appliances.*

Region	Rainwater savings (kL/yr)		WEA savings (kL/yr)
	Indoor + outdoor	Outdoor only	
Sydney	70	48	49
Melbourne	53	37	33
SEQ	66	46	25
Adelaide	43	30	28
Perth	54	38	48

Table 5 shows results for households that use rainwater for outdoor uses only, and for indoor and outdoor uses. These results were derived from analysis of the performance of 5 kL rainwater tanks connected to 100 m^2 roof areas at a single location in each city. Indoor use was defined as rainwater supply to laundry and toilets. Detailed spatial analysis of household water demands, water efficient appliances, rainwater harvesting and numbers of dwellings in each local government area or suburb was also conducted by Barry and Coombes,[10] and included in the assessment of water savings for Perth, Melbourne and Sydney. The mains water savings from rainwater harvesting (Table 5) were combined with the numbers of dwellings from the ABS Community and Housing Profiles and the information in Table 1 to estimate water savings from rainwater harvesting for each region as shown in Figure 2. These results for rainwater savings were combined with numbers of dwellings, savings from water efficient appliances (WEA) in Table 5 and information in Tables 2 to 4 to estimate total water savings in each region shown in Figure 3.

The numbers of dwellings with rainwater harvesting and water efficient appliances in 2016 were determined as an extension of the trend from the period 2007 to 2013. Data from the NSW BASIX Policy[14] shows rainwater harvesting was installed in 80% of new dwellings and rainwater supplied indoor uses in 78% of those dwellings. This data was also incorporated in the estimates for the period 2013 to 2016 for Sydney. Industry sales data was also used to determine that 10% of new houses in Melbourne installed rainwater harvesting after 2013 in response to the Victorian Six Star Policy.

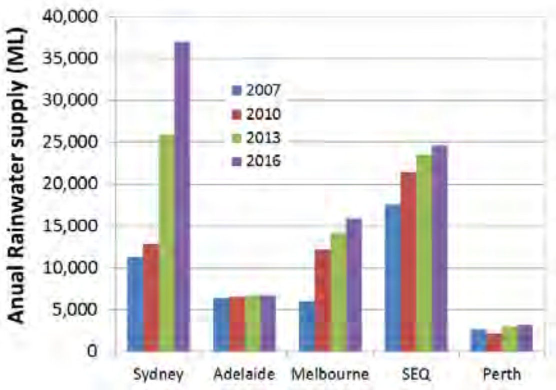

***Figure 2:** Water savings from rainwater harvesting for each region*

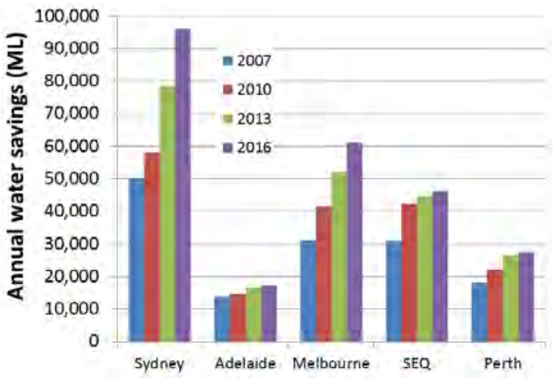

***Figure 3:** Water savings from rainwater harvesting and water efficient appliances for each region*

Figure 2 shows all regions experienced growth in rainwater savings. Sydney, Melbourne and SEQ displayed higher growth in rainwater savings since

ISBN: 978-1-925627-03-9

2007 that was driven by policies mandating or encouraging rainwater harvesting. Sydney had the greatest increase in annual rainwater savings of 27,730 ML (229%) since 2007 and Adelaide has the lowest increase in annual rainwater savings of 348 ML (5%).

Figure 3 demonstrates that all regions experienced growth in annual water savings from rainwater harvesting and water efficient appliances since 2007. Sydney had the highest growth in water savings of 46,440 ML (93%) and Adelaide had the lowest growth in water savings of 3,253 ML (23%). This analysis has demonstrated that local solutions such as water efficient appliances and rainwater harvesting at dwellings has made a substantial contribution to reducing potential growth in water demand in each region. The magnitude of household savings and the rate of growth in those savings is different for each region.

4 HOUSEHOLD WELFARE AND UTILITY OPERATING COSTS

Household expenditure on utility water services impacts on household disposable income which influences household welfare and ultimately consumption in the economy. Household welfare was considered a macro-economic indicator of economic efficiency of water utilities in each region. Utility water operating costs were found by Coombes et al., (2015) to be a dominant proportion of the costs of providing urban water services and a measure of the efficiency of utility services.[1] Water operating costs are considered a micro-economic indicator of utility performance in this investigation.

4.1 NATIONAL CONSUMER EXPENSES AND URBAN WATER USE

National results for total consumer (Total Bill) and household expenditure (Total Household Bill) on utility water and sewerage services, and total urban water use (Water Use) was derived from BOM[11] and NWC[12] data as shown in Figure 4.

Figure 4 reveals that total expenditure on urban water services increased by 95% ($6,695 million) and household expenditure increased by 116% ($5,450 million) for a 3% (88 GL) increase in utility supply. The change in Consumer Price Index (CPI), a measure of the changing value of money over time or inflation, during the same period was 38%.[15] Determination of the present values of national expenses (adjusted for inflation effects) for all urban water and sewerage services reveals a 41% real decline in economic efficiency. These results indicate that the historical national average real marginal cost of urban water services was $46/kL. This is a significant national average loss of economic efficiency of utility water services to urban areas.

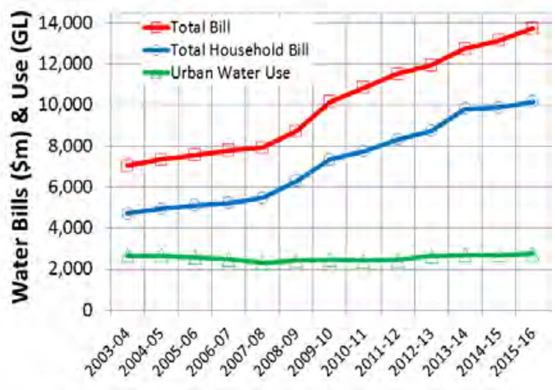

Figure 4: *National expenditure for all connections (Total Bill) and households (Total Household Bill) on utility water services and urban water use.*

Figure 4 reveals that household expenses are a substantial proportion of the total consumer revenue paid for urban water and sewerage services. The proportion of household expenses has increased from 67% to 74% whilst the proportion of household water use has declined from 61% to 60% of total urban water use. Households are paying a greater proportion of urban water revenue. National results for household expenditure on utility water and sewerage services (Total Household Bill), household expenditure on utility water services (Household Water Bill) and household water use were also derived from BOM[11] and NWC[12] data and shown in Figure 5.

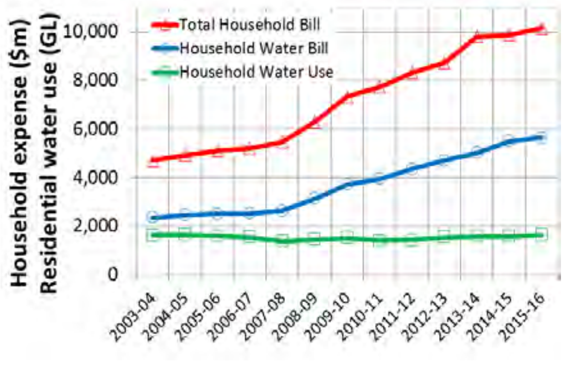

Figure 5: *National expenditure by households on utility water and sewerage services and household water use.*

Figure 5 highlights that household water bills increased by 140% ($3,290 million) for a 1.7% (28 GL) increase in household use of utility water services. These results represent a real increase in household expense for utility water services of 74% and a real historical marginal cost of $85/kL for utility water supply to households. The historical real marginal cost for utility water and sewerage services to households was $140/kL. These results for real increases for total consumer and household expenses, and historical marginal costs of utility services represent a substantial loss in economic efficiency from a national perspective.

4.2 REGIONAL HOUSEHOLD EXPENSE FOR UTILITY WATER SERVICES

The magnitude and patterns of household expenditure for utility water services are unlikely to similar across Australia. Household expenses for utility water services is presented for Sydney, SEQ, Melbourne, Adelaide and Perth regions in Figure 6.

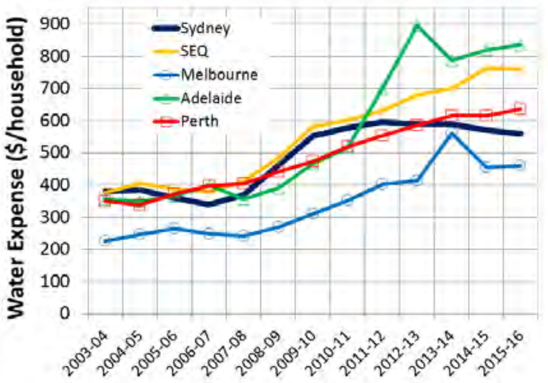

Figure 6: *Regional average annual expenditure by households on utility water services in Sydney, SEQ, Melbourne, Adelaide and Perth regions*

Figure 6 shows all regions are subject to increases in annual household expenses for utility water services. The trend for average annual household expenses for Sydney is different to the other regions with household expenses stabilising and declining after the 2009-10 financial year. This result is consistent with the greater and more substantial increases in household water savings of 46,440 ML (93%) in Sydney that is presented in Figure 3. The nominal (actual) and real (adjusted for inflation) changes in household expenses for utility water services is summarised in Table 6 for each capital city region.

Table 6: *Nominal and real changes in household expenses for utility water services for Sydney, Melbourne, SEQ, Adelaide and Perth*

Region	Change in household water expense			
	Nominal		Real	
Sydney	$180	47%	$35	7%
Melbourne	$236	104%	$150	48%
SEQ	$381	101%	$237	45%
Adelaide	$479	134%	$343	70%
Perth	$285	81%	$151	31%

Table 6 reveals that Sydney households experience the smallest real increase in household expenses for utility water services of $35 (7%). The remainder of the regions were subject to higher increases in real household expenses for utility water services ranging from $151 (31%) for Perth to $343 (70%) for Adelaide.

Median available household income (AMI) in each region was defined using the ABS Population and Housing[16] data as median income less taxation (disposable income) less mortgage or rent expenses. The proportion of household water expense (HWE) of available income was defined as (HWE/AMI). Increased real impact on household welfare was defined the change in real household water expense (HWE) divided by available household income (AMI). These values are summarised in Table 7.

Table 7: *Available median income (AMI), utility water expense (HWE) and real effect on households in Sydney, Melbourne, SEQ, Adelaide and Perth*

Region	AMI ($/yr)	HWE ($/yr)	HWE /AMI (%)	Change HWE/ AMI (%)
Sydney	41,530	560	1.35	0.08
Melbourne	39,180	461	1.18	0.38
SEQ	39,090	461	1.95	0.61
Adelaide	33,130	836	2.52	1.04
Perth	40,120	636	1.58	0.38

Table 7 shows that household expense for utility water services were the lowest proportion of available household income in Melbourne (1.18%) and highest proportion is in Adelaide (2.52%). Sydney was subject to the smallest change in household expense as a proportion of available income (0.08%) and the largest increase was experienced by Adelaide (1.04%). The increased proportion of available household income spent on utility water services reduces the funds available for consumption of goods in the economy which impacts on the gross domestic product (GDP) and household welfare.

Mack and Wrase (2017) highlight that the American Environment Protection Agency recommends that expenses for utility water services should be less than 2% of median household income.[7] Household expenses in Adelaide may exceed this criteria. However, the impact on lower income households (gross weekly household income of $650) in each region is significant – for example, household expense on utility water services is greater than 2.3% of available income in 17% of Sydney households and greater than 10.5% in 23% of Adelaide's households, and the changed impact since 2003 is 0.4% of available income in Sydney and 4.3% of available income in Adelaide.

The expense of utility water services in lower income households was greater than 9.6%, 8% and 5.8% of available income in SEQ, Perth and Melbourne. The impact of real increases in utility water expenses on lower income households was 3%, 1.9% and 1.9% of household available income for SEQ, Perth and Melbourne.

The economic efficiency of utility water supply, as defined by household expenditure, has declined in all of the regions which impacts on household welfare and gross domestic product. These impacts are substantially reduced in Sydney that has the highest growth in water savings due to water efficient appliances and rainwater harvesting.

These results indicate that higher growth in water savings has driven down utility water tariffs (Sydney has the second lowest usage and lowest fixed utility water changes) which has reduced household expenses for utility water services across the entire Sydney region relative to other regions. This provides additional benefit of reduced utility water expenses to low income households.

4.3 REGIONAL IMPACTS ON WATER OPERATING COSTS

The change of utility water operating costs per connection, during the period 2003 to 2016, was examined to understand the efficiency of the urban water systems in each region as shown in Figure 7.

Figure 7 shows that utility operating costs of providing water services has increased across all regions since 2003. The lowest and highest increases in utility water operating costs were in Sydney (59%) and SEQ (269%).

Figure 7: *Regional utility operating costs in Sydney, SEQ, Melbourne, Adelaide and Perth regions*

The nominal and real changes utility water operating costs per connection for each region is presented in Table 8.

Table 8: *Nominal and real changes in utility water operating costs per connection for Sydney, Melbourne, SEQ, Adelaide and Perth*

Region	Change in operating costs			
	Nominal		Real	
Sydney	$148	59%	$53	15%
Melbourne	$361	158%	$273	85%
SEQ	$565	269%	$485	167%
Adelaide	$271	140%	$197	73%
Perth	$162	76%	$81	28%

Table 8 demonstrates that SEQ (167%), Melbourne (85%) and Adelaide (73%) have experienced substantial real increases in operating costs since 2003. Sydney (15%) and Perth (28%) had the significantly lower real increases in water operating costs. Sydney experiences a different pattern of growth in water in utility water operating expenses that stabilises after the 2007-08 financial year that consistent with the growth in household water savings (Figure 3). In contrast, the SEQ region is subject to a high growth in water utility operating costs that may be driven by implementation of a regional water grid after 2008.

5 DISCUSSION

This study aimed to understand the effect of distributed local solutions, such as household water efficiency and rainwater harvesting, on the economic efficiency of urban water services in selected capital city regions. The changes in household expenses for utility water services, household welfare, historical marginal costs and the water operating costs of water utilities were characterised as describing economic efficiency. A

fairly long timeline (2003 – 2016) of demographic, economic and water resources data was examined.

Analysis of all urban water systems in Australia revealed a 41% average increase in real revenue for water and sewerage services and a 3% increase in total urban water supply. The average historical marginal costs (2003 – 2016) were \$46/kL for urban water supply. The total revenue earned by urban water utilities has increased substantially in real terms and the economic efficiency of utility urban water services has declined from a national perspective.

The proportion of urban water revenue paid by households has increased from 67% to 74%. Total household water use has declined from 61% to 60% of national urban water use. Households provided a 74% real increase in revenue for water and sewerage services and the real marginal cost of providing these services to households was \$140/kL. These results indicate substantial economic inefficiency of utility water services and it is unlikely that distributed solutions are not competitive – on average, a medium run marginal cost of distributed alternative supply of less than \$140/kL would be more efficient.

It is accepted that regional characteristics and economies of scale of urban water utilities may be vastly different to the national average performance. So the behaviour of urban water systems in capital city regions that also include desalinated water supplies was examined. Average annual household water use was found to decline or stabilise in the South East Queensland, and Greater Sydney, Melbourne, Adelaide and Perth regions. The improved or stable efficiency of annual average household water use was experienced in the context of considerable dwelling growth in each region. It would seem that water use efficiency of housing stock is improving in most regions.

Multiple layers of historical (2007 – 2013) and spatial (suburbs, local government areas, statistical regions) information about demographics, and numbers of dwellings with water efficient appliances and rainwater harvesting was combined to understand the changes in household water efficiency in each region. All of the selected capital city regions were subject to increases in the proportion of houses with water efficient appliances. Greater proportions of dwellings in Sydney, Melbourne and SEQ included rainwater harvesting. A significantly higher proportion of rainwater harvesting systems in Sydney were supplying household indoor uses. The increased numbers of water efficient houses are contributing to reduced or stable average household water use in each region.

This information was combined with observed residential water at each suburb or local government area in systems analysis[9,10] to quality the water savings from rainwater harvesting and water efficient appliances. All regions yielded significant water savings at households but the Sydney region displayed the largest growth in household savings (46,440 ML) since 2007. Substantial real increases in average annual household expenditure on utility water services of 31% (\$151) to 70% (\$343) were experienced across the regions. Households in the Sydney region only experienced a 7% (\$35) real increase in expenditure on utility water services and the growth in household expenses for utility water services stabilised and declined after the 2009-10 financial year.

Real increases in household expenses for utility water services were shown to impact on available income and associated household welfare in each region. Reduced disposable income will also reduce consumption in the local economies. The impacts of changes in utility water expenses on household welfare were lowest in Sydney. The overall reduction in household water use due to water efficient appliances and rainwater harvesting has also produced lower tariffs for water services in Sydney that benefit all households. Examination of the utility water operating costs revealed real increases in operating costs in all regions ranging from 15% (\$52/connection) in Sydney to 167% (\$485/connection) in SEQ. Sydney also experiences a different pattern of growth in utility water operating costs that stabilises after to 2007-08 financial year.

The household water savings in the Sydney region and associated economic benefits are substantially greater than the other regions that rely on minimum standards or short term subsidies for water efficiency and optional local water supply solutions such as rainwater harvesting. The Sydney region is also subject to the lowest growth in household expenditure for utility services and in utility water operating costs. This has produced economic benefits for all households via lower water tariffs.

New and renovated dwellings in the Sydney region are required by the BASIX State Environmental Planning Policy to reduce water use by 40% in comparison to a reference year. This policy intervention has acted as a market mechanism to

create widespread local scale competition for water services via household water efficiency and rainwater harvesting. This competition has improved the economic efficiency of utility water supply by reducing operating costs and household expenditure relative to other regions. The average annual economic value relative to the other regions for reduced utility water operating costs are $53 m - $810 m and for household expenditure are $218 m - $578 m. It is noteworthy that the values of water saving at households were not included in this analysis. The household benefits revealed in this investigation are produced by lower utility tariffs that result from distributed water savings.

This investigation has shown that household water efficiency and rainwater harvesting – distributed solutions – provide benefits to households, water utilities and whole of society. These distributed approaches improve the economic efficiency of the entire urban system. These methods and insights have application to understanding the value of a wide range distributed or multiple scale solutions that characterise Water Sensitive Urban Design approaches. The results in this investigation suggest that an opportunity of a new economy of solutions at multiple scales. However, as shown by Barry and Coombes (2017), understanding the benefits and opportunities of multiple scale solutions requires detailed bottom up investigation of data and systems analysis. Use of top down averages or assumptions provides an illusion of minimum benefit from distributed solutions.

6 CONCLUSION

Systems analysis of historical demographic, water resources and economic data has revealed the benefits of distributed solutions for household water efficiency and rainwater harvesting. A policy requirement for new and renovated dwellings to meet water savings targets in Sydney has acted as an economic market mechanism to drive higher household water savings, lower water tariffs, improved household welfare and more economically efficient utility water services. These methods and insights have broader application in discovering the new economy benefits of water sensitive urban design approaches.

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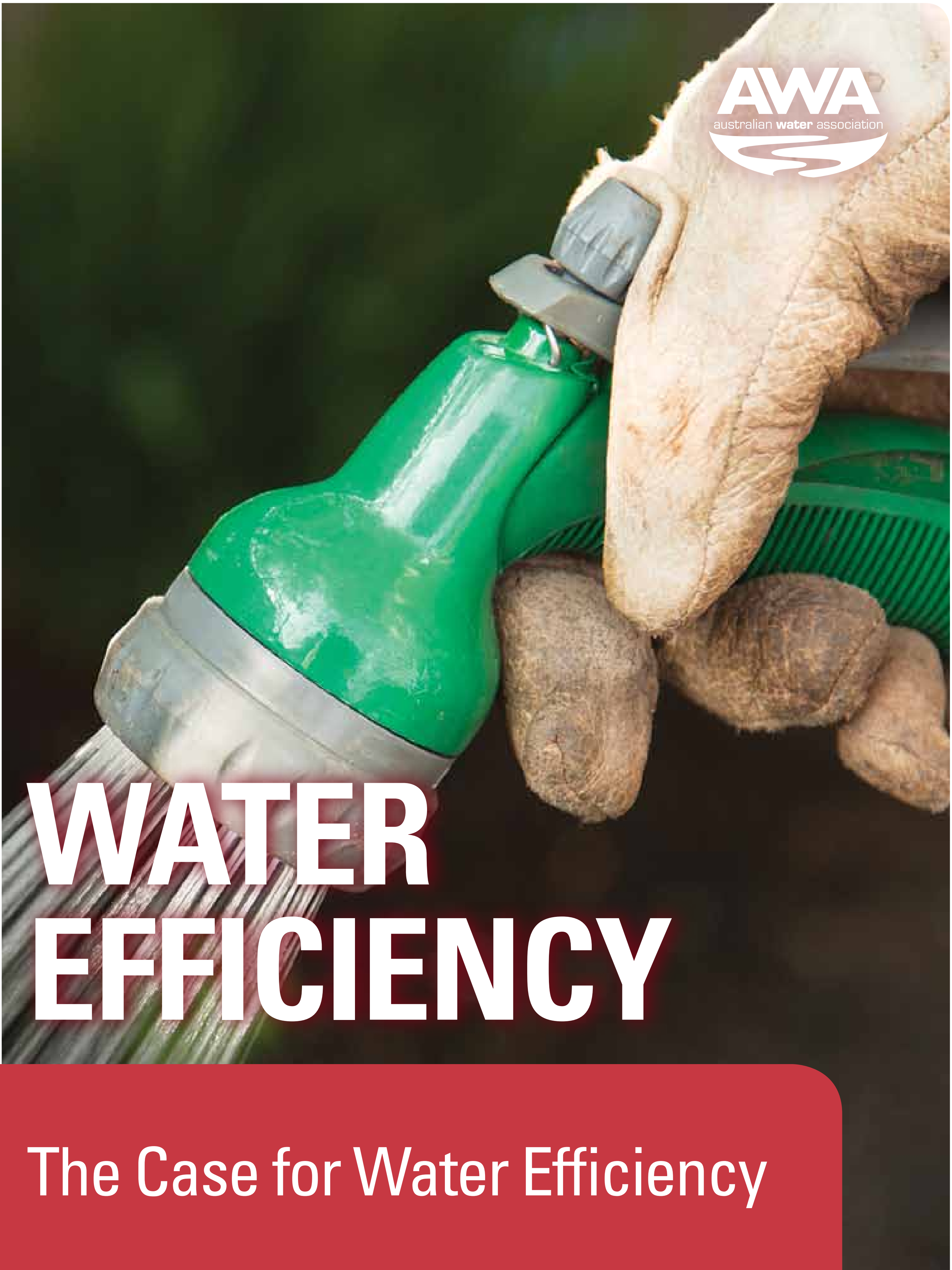


AWA
australian water association

WATER EFFICIENCY

The Case for Water Efficiency

AWA Position Paper – OCTOBER 2012

Contents

This paper has been developed by the Water Efficiency Specialist Network of AWA, in particular:

- Reid Butler, Manager – Water and Environment Sydney, BMT WBM Pty Ltd
- Damien Connell, Contract Manager, Smart Water Fund
- Julian Gray, CEO, Smart Approved WaterMark
- Dr. Mark Henry Rubarenzya, Principal Consultant, Water Resources, Sustineo Pty Ltd
- Andrew Speers, National Manager, Programs and Policy, AWA

It was adopted as an AWA Position Paper on 8 August, 2012.

1. Scope

This position paper describes the role of water efficiency in urban water use in Australia and identifies emerging issues. It is written for those with responsibility for developing policy and making decisions on how water is delivered, used and managed and for those with an interest in such matters.

Water services in the 21st century will differ in fundamental ways from the systems that preceded them, and which were directed almost exclusively at protecting community health. In this century, water supply provision will not just provide healthful water and treatment of wastewater. It will: be better integrated with other urban services; deliver better asset maintenance strategies; include alternative supply options; explicitly consider the environmental, energy and other costs associated with water supply and wastewater management; and focus on provision of an integrated service offering to customers. Advanced water efficiency will be an integral component of such an offering.

It is within this context that this paper presents the case for consideration of water efficient policies and practices. Whilst reference is made to operational efficiency – including leakage control and water management policies and practices that lead to better integration of water supplies within the urban environment – it is directed primarily at water efficiency at the point of use.[1]

1. For an overview of the context of water efficiency, see White, S. (2010). "Securing water supplies through sustainable water management." LGSA Water Management Conference. Orange, LGSA.

2. Synopsis

- Water efficiency is an economically viable way to enhance water security in many circumstances. Water efficiency also makes sense in its own right and is worthwhile even when water security is not a goal; water efficiency can increase the availability of water for environmental, economic, cultural, spiritual and aesthetic purposes.
- Australia's climate is highly variable and emerging pressures such as population growth will affect the security of water supplies in ways that are difficult to predict. A changing climate will exacerbate these pressures. Flexibility is required to deliver effective solutions, and opportunities to achieve greater water efficiency must always be part of these solutions.
- Water efficiency must be considered equally with supply-side options in the development of any strategy to improve long term water supply security.
- In line with the 1994 *COAG Water Reform Framework* and the *National Water Initiative*, **all** costs associated with water supply should be internalised. This would facilitate comparison of demand and supply-side water security options.
- Calculation of the benefits of water efficiency and of options to improve supply should not just include those items that are easily monetarised. The community holds strong views about other values that can be realised through water efficiency. Such values must always be taken into account in any comparison of alternatives.
- Greater consistency in approaches taken to water efficiency across the country would facilitate the sharing of experiences and would minimise the risk of research being duplicated.
- Skills, knowledge and practices in delivering water efficiency need to be maintained during times of plentiful rainfall.

3. Definitions

'Water efficiency' refers to the suite of practices and policies that maximises the benefit gained from every unit of water used.

'Water conservation' refers to approaches that prevent the wasteful and excessive use of water resources. It is the view of AWA that water efficiency and water conservation are synonyms, as wasteful practices produce no benefit.

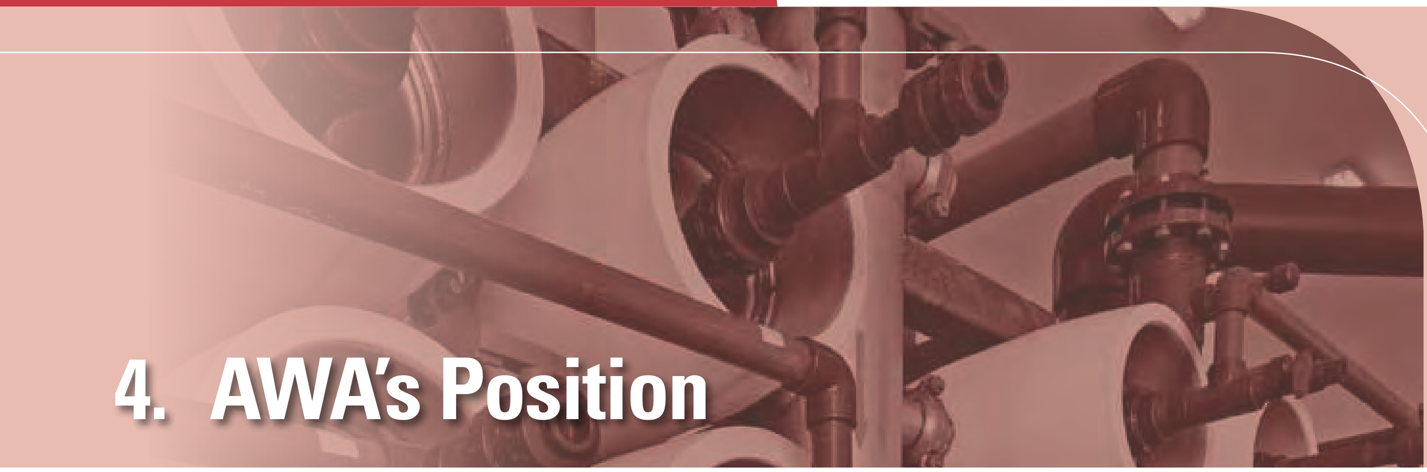
'Water restrictions' refer to those voluntary or mandated limits on the volumes of water that can be used, the time of use or the purposes to which water can be put that may be applied from time to time in response to supply insecurities. Water restrictions introduced in Australia differ from region to region and may be tightened or relaxed in line with relative availability of water.

'Demand management' refers to "*any regulatory, policy, technical, service or commercial interaction with customers or consumers that enables volumes to be managed to minimise economic costs and environmental impacts to society*" (Cooperative Research Centre for Water Quality and Treatment 2006). In other words, demand management initiatives may include water efficiency but might also include regulations, changes to price and infrastructure improvements intended to reduce demand on potable water supplies.

'Water Security' refers to the extent to which consumers can rely on there being a consistently available, high quality water supply that meets their demands.

'Supply-side' options refer to those approaches that secure greater volumes of water through the accessing of new supply sources.

'Demand-side' options refer to those approaches that increase water security by reducing consumers' water needs (see also 'Demand Management', above). Supply-side options are at the opposite end of demand-side options in an integrated water security strategy.



4. AWA's Position

General

1. Water efficiency offers significant potential to enhance water security. Water efficiency measures should be considered alongside all other options for improving water security.

2. The breaking of drought over much of Australia does not reduce the importance of water efficiency. Climate change and population growth will mean that in future more will need to be done with less. Skills, knowledge and practices in delivering water efficiency should be maintained.

3. Water efficiency can also make economic sense in its own right and could be employed even when water security is not a goal (e.g. to reduce treatment operational costs).

4. Water efficiency is not a goal unto itself. Where the costs of its implementation are greater than the benefits gained, or where it does not compare favourably on a triple bottom line basis with supply-side options, it should not be pursued.

5. In making comparisons between demand and supply-side options, the full costs and benefits of options available should be considered, including non-monetary values, external costs and benefits.

6. In line with the 1994 *COAG Water Reform Framework* and the *National Water Initiative*, externalities associated with water supply should be internalised. This would facilitate comparison of demand and supply-side water security options.

Water Prices

7. Price is an important mechanism for stimulating water efficiency. AWA strongly supports full-cost recovery pricing, and research into the value or otherwise of scarcity pricing.

8. Prices should be reviewed to ensure they are structured in a way that best rationalises water consumption and, with respect to developer charges, enables developers to capture the benefits of innovations in water efficiency incorporated in their developments.

Information, Research and Technology

9. Information on the benefits or otherwise of water efficiency measures should be shared freely among all jurisdictions to minimise the risk of research efforts being duplicated and mistakes being repeated.

10. Water monitoring data should be used thoughtfully to identify and research the successes and failures in water efficiency to date and to provide guidance for future actions and programs.

11. Effort should be directed to ensuring that water efficiency measures are considered as an alternative to system expansion. Such 'mainstreaming' will help to ensure that the best option from the suite of options available is always chosen.

12. AWA encourages research and development of technological advances to achieve water efficiency.

13. AWA supports the widespread adoption of schemes such as WELS and Smart Approved WaterMark.

Accreditation and Training

14. AWA strongly encourages the development of training courses and guidelines that are consistent nationally. Courses should be generic enough to be used internationally and flexible enough to be updated to respond to new ideas and technologies.

5. Why is Water Efficiency an Important Issue?

Over the past decade there has been significant investment in water conservation and efficiency measures (including water restrictions) as part of crisis management during drought. Recent rainfall across many of Australia's cities has, however, led to the lifting of water restrictions in many areas and reduced the emphasis governments and some utilities place on water efficiency measures. Nevertheless, there are still some areas in Australia that have not returned to historical average rainfall patterns, notably much of Western Australia and South Australia.

The statement that Australia is the driest inhabited continent on the planet, while true, masks regional variations. It is these variations that affect the need for and viability of water efficiency measures, not average precipitation and evaporation across the continent. The availability of water for urban purposes depends on a wide range of factors, including:

- Variability of rainfall across years
- Evapotranspiration (the amount of water vapour returned to the atmosphere through the transpiration of vegetation or evaporation from water bodies or runoff) (Chiew, Wang et al. 2002)
- The volume of water that percolates to groundwater tables, the accessibility of those groundwater tables and the rate at which they recharge over time
- The volume of storage available (which includes dams, reservoirs and managed aquifer injection and recovery)
- Availability of surface water flows (rivers, creeks and streams) and limitations (caps) that may be imposed on that resource
- The extent of loss from distribution systems
- The availability of recycled water and/or desalinated water
- Population and the rate of water consumption per head of population
- The intensity of water use by industry and commercial establishments and competition for available resources from other industries such as agriculture, forestry and energy generation
- Other factors such as accessibility and cost, among others[2]

Each of these factors varies from area to area. Relative security of water depends upon the interaction of these factors and will vary over time. It may be difficult to predict the relative security of water supply in a particular area in future due to uncertainty related to population and demographic change, changes in industrial water consumption and climate change.

Rainfall across many areas of Australia (but certainly not all) has returned to historical averages at periods over the past two years. This has led to an increase in stored water levels in Sydney, Melbourne and Brisbane and other centres, mainly on the east coast and has contributed to the lifting of "Exceptional Circumstances" declarations in all areas.[3]

The water industry has recently expressed its strong support for continued conservation and efficiency measures. The *AWA/Deloitte State of the Water Sector Survey 2012* included the question "Drought conditions have eased across much of Australia over the past 18 months. To what extent should water conservation and efficiency programs be curtailed during wetter periods?" and 67% of respondents answered "Not at all" or "Marginally" (AWA/Deloitte 2012).

A continued focus on water efficiency remains important because:

- Water still remains the Australian public's number one environmental issue (Mobium Group 2011). There is an expectation that the water industry, working with the community, will be an effective steward of the resource.
- When assessing different measures on a triple bottom line basis (Figure 1), water efficiency has the potential to save energy and money and delay the construction of major water supply and treatment infrastructure in the future (Nelson, South East Water et al. 2010).

Figure 1 Comparison of management options using a Triple Bottom Line assessment. (Nelson, South East Water et al. 2010)

2. The National Water Commission's website (www.nwc.gov.au) contains information on factors affecting urban water availability and projects related to quantification of Australia's water resources among a wide range of other matters. Information on water accounting is available at http://www.nwc.gov.au/rnws/accounting

3. See www.daff.gov.au/agriculture-food/drought/ec

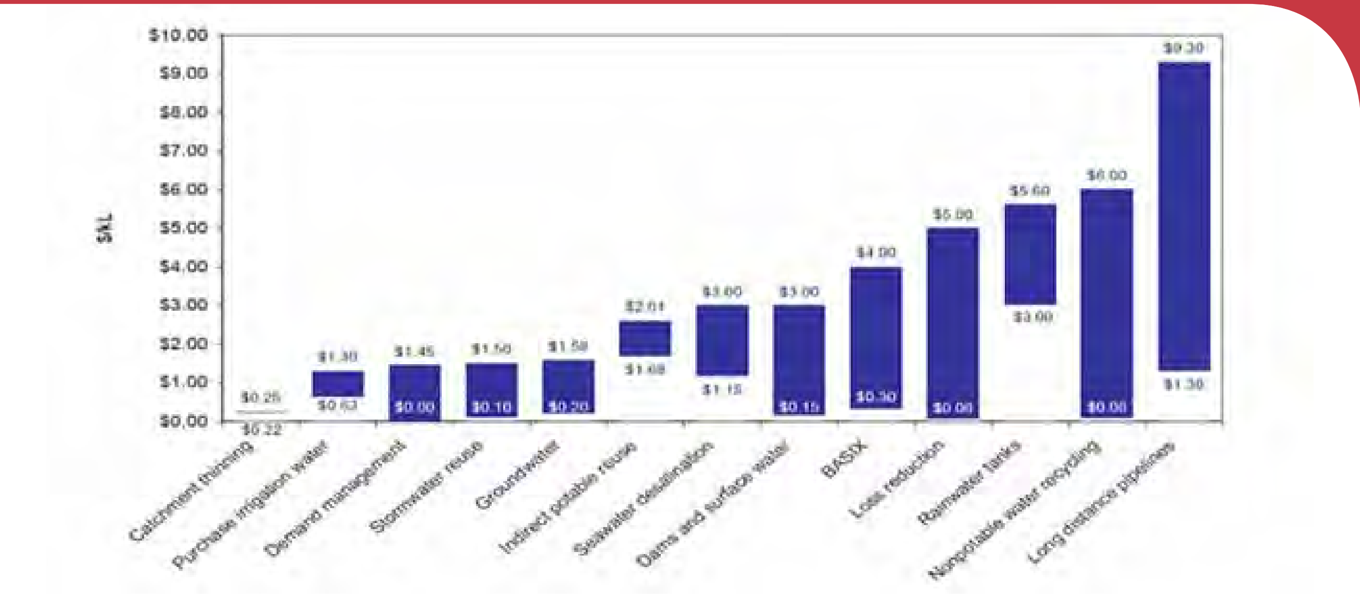


Figure 2: Direct Costs of water supply/demand options (Marsden Jacob Associates 2006)

- Water efficiency can be cost-effective, whether water is plentiful or in short supply. *The Melbourne Joint Water Efficiency Plan* (Nelson, South East Water et al. 2010) revealed, for example, that 'Demand Management' is among the cheapest of options for enhancing water security (see Figure 2).
- Water efficiency remains an important element of water supply security strategies in many urban areas.[4] Figure 3 shows the contribution that might be made to future water supply security for Sydney by water efficiency measures.
- Retention of knowledge and skills to operationalise these and other water supply strategies will be critical to the success of these strategies.
- Water efficiency measures are enduring; producing benefit for many years after the initial investment is committed. Experience in Brisbane, Melbourne and Sydney shows that even when broad water efficiency programs are curtailed (such as the Target 140 and 155 programs) water consumption does not return to pre-program levels. The continuing water savings are a combination of water efficient technologies being hardwired into infrastructure (e.g. dual flush toilets) and changes in consumer behaviour.
- Water efficiency may produce benefits other than the conservation of supplies such as increased availability of water for environmental, cultural, spiritual and aesthetic purposes, reduction in energy use and related carbon emissions.
- Householders and businesses may reduce their costs if they continue to be water efficient. In this respect, provision of information by utilities about ways in which customers can be 'water smart' is justified, as is investment in programs to promote water efficiency in the non-residential sector. Many investigations into high water-use businesses have shown that significant water savings are available if the right support and incentives are provided in partnership with business customers (*Victoria's WaterMAP*[5] approach may provide a good model). Investment to reduce water consumption by businesses often has a short pay-back period.
- By engaging and supporting householders and businesses to make water efficient choices that suit their circumstances and personal preferences, utilities and other water service providers develop closer, more collaborative relationships with customers. This is good business practice.
- Australia's skills and experience in water efficiency can be exported for the economic benefit of the nation.
- Efficient water use can be vital in times of emergency. During recent floods in Brisbane, water contamination required the implementation of water efficiency practices to allow for 'breathing space' while critical water supply and treatment infrastructure was brought back online (Hanna and Waters 2011).

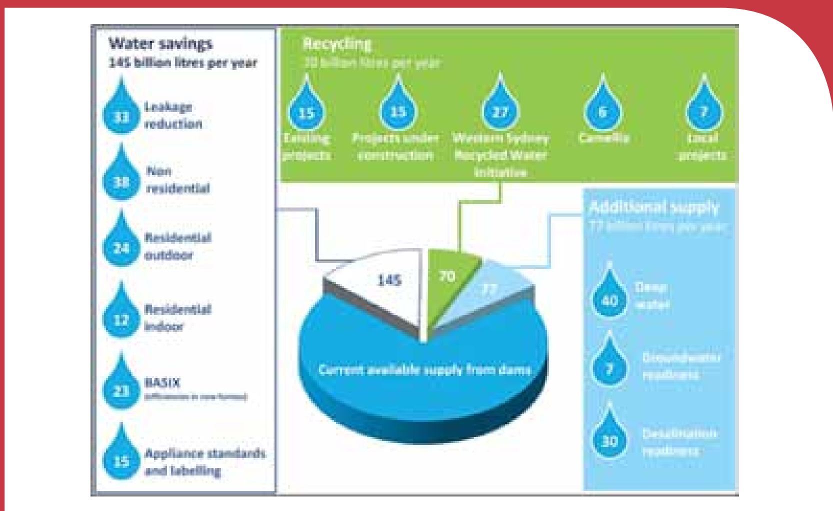


Figure 3 – Relative Contribution to Supply and Demand: Sydney (White 2010)

4. See, for example Water Corporation (2011). Water Forever Whatever the Weather: Drought-proofing Perth; NSW Office of Water (2010). 2010 Metropolitan Water Plan; and http://www.citywestwater.com.au/residents/saving_water.aspx.

5. See www.water.vic.gov.au/saving/industry/watermap

The breaking of drought in many areas has reduced the immediate need for significant investment to be made in water efficiency measures (at least in terms of there being a particular imperative to conserve water). This provides breathing space for some governments and parts of the water industry to review the impact of efficiency measures. This is an ideal opportunity to take a careful strategic review of the approaches taken to water efficiency to determine which approaches are the most effective. The gathering of this information will also facilitate sharing of data between jurisdictions and will provide opportunities to 'mainstream' water efficiency so that it becomes a standard way of doing business.

Avoiding the need to augment water supplies or reducing users' water bills are not the only reasons water efficiency might be pursued, nor is demand management at the point of use the sole focus of efficiency policy. According to the Australian Bureau of Statistics, 7% of water supplied in Australia was 'consumed' by the water industry in 2000-2001 (ABS 2004). In 2004-2005, this was 11%, when the total national consumption was lower (ABS 2006). In 2011 CSIRO reported that this consumption is "mainly the losses of water that occur in supplying water and providing sewerage services" which may include wastewater generated as a result of water treatment process, water used to wash down facilities, water consumed in mains flushing (cleaning) and water loss through cracked and broken pipes, unmetered water and water theft (CSIRO 2011). While the performance of Australian systems is at least consistent with other developed nations if not notably better, new technologies and practices are emerging that may lead to further reductions in loss at a reasonable cost.[6]

It should also be noted that a continuing focus on water efficiency will be justified because of several significant challenges facing the nation. Foremost are population growth/demographic change and the rapid urbanisation of the city centres. These pressures will be exacerbated by climate change, even if only the most conservative estimates of the impact of climate change on the reliability of rainfall come to pass. Thus, Australia is almost certainly facing circumstances in which it will be required to provide water for a larger population (and, potentially, higher water use industries) and to do so in drier conditions.

Regional variations in population growth and rainfall in future may mean that areas now considered water secure will be tested and others will face significant investment to maintain water security levels. A further challenge is that of the rising cost of energy and the connection between energy generation, the production of greenhouse gases and water supply. In short, there are strong links between water use and energy demand and between energy generation and water demand.

6. There are a number of measures for 'non-revenue water' also known as 'unaccounted for water'. One is kilolitres lost per kilometre of water main. Australia's rate against this indicator is 4.4Kl/Km which compares favourably with England and Wales at 10/Kl/Km but less well against the Netherlands at 1.5Kl/Km (see Danish Water and Wastewater Association (2010), which includes data from DANVA using its own data and data from OFWAT, the UK water industry regulator).

Each of these challenges is discussed further below.

A word of caution…

Promotion of water efficiency measures, changes to water prices to stimulate conservation, restriction and other measures directed to reducing water demand (each discussed in this paper) may have the effect of stimulating a shift to alternative sources of supply. This may be appropriate and beneficial, but should be assessed on a case-by-case basis as there can be undesirable impacts. For example, a shift to local groundwater supplies may deplete aquifers or lead to saline intrusion, and more widespread use of rainwater tanks may lead to a significant increase in energy usage. It is important, therefore, that water efficiency is considered in context and the outcomes of change be considered alongside the benefits derived from reduced water consumption.

5.1. Climate Impacts

While a trend towards a warmer and drier future has been identified, the extent of the change and the timeframe of this change are less well known. There is significant variation between best and worst case scenarios projected by both CSIRO and the United Nations Intergovernmental Panel on Climate Change (IPCC). Nevertheless, the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) indicated that global temperature increase would lead to a dramatic drop in the likelihood of rainfall over the main urban population centres of Australia (PMSEIC 2010). Figure 4 shows the predicted changes in temperature over the continent for scenarios of global temperature increases of 2 deg and 4 deg, respectively. For each prediction, a corresponding expected change in precipitation over the continent is shown for both the summer and winter months. It is observed that in both scenarios of temperature rise there is an uneven precipitation response across the continent which is more pronounced during the winter months.

While there is considerable uncertainty about the impacts of climate change, there is a strong likelihood that many of Australia's cities will be affected negatively in future and that supply planning should include water efficiency measures. A multi-faceted water supply and demand strategy is needed to produce a robust, resilient and integrated approach to water management in the face of climate change.

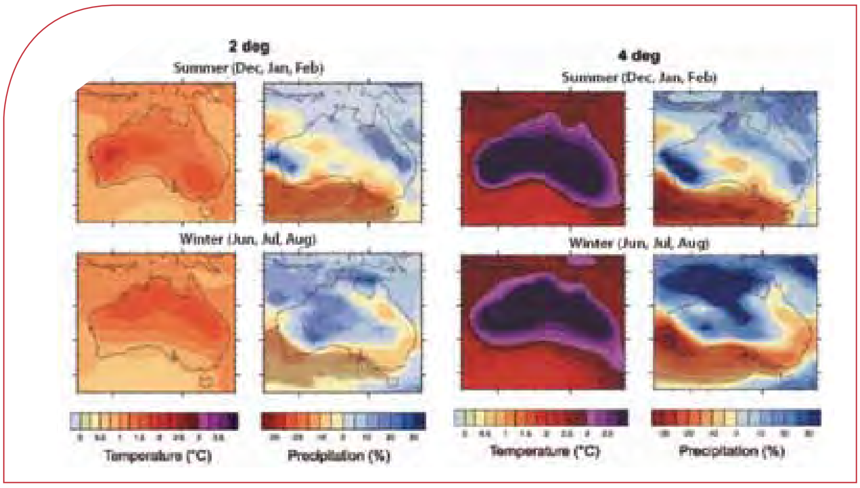


Figure 4. Variability in Temperature and Impacts for Precipitation and Temperature. (PMSEIC 2010)

5.2. Population and Demographic Impacts

Population growth is also a major driver of urban water demand. The Australian Bureau of Statistics population projections suggest that between 32.9 and 42.5 million people will be living in Australia by 2056, one-and-a-half to two times more than our current population (Australian Bureau of Statistics 2008).

The Water Services Association of Australia (WSAA) estimates that for a variety of reasons (including the introduction of more water efficient practices) per-capita water use will drop by around 9% by 2056 on 2009 levels (Water Services Association of Australia 2010).

Nevertheless, under the influence of population growth, WSAA also estimates that water demand across Australia's major capital cities could rise between 961GL to 1612GL by 2056, the higher estimate representing more than a doubling on 2008/9 consumption levels.

In addition to population growth, the demographic structure of Australia's cities is changing. This too has implications for future water demand, although there is significant uncertainty about how demographic change will affect water demand.

The two main features of demographic change are an ageing population and the growth in single-person living. A significant proportion of new housing development occurs in existing areas, largely through the construction of units.

This can impose new pressures on existing supply systems. While there may be a reduction in outdoor space requiring irrigation, the timing of water demand may change affecting the way in which infrastructure is renewed, maintained and designed.

While the more widespread introduction of water efficient technologies, increases in the price of water (which are expected to stimulate a reduction in demand) and more widespread use of water-sensitive urban design practices might curb total water demand, uncertainty about the effects of a combination of population growth and demographic change require a continued focus on water efficiency.

> "THERE IS ALSO A STRONG LINK BETWEEN ENERGY GENERATION AND WATER CONSUMPTION, AS SIGNIFICANT VOLUMES OF WATER ARE NEEDED TO PRODUCE POWER."

5.3. Water/Energy Nexus and the Price on Carbon

A significant amount of energy is consumed in the capture, treatment and delivery of potable water throughout urbanised areas in Australia; there is a direct link between water consumption and energy consumption. Energy consumption will likely rise as the population increases and as water sources that are more energy intensive are utilised (e.g. water sourced from remote locations requiring pumping and the use of lower quality water that requires energy intensive treatment including wastewater, stormwater and ocean water).

There are various ways in which energy is conserved when reducing water use. On a site basis, less energy is required to heat water. On a network distribution scale, less energy is required to treat and pump water from the supply dam, groundwater source or recycling facility and on-site. Water distribution pump sizes can also be optimised to match demand levels better.

Research by CSIRO has suggested that total utility energy use in 2007 was equal to only 15% of the total energy used Australia-wide in domestic hot water heating (Kenway, Lant et al. 2009). In other words, it takes only a relatively small decrease in hot water usage in households to offset all of the energy used in conveying treated water to households in the first place. This is a strong argument for water efficiency.

If, as suggested in some future projections, Australia's population increases by 25% by 2030 the additional energy required to supply water at a consumption rate of 300 litres/per person/per day (l/pp/pd) is 26-36 petajoules, whereas the increase of the same population consuming 150 l/pp/pd would effectively be zero. See Table 1 below:

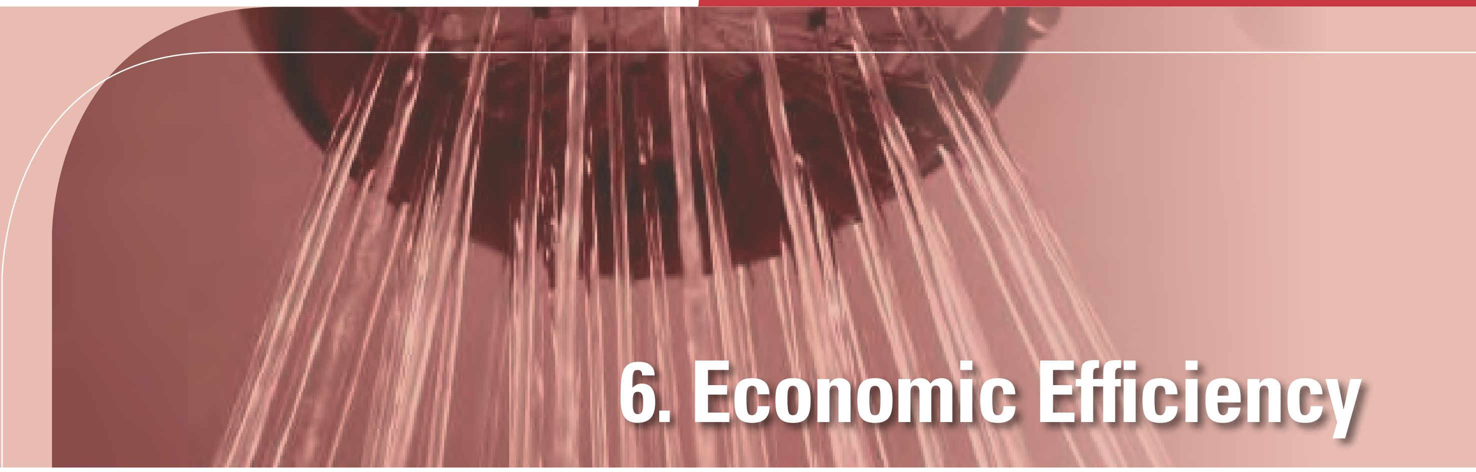
Table 1 Implications for future energy use of water conservation
(Kenway, Priestley et al. 2008)

Consumption per capita in 2030[7]	Anticipated increase in energy (Petajoules)	Anticipated % increase in energy use
300 L/cap/d	26-36PJ	260-400% increase
225 L/cap/d	16-41PJ	130-200% increase
150 L/cap/d	7PJ	0% increase

There is also a strong link between energy generation and water consumption, as significant volumes of water are needed to produce power. With a tax now imposed on carbon and subsequent rises in the carbon price from $23/tonne to $25.40/tonne over the next three years (Commonwealth of Australia 2011), water-related energy savings will become more attractive financially in the future.

Finally, reduction in materials use can arise from water efficiency measures. These might include a reduction in pipe diameters, reduction in wear and tear on pipes and pumps and the like. Such material use reduction can reduce energy and water use and may produce fewer greenhouse gas emissions.

7. Based on a population increase over 2007 levels of 25% and existing water supplies used.



6. Economic Efficiency

Whilst this paper sets out the case for a continued focus on water efficiency, it is not AWA's contention that water efficiency is the answer to every water security challenge. Those with responsibility for augmentation of water supplies have a diversity of options available to them. The cost of accessing these alternatives depends on local circumstances. Factors such as geography, population, accessibility, quality and others all affect the cost that would be incurred in utilising the resource and, by extension, the price paid by consumers.

The notion that water efficiency should always be the option preferred by policy makers because it represents a reduction in use of the resource is not one that AWA shares. Rather, it is the position of the Association that investments in water security must be directed to the most economically efficient water source. Generally speaking, this might be defined as the resource that meets requirements at the lowest overall cost. There is no justification for always seeking to conserve a resource, as the cost of such conservation might outweigh the social benefit. For example, if funds are committed to efficiency, and the costs of that commitment are greater than accessing a new water source, the community's funds are being misallocated. To make such investments is to say to the community that there is greater benefit in water conservation than, for example, education or health, because over-investment in water efficiency may mean fewer dollars are available for those services. It should not be up to water managers to determine how the community's funds are spent.

To provide a more concrete example, the Productivity Commission in its report on urban water (2011) noted that some water efficiency programs provided a subsidy for the purchase of water efficient appliances, but that the effective cost of water conserved as a result of these subsidies ranged to $33,395 a megalitre (in the case of subsidies paid in Melbourne on AAA-rated dishwashers for householders) (Productivity Commission 2011). This is taxation revenue or money raised from water rates that could have been used for a more socially beneficial purpose or to reduce water charges overall.

This said, water efficiency measures are frequently the most cost-effective options for promoting water security. It should be self-evident that a resource that is not used will often be cheaper than one that is, if for no other reason than storage, transport, energy, materials and other costs are avoided from the outset. Some of the data in *Figure 2* shows this to be the case.

Improved maintenance and management techniques may reduce wastage and loss cost-effectively. AWA does not argue for over-investment in system maintenance any more than it argues for over-investment in demand management or other efficiency measures. However, where there is a positive cost-benefit arising from a particular efficiency measure, it should be pursued.

Clearly, this means that water managers have to pay particular attention to quantification of the costs of avoided water use. Whereas the costs of actual water consumption are generally transparent (as the cost of transport, energy, materials and other inputs need to be met) the costs avoided by reduced water consumption are not always clear (as in the case of avoided energy). Such avoided costs need to be identified and quantified or the potential will exist for poor decisions to be made about the relative costs of water supply options. It is certainly the case that a decision to, say, construct a new dam will be sub-optimal if the full costs and benefits of all available options are not considered (see also Section 7.3 on *Pricing*, and Section 5 *Why is Water Efficiency an Important Issue*).

> "IT IS THE POSITION OF THE ASSOCIATION THAT INVESTMENTS IN WATER SECURITY MUST BE DIRECTED TO THE MOST ECONOMICALLY EFFICIENT WATER SOURCE."

7. Discussion

The remainder of this paper deals with the current state of urban water efficiency, which can be discussed by breaking it into key elements, each of which has its own specific issues. Broadly these are:

1. **Water Restrictions and Mandated Efficiency Standards**
2. **Externalities and Comparison of non-Monetary Costs and Benefits**
3. **Pricing**
4. **Education and Community Awareness**
5. **Water Auditing and Meter Monitoring (Smart Meters)**
6. **Technology**
7. **Consistency of Approaches to Water Efficiency**
8. **Emerging Issues**

7.1. Water Restrictions and Mandated Efficiency Standards

Throughout Australia's European history water restrictions have been used during times of water shortage to extend supplies. Limits have been placed on total volume of water that may be used, the time of day it may be used, or the days of the week. Some practices, such as hosing down of hard surfaces or car washing have, at times, been banned completely and, in some cases, permanently. Restrictions have been enforced with varying degrees of rigour; frequently it is community (peer) pressure that stimulates compliant behaviour by householders, businesses and local governments.

While restrictions should always remain an option available to policy-makers in emergency situations, they can be a blunt instrument that may not produce the greatest social good. For example, restrictions on irrigation of a playing field potentially prevent use of that facility, with all the concomitant impacts this may produce (loss of recreational opportunities, diminution of community health). Similarly, industries subject to water restrictions may lose sales or productive capacity, the value of which may be significantly greater than the value of water saved. AWA believes that restrictions should, therefore, be used only in the case of emergency.

The exceptions to this rule are those options that improve water efficiency at little or no cost, such as bans on the unnecessary hosing down of hard surfaces, or the introduction of watering regimes in commercial establishments. The effectiveness of such permanent water efficiency regimes have been well researched in a number of jurisdictions, are targeted and justified on a range of criteria including cost-benefit. The horticultural industry in Perth has, for example, collaborated with the Water Corporation in responding to proposals to limit the days on which watering can occur. The industry now saves water, and saves money. The type of efficiency regime may vary from area to area according to local circumstances, but should be considered as a component of any comprehensive water management and security strategy.

It is also possible to provide incentives to stimulate the uptake of water efficient practices. These may take the form of subsidies, or requirements that appliances or processes achieve a minimum level of efficiency. Recently, the Productivity Commission suggested that the role of governments should be restricted to the provision of information about the relative water efficiency of various practices and appliances, rather than the mandating of water efficiency options by states, water utilities and other authorities, as the monetary costs of each unit of water saved through the mandating of water efficiency are sometimes greater than the current price charged for that unit of water (Productivity Commission 2011).

AWA recognises that the monetary value of the water saved through some water efficiency activities can be less than the money invested in implementing the change. However, rather than restricting governments' role to that of information provider, governments and utilities should continue to support options where the benefits gained outweigh the costs. These would include 'no regrets' options, where the cost of water efficiency appliances (e.g. dual-flush toilets) is now no greater than their alternative and other programs developed in collaboration with affected customers.

7.2. Externalities and Comparison of Non-Monetary Costs and Benefits

While AWA does not support restrictions or mandates that cost more than the benefits they produce, it is concerned that the cost-benefit analyses used often do not include all costs and benefits, consequently under- or overstating the case for the introduction of water efficiency measures, or distorting any comparisons that might be made with the costs and benefits of supply-side options. As early as 1994, the Council of Australian Governments (COAG) urged that externalities associated with water services be internalised (COAG, 1994). Externalities are those costs and benefits incurred by third parties as a result of an activity carried out by others for which they are not compensated or do not pay. For example, an angler whose catch is reduced as a result of pollution from a sewage treatment plant incurs a loss for which those using the plant are not providing compensation. As long as such costs are not 'internalised' the price of the service will be lower than it should be, leading to over-consumption. AWA believes that more effort should be directed to dealing with such externalities.

Furthermore, there is difficulty in monetarising some benefits and costs arising from water efficiency. It is difficult, for example, to place a value on the loss of recreational opportunities arising from the flooding of a valley for water supply. This does not, however, provide an excuse for not dealing with such issues, and there is a range of methodologies available for comparing non-monetary costs and benefits.[8]

8. It is acknowledged that internalisation of externalities is not a simple matter. Nevertheless valuable work has been done across a number of years. Interested readers might review Bowers, J. and M. Young (2000). "Valuing externalities: A method for urban water use." CSIRO Urban Water Program. Adelaide, CSIRO and/or Frontier Economics (2011) Externality Pricing in the Australian water sector. Waterlines Report, National Water Commission, Canberra

> "...THE PRICE PAID BY CONSUMERS ACCURATELY REFLECTS THE LONG-TERM COSTS OF SUPPLY AND IS ECONOMICALLY EFFICIENT"

7.3. Pricing

In 1994 COAG agreed to a package of water reforms directed to increasing efficiency and ensuring that water utilities were sustainable. Among the measures adopted was a move to full-cost recovery pricing and the removal of cross-subsidies between user groups (e.g. the commercial and residential sectors). These reforms have meant that consumers generally pay on average the full cost of water services. The reforms have introduced a financial discipline that is vital and have ensured that funds are available for operation and maintenance of the system into the future. Charging an accurate price for water also means that consumers have rationalised water use.

As discussed above, water restrictions and water efficiency standards are important tools available to policy makers to require or encourage water efficiency. Price is clearly another tool but, to date, the price charged has not been linked to availability of the resource (as it is to other commodities such as petrol), only to the long-run marginal costs of providing water services.

The Productivity Commission, among others groups, has argued for research into the efficacy of more innovative approaches to water pricing. Among these would be included:

- Scarcity pricing of water, which would see water prices rise in times of water shortage, in much the same way as other commodities. The Productivity Commission argues that this would be an economically efficient means of allocating water as the price paid would more accurately reflect availability and the value derived by consumers from the water purchased.
- Allowing urban consumers a choice in water service offerings. For example, paying a higher price for water that would never (or very rarely) be restricted or paying less for a service that would be subject to restrictions more frequently

AWA believes strongly in ensuring that the price paid by consumers accurately reflects the long-term costs of supply and is economically efficient, and supports investigations into alternative approaches or refining of options that might better achieve these ends. The Association believes, however, that such investigations should closely consider equity and community support for new or refined pricing regimes.

There is also a case for research to be carried out into the optimal mix between access charges (fixed charges) and usage charges. In Australia, each household and business pays a fixed price for access to the water supply system and then incurs a cost for each unit of water consumed. It is argued that because the cost of water supply infrastructure is so high and lumpy, the fixed charge is necessary to ensure sufficient funds are available to invest in future water supplies. However, the greater the fixed component of water prices, the less incentive there is for consumers to conserve water because they cannot avoid the fixed charge. In the interests of water efficiency, AWA believes a review of water charges is warranted.

A further aspect of pricing is related to developer charges – those prices charged to developers for the additional demand placed on infrastructure as a result of their developments. In some jurisdictions, developer charges are no longer imposed, but where they are there is commonly no difference in the price charged to a developer of a water efficient sub-division and one whose development is not so innovative. Where more water efficient developments attract access charges that are as great as those paid by traditional developments there is no incentive for improved performance (aside from the premium that might be charged to purchasers). AWA believes that where upstream water supply savings are generated, there is justification for savings to be passed downstream to developers, as well as consumers.

Pricing is a vital part of the water efficiency mix. If water is underpriced it will be over-consumed. In this regard, AWA strongly supports full cost-reflective pricing and also supports research into the benefits that might be gained through regular and thorough reviews of water pricing regimes. AWA also supports policy analysis directed to eliminating cross-subsidies between users, including analysis of the impact of developer charges and the structure of water charges overall to ensure that the right incentives are provided to consumers to use water efficiently. AWA believes that the impact of not carrying out such analysis would be to allow a situation to emerge (or persist) in which selection of one water source over another, more sustainable source, is made simply because the full costs of harnessing the former are not fully accounted for.

7.4. Education and Community Awareness

The effectiveness and rate of uptake of water efficiency measures requires consumers – residential, industrial and commercial – to be aware of the options available, how they should be used or incorporated into existing systems and their performance specifications. Significant efficiency gains can be made if consumers are merely made aware of how much water they use for particular activities and how this water use might be curbed through changes in practice. Education and community awareness are essential elements of water efficiency campaigns in time of scarcity, but even when water supplies are secure it would seem incumbent on utilities to provide advice on water efficiency so that consumers can make informed choices about the water they use.

As a result of the education and awareness-raising measures employed to curb demand in areas in which water has been and may continue to be water short, Australians are among the most water-aware of the world's citizens. This water-awareness has served the country well, and will continue to do so if reinforced. Delivery of cost-effective water services will be achieved more readily if the community is provided with information sufficient to ensure it does not lose its water-literacy over time.

" AUSTRALIANS ARE AMONG THE MOST WATER-AWARE OF THE WORLD'S CITIZENS. THIS WATER-AWARENESS HAS SERVED THE COUNTRY WELL, AND WILL CONTINUE TO DO SO IF REINFORCED. "

Education does not end at the point at which consumers are informed of the options available. Often householders and the managers of commercial premises are unaware of the impacts of their approaches to water management, or how systems or water efficient appliances should be operated to produce maximum benefit. For example, customers may use potable water instead of recycled for outdoor water use in areas with dual reticulation systems. Such behaviour can increase system costs as peak demand is transferred from the recycled system to the potable system, unnecessarily requiring more water to be supplied through the potable system, affecting pumping, storage and transport costs.

AWA strongly urges that comprehensive information be provided to consumers to enable them to make effective choices and to use systems appropriately.

There is a strong argument for more consistent messages to be delivered by utilities operating in different jurisdictions and for exchange of information between utilities about the campaigns and collateral that have been most effective. AWA applauds efforts by its sister organisation, the Water Services Association of Australia (WSAA) which represents the major water utilities, to facilitate exchange of information and promote consistency in messages to the community.

7.5. Water Auditing and Meter Monitoring (Smart Meters)

Monitoring of water flow through meters (such as those installed on utility water mains) is required to get a true picture of the operation of the utility distribution system as well as a specific site's actual water consumption. Increasingly, 'smart meters' are being used to improve information about water consumption patterns of end-users.

These devices have a 'real time' monitoring device incorporated in their design, which provides data that can be used by utilities to provide a more accurate picture of site water usage and by the managers of water supply systems for identifying supply problems. A number of utilities have embarked on programmes to install 'data loggers' at commercial premises to provide a finer, more immediate, analysis of water use.

The information obtained provides input to 'Water auditing' programs carried out at these premises to improve their water use and management practices. This information is a fundamental pre-cursor to the design of good water efficiency programs.

The National Business Water Efficiency Benchmark Project (Mulley, Nelson et al. 2012) is an initiative managed by several water utilities in various states that uses consumption data derived from audits and from 'de-identified customer data' and compares this across a group of similar industries to understand water use characteristics and identify efficiencies. The project aims to identify best practice usage levels across a range of industrial and commercial users and should be promoted to participating utilities and their business customers when completed. Various other research projects based on smart meter data are being undertaken by universities, utilities and CSIRO to optimise system operations and determine the savings in potable water that may be available.

The savings achieved through implementing water efficiency programs are quantifiable through monitoring. Similarly, utility distribution system managers need to regularly monitor and report on their effective delivery of water across the network. However, leaks and inefficient practices cannot be completely removed because they arise over time through wear and tear and poor management. To maintain savings continual vigilance is needed through monitoring, training, regular maintenance and investment in new maintenance and management techniques.

The improvements in water meter accuracy and the delivery of monitored data to easy-to-read interfaces such as phone apps and web portals in homes and workplaces should strengthen the awareness of water efficiency and the ability to identify and act upon issues.

AWA strongly supports the improved monitoring of water consumption patterns and research based on the information obtained. The factsheet '*What are Smart Meters?*' (Australian Water Association 2012) details the current and possible future technology and applications.

7.6. Technology

Technology has had an important role to play in water efficiency. As previously mentioned, water efficient versions of many appliances and fixtures are now readily available and information on their performance is provided through the Water Efficiency Labelling and Standards (WELS) and Smart Approved WaterMark schemes. In NSW, the BASIX scheme mandates the use of a minimum WELS rating for fixtures and appliances in all new buildings. Similarly, in Western Australia the Building Code mandates the use of Smart WaterMark approved pool covers for new pools and spas. Retailers are required to show the WELS rating on appliances and tap-ware. The technology behind these fittings has advanced to the extent that they provide a consumer experience similar to that of older fittings. As a result, the early consumer resistance to low flow fixtures has largely abated.

Notwithstanding the success of the WELS approach there may be grounds for improving the rigour of the scheme by demanding the adoption of minimum efficiency standards for WELS rated products and, potentially, integrating WELS rates with the Equipment Energy Efficiency (E3) rating so that consumers better understand the running costs of appliances. It should be noted that all Melbourne water utilities undertake Residential Appliance Stock Surveys that involve understanding the appliances and fittings in people's homes and how they are used.

AWA supports the widespread adoption of schemes such as WELS and Smart Approved WaterMark. With the withdrawal of some rebates for water efficient appliances, there has been a tendency for commitment to the WELS rating scheme to fall away, leading to the reintroduction to the market of appliances that are not water efficient and on which no data are available to enable consumers to make an informed choice.

> "THERE HAS BEEN A TENDENCY RECENTLY FOR APPLIANCES THAT ARE NOT WATER EFFICIENT AND ABOUT WHICH THERE IS LITTLE CONSUMER INFORMATION TO BE REINTRODUCED TO THE MARKET."

Advances in residential water efficiency technology have occurred in irrigation, domestic appliances, greywater reuse, high-pressure cleaning and pool system water reuse, among others. While there is good information on the water efficiency of many of these technologies, knowledge gaps exist both in the impact of people's behaviour on their effectiveness, and in the efficacy of certain garden products such as mulch, wetting agents and soil ameliorants. Further research is needed to address these gaps.

In the non-residential sector there have been significant improvements in water efficiency across a range of technologies from cooling towers and commercial cleaning equipment through to laundry and restaurant appliances. Hybrid cooling towers, for example, use much less water than a conventional water-cooled system, although there is often an increase in energy consumption which needs to be balanced with the value of water saved and any reduction in capital cost. Other improvements are very cost effective as they are simple to implement. Merely providing a broom rather than washing down hard surfaces can save a significant volume of water over a period. Process reformulation – such as adjusting spray nozzles on production lines to accurately hit their targets or installing automatic shut off devices that activate once a cycle is finished – can similarly be simple, cheap and effective. On-site recycling systems are being implemented on sites that enable the wastewater stream from one process to be the feedwater for another.

Notwithstanding the comments above, further research could usefully be conducted into the availability and efficacy of water efficient technologies for use in outdoor areas and in commercial processes at smaller scales than those encountered by large area water managers, or heavy industrial processes.

Each of the developments described above represents a rapidly developing field. AWA strongly supports objective analysis and research into the cost and benefits of the following:

7.6.1. Recycling and Decentralised Systems

Traditionally, water has been distributed from centralised systems, the source water typically being a dam, groundwater or a river. Advances in technology have made small scale water recycling facilities cost-effective in some situations enabling wastewater to be reused for a variety of purposes.

Decentralised approaches can address water security issues and may produce efficiencies, including a reduction in materials and energy use and a reduction in dependence on centralised supplies which may be cost effective. However, the cumulative energy demand of smaller systems is often higher in many situations, and other issues such as disposal of by-products (wastewater, brine, biosolids and residuals) may be problematic.

There may also be implications for system integrity and cost if existing urban areas are excised from the centralised system. Further research into these issues is needed to quantify their impact. It should also be noted that recycling, as with desalination, is not an efficiency measure in itself – although it may produce efficiencies – as the water that is produced may still be used wastefully.

7.6.2. Distribution System Maintenance

Network performance is also an area in which technological improvement can lead to a reduction in the volume of water drawn down from established water sources. Substantial water savings can be achieved if investment is made in reducing leakage and deterioration of the network. AWA applauds the Australian water industry's significant achievement in leakage control and supports continued developments in this important area.

To this must be added improved management of water pressures, use of new materials, improved metering of network flows and techniques to rehabilitate pipelines in situ. These techniques improve the overall efficiency of the distribution network, but have no or little impact on the consumption of water at the end of the pipe.

Note should also be made of technologies that may reduce total water demand, but which are directed to improving system performance or reconfiguring systems using smaller scale and new technologies, or by better integrating water systems into the design of cities. These are not demand management initiatives, but they may improve the efficiency of system operations. Of particular note are strategies that build efficiency into systems as they are expanded to new growth areas.

The Water Corporation has, for example, adopted approaches that enable pressure to be managed more effectively in new development areas. The result is less water loss and fewer pipeline failures, without any diminution in service quality at the customers' tap.

7.6.3. Water Sensitive Urban Design

Significant improvements can be made in the design of urban areas in order to better integrate urban services, including water, and maximise their value. The federal government with local, state, national and private research partners has recently funded a Cooperative Research Centre for Water Sensitive Cities to "deliver the socio-technical urban water management solutions, education and training programs, and industry engagement required to make Australian towns and cities water-sensitive". Research investment is directed to enabling urban areas to "use efficiently the diversity of water resources available within towns and cities; enhance and protect the health of urban waterways and wetlands; …mitigate…flood risk and damage…and create public spaces that harvest, clean and recycle water, increase biodiversity and reduce urban heat island effects" (CRC for Water Sensitive Cities 2012).

Similarly, the Institute for Sustainable Futures, at the University of Technology, Sydney has been engaged in a significant program of research over many years into the development of more sustainable water systems and has recently referred to society's progression to a fourth generation of urban water service provision. This is characterised by an integrated service offering that is focussed on "planned and managed distributed wastewater treatment and reuse, advanced water efficiency, [and] distributed stormwater capture and management integrated into water supply" that could be delivered at "medium financial cost" to households and which would take account of the environmental and social costs and benefits of urban water service provision (White 2010).

> "SUBSTANTIAL WATER SAVINGS CAN BE ACHIEVED IF INVESTMENT IS MADE IN REDUCING LEAKAGE AND DETERIORATION OF THE NETWORK."

7.7. Consistency of Approach to Water Efficiency

Stimulated by drought conditions and backed with evidence of their effectiveness, many federal and state programs were set up to promote water efficiency. Among these were:

- **Victoria - Water Management Action Plans (waterMAPs)**
- **Queensland - Water Efficiency Management Plans (WEMPs)**
- **New South Wales - Water Saver Action Plans (WSAPs)**
- **Western Australia - Waterwise program**
- **South Australia - H2OME and Water for Good**
- **Brisbane - Target 140 program**
- **Melbourne - Target 155 program.**

Many of these were developed without the lessons of existing and predecessor programs being taken into account. The learnings of a program in one state should be noted by other states and the impacts of programs run at an earlier time should be recorded and improved upon in subsequent programs. Lessons can also be drawn from programs and research undertaken overseas. Failure to address this often leads to duplication and waste. The Australian water industry needs to have a coordinated approach to efficiency to maximise its ability to reach the community and industry with the water efficiency message.

As a corollary of this, AWA strongly supports the development of training courses and guidelines that are more consistent nationally. Courses should be generic enough to be used nationally and flexible enough to be updated to respond to new ideas and technologies.

"AWA STRONGLY SUPPORTS THE DEVELOPMENT OF TRAINING COURSES AND GUIDELINES THAT ARE MORE CONSISTENT NATIONALLY"

7.8. Emerging Issues

There are a number of emerging issues that will impact on the future planning and delivery of water efficiency policy and practices across Australia.

Many river systems in Australia are over-allocated. Much effort is currently directed to reducing this over-allocation, the Murray–Darling Basin Plan being a prime example. This Plan and others – required to be developed for each catchment across Australia – will need to take into account climate change, population increase, environmental water requirements and the strong link that exists between the growing middle classes in Asia and demand for more water-intensive foods. Within this context, the demands made by urban centres on the pool of consumptive water available will need to be balanced against demands for water for irrigation, for the environment and for cultural and economic purposes. Efficient water use in urban areas will be expected if cities are to make a claim on water supplies that appears legitimate to other users and to other demands.

New tools and techniques are being developed to help identify and measure the extent of and demands upon water resources, including the management of aging infrastructure by water businesses as they endeavour to drive aging assets to deliver on rising customer expectations. These tools and techniques will help policy makers and water practitioners better plan for future supply and demand in an increasingly complex water network in parallel with increasing customer expectations.

As Integrated Water Management moves from concept through to execution, the efficient use of water through transport to more highly integrated water networks becomes adopted practice; the efficient use of water will increasingly become better understood and monitored in real time. This will be an exciting space to watch for future developments.

Methodologies for assessing the embodied water in commodities are becoming more sophisticated and help identify the "water footprint" of a region or country, including the trade in virtual water (Hoekstra and Chapagain 2008). Water footprinting is a relatively recent development, but methodologies to assess water footprints are becoming more sophisticated and their use is growing.

Continued reform of the water industry may also impact on the adoption and uptake of water efficiency measures by utilities. With increasing privatisation of the water industry, measures may need to be put in place to ensure the pressure to generate profit does not override the wider community benefits of efficient water use.

A short-term challenge for the water industry is the need to continue to innovate and improve water efficiency to address these emerging issues at a time when many of Australia's cities have moved out of drought. Many of the water businesses throughout Australia invest in innovation both internally and through partnering with Universities, private industry, CRCs and water research funding bodies. Water efficiency research will continue to be a part of this innovation.

8. Conclusions

Water efficiency has been an essential component of Australia's response to drought. Much of what has been attempted has been experimental – although solidly grounded – and there have been many successes. The easing of drought conditions across much of Australia has meant that some water efficiency programs have been wound back and most restrictions lifted. This winding back may be justified, but water efficiency should remain on the national water agenda. Water efficiency can often be a more cost-effective means of ensuring supply security than construction of supply-side options and efficiency produces other benefits such as a reduction in energy use, and a sharing of water with the environment and other users (e.g. farmers).

AWA does not argue for water efficiency to be the solution to all water security or environmental challenges. Water efficiency measures are not always the most cost-effective. AWA does believe, however, that water efficiency measures must always be considered in policy decisions related to water supply security or sustainable water management. In comparing the costs and benefits of each of the options available, non-monetarised values and externalities should be taken into account.

AWA believes that the setting of a price that reflects the full costs of supplying water services to consumers is an essential component of water efficiency. If water is under-priced it will be over-consumed. AWA believes strongly that more effort should be directed to internalising externalities associated with all water security options – both demand- and supply-side. To do otherwise will be to distort decision-making and potentially lead to the selection of less sustainable options.

AWA also believes that it is essential that the price charged to consumers fully reflects the cost of supply, and that price structures be economically efficient. There is a strong case for researching the costs and benefits of alternative approaches, including the provision of a range of service offerings, scarcity pricing and others to ensure that the right incentives are provided for consumers to rationalise water use.

While some water efficiency programs have been curtailed, it remains incumbent on governments to provide information to consumers on the relative water efficiency of appliances and of other means to reduce water consumption. Consumers must have the knowledge to make the decisions that will best reflect their personal preferences. Schemes such as the Water Efficiency Labelling and Standards (WELS) Scheme and the Smart Approved WaterMark are strongly supported.

Continued investment in research and technological development is warranted at many levels ranging from household appliances, consumer behaviour, industrial process reformulation, system management and restoration and water sensitive cities, among others. It will also be important that water monitoring data be used thoughtfully, providing evidence for review and extension of water efficiency initiatives.

It will be important that Australia does not lose skills and abilities in efficient water management, not least because the impact of climate change and population growth may reduce available supply and increase demand overall. To this end, there should be a sharing of information, and the development of accredited training courses and guidelines that are consistent nationally.

To meet its water needs in future, Australia will need to ensure its approach is diverse and tailored to circumstances. Water efficiency measures must always be part of the mix. They will not always be the best choices, but in determining the best approaches it will be vital that efficiency measures be given equal weight and that the costs and benefits of all measures are considered dispassionately and accurately.

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Level 6, 655 Pacific Hwy PO Box 222, St Leonards NSW 1590
Tel + 61 2 9436 0055 Fax +61 2 9436 0155 Web www.awa.asn.au
ABN 78 096 035 773

USING SURFACES OF BIG DATA TO UNDERPIN CONTINUOUS SIMULATION IN SYSTEMS ANALYSIS

Peter J Coombes[1], Michael E Barry[2]

ABSTRACT: *The systems framework was designed to explore the multiple scale impacts of water, energy and environmental decisions using a bottom up approach to spatial systems analysis. This approach utilises big data layers of local information to create sub-daily surfaces of climate, stormwater runoff, streamflow and urban water demand. These surfaces of information and a multi-scaled framework of processes permit the generation of multi-site synthetic rainfall and associated continuous simulation of urban processes. This approach underpins the understanding of the multiple scale systems dynamics of water and energy systems. This paper presents the methodology for simulating multi-site rainfall and water demands based on surfaces of climate, demographic, socioeconomic, topography and environmental information. The approach satisfactorily reproduces observed daily, monthly, annual statistics of rainfall and water use at multiple scales. This demonstrates that the method is able to capture the inter-annual persistence and spatial variability of water use and rainfall that exists within the Greater Melbourne and Sydney regions. The systems method was able to adequately estimate regional water demand including the day to day variation, distributions and strong seasonal patterns. The bottom up construct of the Systems Framework can provide robust evaluation of the regional responses of local interventions such as Water Sensitive Urban Design.*

KEYWORDS: Big Data, Synthetic Rainfall, Scales, Continuous Simulation, Water Demand, Stormwater

[1] Peter J Coombes, Urban Water Cycle Solutions, Newcastle, Australia. Email: peter@uwcs.com.au
[2] Michael Barry, BMT WBM, Brisbane, Australia. Email: michael.barry@bmtwbm.com.au

ISBN: 978-1-925627-03-9

1 INTRODUCTION

The systems framework[1] was designed to explore the multiple scale impacts of water, energy and environmental decisions using a bottom up approach to spatial systems analysis. This approach utilises big data layers of local information to create sub-daily surfaces of climate, stormwater runoff, streamflow and urban water demand. These surfaces of information and a multi-scaled framework of processes permit the generation of multi-site synthetic rainfall and associated continuous simulation of urban processes. This approach underpins the understanding of the multiple scale systems dynamics of water and energy systems.

This paper presents the methodology for simulating multi-site rainfall and water demands based on surfaces of climate, demographic, socioeconomic, topography and environmental information. The approach extends the previous work of Coombes et al., (2003).[2] Climate series generated by the multi-site method were used with non-parametric matching sourced from molecular sciences to incorporate water balances in households in a regional water demand model to estimate daily water demand in the Sydney and Melbourne regions. This bottom up method was evaluated using observed spatial variability of climate and water use within the Greater Melbourne and Sydney urban regions by comparison to observed daily, monthly, annual statistics of rainfall and water use at multiple sites.

2 INCLUDING SPATIAL CLIMATE

Urban areas are subject to considerable spatial and temporal variation in climate (rainfall and temperature) that is a driver of spatially variable stormwater runoff and water use behaviours. The Systems Framework processes account for this variability of urban systems by incorporating bottom up inputs throughout urban regions in continuous simulation.[1] This process involves methods to transform typically fragmented data from inconsistent time periods (such as from the Bureau of Meteorology) into temporally and spatially continuous surfaces of information from the same time period.

The non-parametric nearest neighbourhood schemes outlined by Coombes et al., (2002; 2004) are utilised to develop spatial surfaces of daily rainfall, days with rainfall (a measure of rainfall frequency), and minimum and maximum temperatures.[2,5] This process is described for constructing surfaces of daily rainfall for a given region as follows:

1. Define the boundaries of the required region (such as the Greater Melbourne and Greater Sydney water supply regions) and subdivide into zones required for analysis (such as local government areas);
2. Select all observed daily rainfall records within or near the region and prepare records for analysis;
3. Evaluate all rainfall records to determine lengths and completeness of data;
4. Determine the distances from the centroid of each selected zone to the locations of all rainfall records;
5. Select the time horizon of the new daily rainfall surface (such as 1913 to 2013) that occurs within the time period of the observed rainfall data;
6. Construct a complete daily rainfall record for each zone using the nearest complete sequences of observed rainfall that matches the time period of missing data;
7. Provide statistics about the development of the rainfall record for each zone such as main source of observations (BOM file number) and distance from the zone, and details of observed rainfall sites and associated distances from zones used for infill of missing data.

This process to produce daily rainfall surfaces is enacted using computer software within the Big Data part of the Systems Framework.

2.1 RAINFALL DEPTH AND FREQUENCY

Development of surfaces of daily rainfall and associated frequency of rainfall (annual rain days) for Greater Melbourne and Sydney regions for the period 1913 to 2013 is presented in this section. These results were used to construct the spatial plots of average annual rainfall and rainfall days for the Greater Melbourne region shown in Figures 1 and 2. These Figures demonstrate that the Greater Melbourne region experiences a high level of spatial variation in rainfall depth and frequency with higher values in the east to lower values in the west. Development of a daily rainfall for each of the 36 zones in Greater Melbourne involved analysis of 494 daily rainfall records from the BOM.

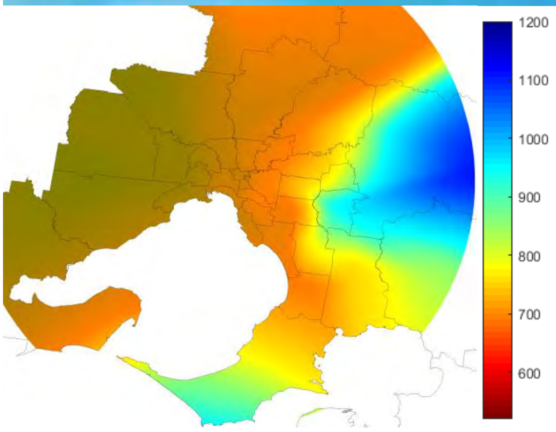

***Figure 1:** Average annual rainfall depth across Greater Melbourne (1913 – 2013)*

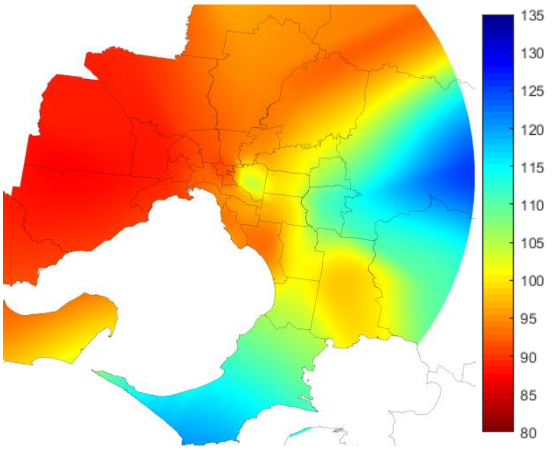

***Figure 2:** Average annual days with rainfall across Greater Melbourne (1913 – 2013)*

The outputs from this process include diagnostic information and statistics from each zone. For example, construction of daily rainfall for the Banyule zone involved selection of adjacent rainfall records from minimum, mean and maximum distances of 1.3 km, 4.32 km and 7.2 km. Average monthly statistics for average daily rainfall and rain days are also produced.

Daily rainfall was also constructed for 46 zones across the Greater Sydney region. The resultant surfaces of average annual rainfall and rainfall days are shown in Figures 3 and 4. These Figures show the spatial variation in rainfall depth and frequency that varies with distance from the coast. The method utilised 493 observed rainfall records to reproduce this variability across 46 local government zones.

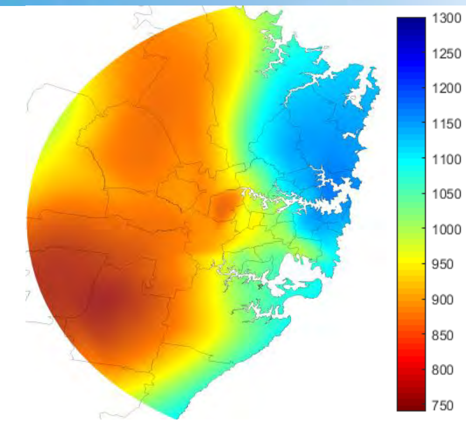

***Figure 3:** Average annual rainfall depth across Greater Sydney (1913 – 2013)*

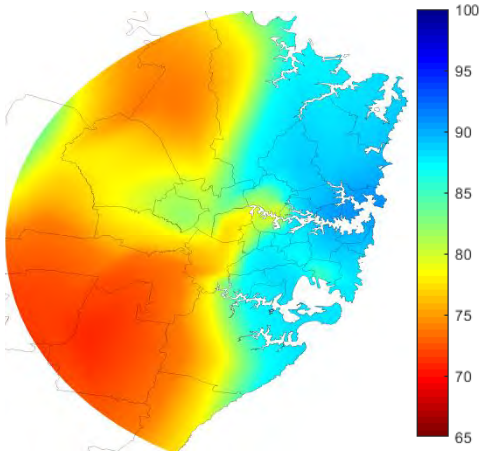

***Figure 4:** Average annual days with rainfall across Greater Sydney (1913 – 2013)*

Construction of daily rainfall for the Ashfield zone, for example, involved selection of adjacent rainfall records from minimum, mean and maximum distances of 0.49 km, 0.85 km and 6.4 km. Creation of a spatial surface of daily rainfall records of the same length has reproduced the natural spatial variation of rainfall and permits relative analysis of the solutions throughout the region.

2.2 SURFACES OF CONTINUOUS RAINFALL

The Systems Framework utilises the software engine from the Probabilistic Urban Rainwater and wastewater Reuse Simulator (PURRS) to continuously simulate local water balances at sub-daily time steps (typically 6 minutes).[6] This detailed local process is necessary to capture the distributed local behaviours of people, buildings and land uses that impact on infrastructure and

ISBN: 978-1-925627-03-9

ecosystems, and drive the performance of the entire system. Continuous rainfall (6 minute time steps) records of equal length are required for each local zone within a region to facilitate simulation of local behaviours. Synthetic continuous (6 minute time step) rainfall records are derived for each zone using the local synthetic daily rainfall within a non-parametric nearest neighbourhood scheme.[3] Data from nearest observed pluviograph rainfall records is utilised to disaggregate daily rainfall into a synthetic continuous rainfall record. The concept is illustrated in Figure 5.

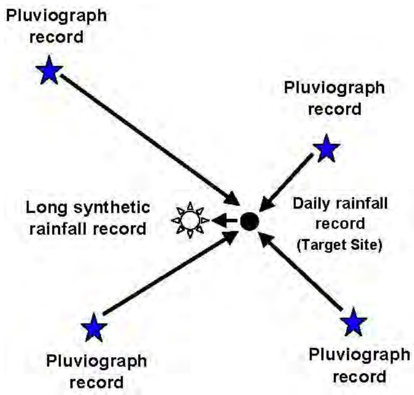

Figure 5: Diagram of the non-parametric nearest neighbourhood scheme for development of synthetic continuous rainfall records

Figure 5 shows the concept that is enacted for each day in the daily rainfall record to select a day of pluviograph rainfall (6 minute intervals) using climate and seasonal parameters, and a ranking scheme. The non-parametric scheme matches climate and seasonal parameters (daily rainfall depth, month, count of days since last rain event) at the daily rainfall and at the nearby pluviograph rainfall sites to select a day of pluviograph rainfall from the most appropriate nearby pluviograph record.

Nearby pluviograph records are ranked on the basis of proximity to the location of the daily rainfall record, similarity of seasonal rainfall depths, topography and distance from the coast. This allows disaggregation of daily rainfall records into a series of storm events and dry periods that constitute a synthetic continuous rainfall record. The pluviograph rainfall records from the BOM used to make synthetic continuous rainfall for Banyule (for example) are summarised in Table 1.

Table 1: Pluviograph rainfall records (BOM) used to make synthetic continuous rainfall for Banyule

Location	Number	Period (yrs)	Distance (km)
Bundoora	86351	1984 - 2012	4.1
Preston Res	86096	1929 - 1974	7.2
Melbourne RO	86071	1873 – 2011	13.1
Mitcham	86074	1939 - 1977	13.4

3 INCLUDING SPATIAL RESIDENTIAL WATER USE

The use of average water demands and household sizes to simulate the performance of urban water strategies produces considerable errors and uncertainty.[7] Annual average household water demands were derived for local government areas using water utility billing records for Greater Melbourne (2004 to 2005) and for Greater Sydney (1996 to 2003) as shown in Figures 6 and 7. It is important to note that these results for annual average water use are the average of all dwellings types and households sizes within each local government area. Nevertheless, Figures 6 and 7 reveal that average household water use for local government areas is subject to significant variation across the regions. This variation is influenced by a range of factors including the distribution of dwelling types, household sizes, climate and household income. It is a key issue that the average household water use for each zone is not the actual water use in each dwelling.

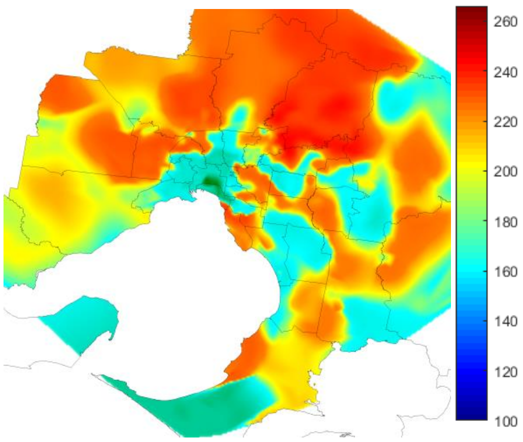

Figure 6: Average annual residential water demand across Greater Melbourne (2004 -2005)

The performance of urban water strategies is primarily dependent on water use behaviour at each household, building and land use.

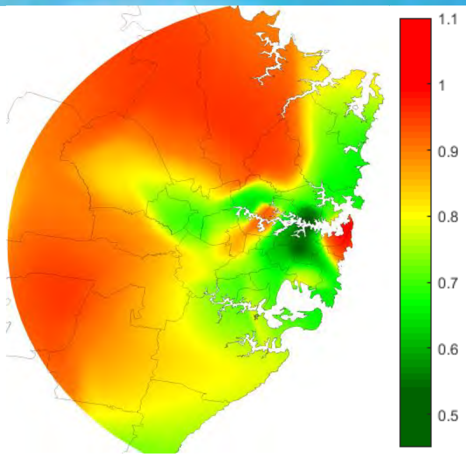

Figure 7: *Average daily residential water demand across Greater Sydney (1996 – 2003)*

Information about the distribution of household sizes and dwelling types was available for local government areas from the Australian Bureau of Statistics.[8] Water demands at any location are dependent on the distribution of household sizes and dwelling types. As demonstrated in Figure 8 for the Melbourne zone and in Figure 9 for the Wyndham zone, distributions of dwelling types and household sizes are vastly different across a region. These local variations of household sizes and dwelling types are included in the Systems Framework to overcome these differences that skew average water use values.

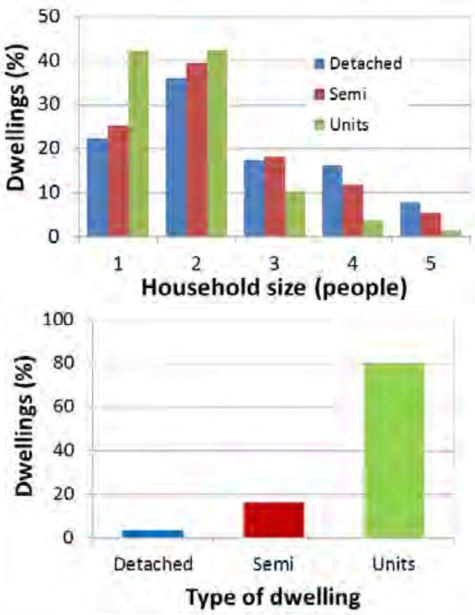

Figure 8: *Distribution of household sizes (top pane) and types of dwellings (bottom pane) for Melbourne local government area*

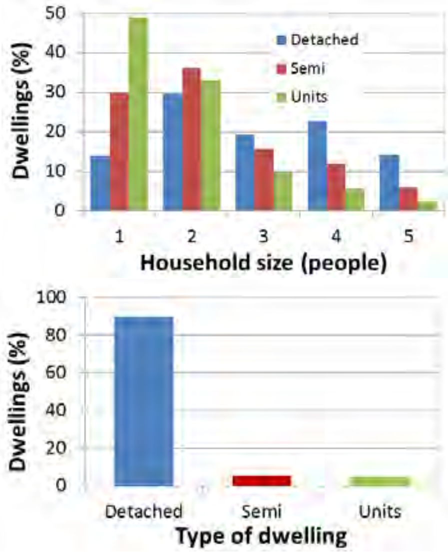

Figure 9: *Distribution of household sizes (top pane) and types of dwellings (bottom pane) for Wyndham local government area*

As shown in Figure 8 and 9, for example, the dwelling stock in each zone comprises different dwelling types that also generate different behaviours that will influence the characteristics of household water use. A detached dwelling may allow opportunity for significant outdoor water use whilst a unit dwelling is unlikely to provide opportunities for significant outdoor use. The known distributions of household sizes and dwelling types provide an opportunity to disaggregate average household water demands sourced from a water utility for a local government area into the likely water demands in each dwelling. This task also requires an estimate of the proportion of water demand that is used outdoors.

The variability of outdoor water use for various household types in different climate zones is not usually measured. A unique study of household water use analysed indoor and outdoor water use in 192 houses across 5 climate zones, 14 demographic regions and 12 years in the Hunter region of New South Wales and derived relationships for estimating monthly average daily outdoor (OutDem: Equation 1) and indoor (InDem: Equation 2) use as follows:[4,9]

$$\begin{aligned} OutDem &= 7.5M - 11.3AveR - 0.025Inc \\ &- 0.82Rdays + 24.44G + 19.1AveT - 251 \end{aligned} \quad (1)$$

$$\begin{aligned} InDem &= 27.8 + 145.7P - 0.4M - 10.6AveR \\ &+ 6.7Rdays - 0.16Inc - 12.3G + 0.49AveT \end{aligned} \quad (2)$$

where P is household size, M is a seasonal index with values from 1 to 6 (January and December = 1; June and July = 6), Inc is the average income of people in the household, AveR is average monthly daily rainfall, G is annual population growth, Rdays is the number of rain days in each month and AveT is the average monthly daily maximum temperature.

The relationships for monthly average daily indoor and outdoor use were derived using the climate outputs derived using processes described in Section 2 and using socioeconomic data from the Australian Bureau of Statistics (ABS). These water use values are used as central boundary conditions in the climate and economic dependent water use simulations of dwellings within the Systems Framework. The process of developing calibrated household water use models is summarised as follows:

1. Determine monthly average daily indoor and outdoor water use for each zone in a given region using Equations 1 and 2;
2. Use monthly average indoor and outdoor water use boundary conditions with synthetic continuous rainfall, climate and demographic statistics in the PURRS model. Outdoor use in a semi-detached or unit dwelling is 10% or 5% of outdoor use in a detached dwelling. Outdoor use is independent of household size. Simulate the performance of 5 household sizes in each of 3 dwelling types (for example);
3. Combine distributions of household sizes and dwelling types with results from the preliminary simulations of water use at each dwelling to develop an average water use for each zone;
4. Adjust observed water use values to account for take up rates of water efficient appliances and rainwater harvesting. This information was sourced from the data underpinning the ABS Environmental Series publications[10] as discussed in Coombes et al., (2018)[11]. This process develops the base water use of households for use in calibration. Additional dwellings with water efficient appliances and rainwater harvesting is added to simulations after calibration to ensure accurate responses;
5. Compare observed average water use (from a water utility) to the simulated average water use for the time period and intervals of available observations. For example, the observed time period for Sydney was 1996 to 2003 and the interval of observations was quarterly. Calibrate the local scale models to reproduce the observed average water use. This process provides calibrated indoor and outdoor use values for each household size in dwelling type for each zone (see Figure 10).

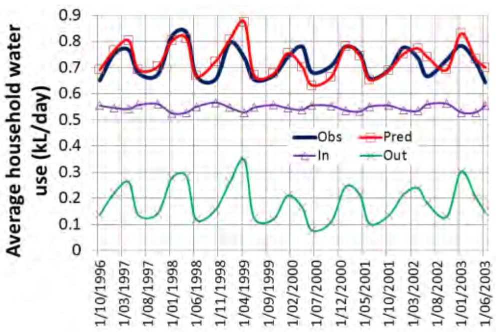

***Figure 10:** Calibration of the household water use models to observed water use in the Bankstown local government area (1996 – 2003)*

Figure 10 demonstrates the calibration of observed and predicted average household water use for the Bankstown local government area using observed data from Sydney Water Corporation. The calibrated average daily indoor and outdoor uses for the area are also shown in Figure 10. The residential land uses were combined with non-residential land uses including agricultural, commerce, industry, education, medical, forests, irrigated parks and transport. Local scale continuous simulations are completed for each dwelling type with different levels of known water efficient behaviours and for land use in each zone at time steps ranging from one second to six minutes using the local sequences of rainfall data. Outputs from the local scale analysis include sequences of water demands, wastewater discharges, stormwater runoff, energy demand, water quality, soil moisture and finances. These results are combined with climate data and passed to the Transition Framework as reference files.

3.1 A FRAMEWORK TO MAKE WATER FLOWS AT A ZONE

The sequences of water use, wastewater flows, stormwater runoff, financial transactions and energy use from the local scale analysis were combined in each zone using town planning projections and replicates of daily spatial climate sequences as shown in Figure 11. A transition framework is used to generate daily water cycle responses for each zone. Sequences of daily water and energy balance, and financial results from local scale are linked using seasonal information and historical climate data (including daily rain depths, cumulative days without rainfall and average daily maximum ambient air temperature) to create resource files of water demand, wastewater generation, stormwater runoff, energy use and economic transactions.

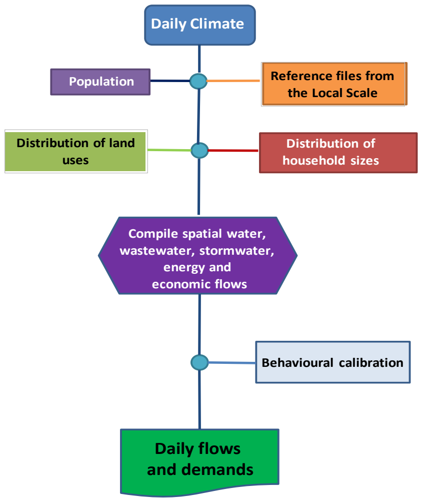

Figure 11: *The transition framework for combining land use behaviours at the zone scale*

This method of non-parametric aggregation (Coombes et al., 2002) generates daily outputs from each zone using the historical resource files and climate replicates generated for the simulation of the regional system.[5] Climate replicates are multiple sequences of equally likely future climate drivers (such as rainfall, temperature) that are generated using Monte Carlo processes.

3.2 REGIONAL SCALE PROCESSES

The Systems Framework combines water, wastewater and stormwater infrastructure networks with waterways and catchments in an integrated network. Spatial and temporal information generated by the lot scale simulations are combined by the zone scale transition as inputs to the network analysis. Details of systems analysis of the Melbourne and Sydney water supply systems are provided by Coombes (2012; 2005).[12,13] The regional scale of the Framework includes water sources from ground water, surface water sourced from regional river basins, shared surface water with other river basins, wastewater reuse and stormwater harvesting. The linked analysis utilises stream flows, reservoir storage volumes, wastewater discharges, information about the operation of water systems and data from global climate model as inputs. The simulations also include operating rules and regional policies such as water restriction triggers. The behaviour of the System Framework is verified at the regional scale using a hindcasting process (described below) that compares predicted and observed behaviours for key processes within historical time periods.

4 RESULTS

The results of predicted rainfall and water demands are compared to observed values in this Section. Recognised two sample statistical tests (t Test and Z scores) are also used to understand the results.

4.1 RAINFALL

The efficacy of the synthetic daily rainfall process was evaluated by comparison to the two longest observed daily rainfall records at Observatory Hill in the Sydney zone and at Melbourne RO in the Melbourne zone as shown in Figure 12. Note that the Observatory Hill daily rainfall record was not used to create the synthetic daily rainfall for the Sydney zone.

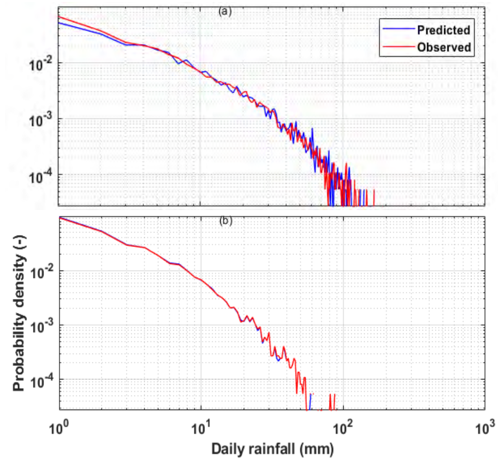

Figure 12: *Observed and predicted daily rainfall for Melbourne (bottom pane) and Sydney (top pane) zones (1913 – 2013)*

Figure 12 shows that the synthetic daily rainfall was similar to the observed rainfall across the entire distribution of rainfall depths in Melbourne and Sydney. The mean synthetic daily rainfall for the Melbourne zone was the same as the observed mean rainfall with 99.99% level of certainty. The coefficient of determination R^2 indicated that the synethetic rainfall described 99% of the variation in the observed rainfall. The predicted 150 average annual rain days were similar to the observed 149 average annual rain days. This result was expected because the Melbourne RO rainfall was included in the process of estimating rainfall for the Melbourne zone.

ISBN: 978-1-925627-03-9

The mean synthetic daily rainfall for Sydney zone was the same as the mean observed rainfall with a 95% level of certainty. The R^2 value indicated that the synthetic rainfall described 96% of observed rainfall. The observed annual average rain depth of 1,221 mm was similar to the predicted rainfall depth of 1,215 mm. The predicted 119 average annual raindays was 15% less that the observed 139 raindays. These results are excellent given that the local Observatory Hill observations were not used to develop the synthetic rainfall for the Sydney zone.

Local scale processes in the Systems Framework rely on synthetic continuous rainfall records to simulate the performance of households and land uses in each zone. The distributions of hourly rainfall totals from Synthetic continuous rainfall and observed pluviograph rainfall was evaluated by comparison to the two longest pluviograph rainfall records at Observatory Hill in the Sydney zone and at Melbourne RO in the Melbourne zone as shown in Figure 13. Note that the lengths of the observed pluviographs was different to the lengths synthetic records.

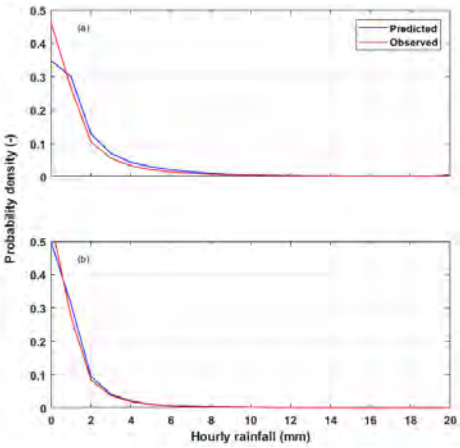

***Figure 13:** Observed and predicted continuous rainfall for Melbourne (bottom pane) and Sydney (top pane) zones*

Figure 13 shows that the predicted continuous rainfalls produced similar distributions of hourly rainfall as the observed records. The small difference between the distributions at the Sydney zone at less than 1 mm hourly rain depth may be caused by the different lengths of the predicted and observed records. These results indicate that use of the synthetic continuous rainfall in local simulations will produce realistic patterns of sub-daily water balance responses such as stormwater runoff, rainwater harvesting and impacts on wastewater networks.

4.2 REGIONAL WATER DEMAND

The "bottom up" process of generating local water use from dwellings and land uses in each zone was evaluated by comparison of historical observed water use to predicted water for the entire Greater Melbourne and Sydney regions. The predicted daily and monthly water demands for Greater Melbourne are compared to the historical observations in Figure 14.

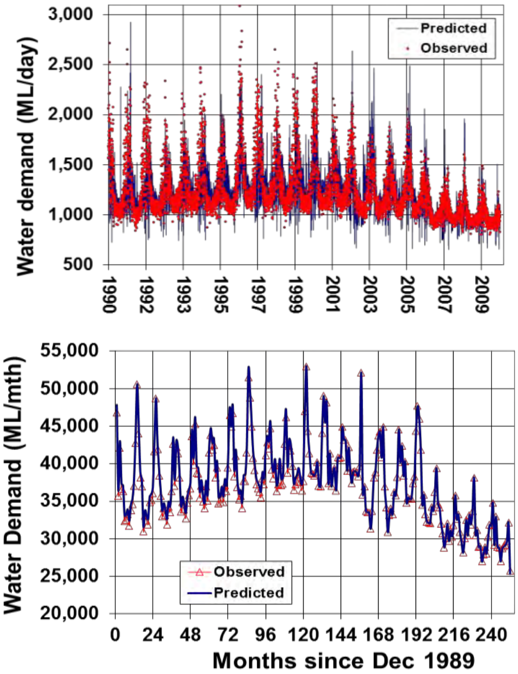

***Figure 14:** Observed and predicted daily and monthly water demands for Greater Melbourne (1990 – 2010)*

Figure 14 demonstrates that the predicted water demands are consistent with the seasonal patterns of the observed demands for the Greater Sydney region. The similarity between predicted and observed water demands in the later portion of Figure 14 also show that the Systems Framework processes has also reproduced the reduced water use due to increased household water efficiency and responses to water restrictions during the period 2005 to 2009.

The mean predicted daily demands for Greater Melbourne are the same as the observed daily demands with 99% level of certainty. The R^2 value indicates that predicted daily demands described 66% of the variation in observed water demands.

The mean of predicted monthly demands are the same as the mean of observed monthly demands with a 95% level of certainty. The R^2 value indicates that the predicted monthly demands describe 95% of the variation in observed monthly demands. These results show that the mean across observation horizon and much of variation of observed water demands for Greater Melbourne were successfully predicted using the framework of bottom up water use from across the region.

The predicted daily and monthly water demands for Greater Sydney are compared to historical observations in Figure 15 for the period 1997 to 2005.

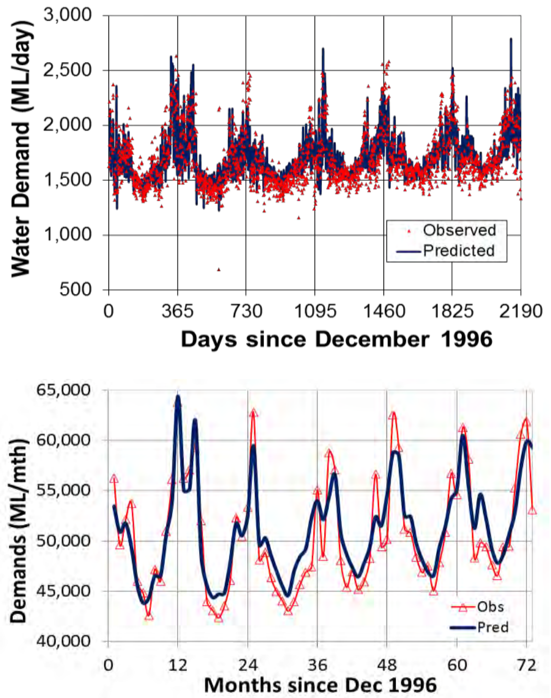

Figure 15: *Observed and predicted daily and monthly water demands for Greater Sydney (1997 – 2005)*

Figure 15 shows that the predicted water demands have reproduced the daily and monthly patterns of regional water demands for Greater Sydney. The predicted and observed mean daily demands are the same with 99% level of certainty and the R^2 value suggests that predicted daily demands describe 62% of the variation in daily observed demands. The mean of predicted monthly demands was the same as the mean of observed monthly demands with a 95% level of certainty. Predicted monthly demands describe 68% of the variation in observed monthly demands as indicated by the R^2 value. Distributions of daily water demands for Greater Sydney (top pane) and Greater Melbourne (bottom pane) are compared to observed demands in Figure 16 for the period of limited water restrictions from 1997 to 2005.

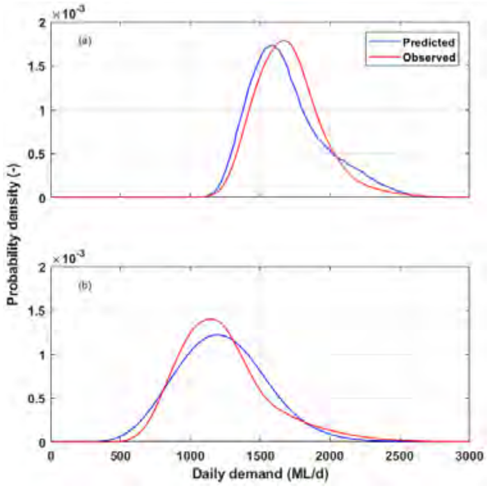

Figure 16: *Distributions of predicted and observed daily water demands for Sydney (top pane) and Melbourne (bottom pane) for 1997 to 2005.*

Figure 16 demonstrates that the distributions of predicted daily demands is similar to the distributions of observed observed daily demands for Greater Sydney and Melbourne. Distributions of predicted and observed daily demands are compared for the period of water restrictions (2005 – 2009) in Greater Melbourne in Figure 17.

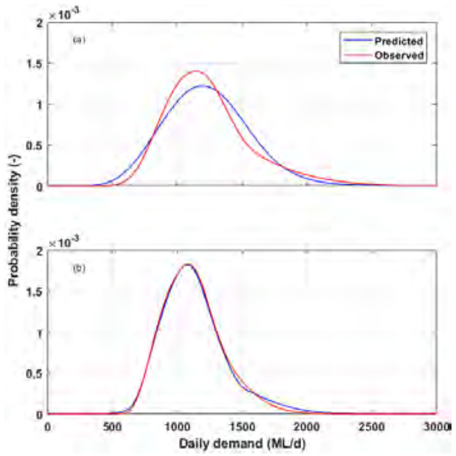

Figure 17: *Predicted and observed daily water demands before water restrictions (top pane) and during water restrictions (bottom pane) for Greater Melbourne*

Figure 17 demonstrates that the bottom up process of predicting water demands was able to produce a high level of agreement with the observed

demands. This indicates the Systems Framework processes were about the predicted the changes in household water saving behaviours and water restrictions on regional water demands.

5 DISCUSSION

This study has highlighted that the Greater Melbourne and Sydney regions are subject to strong spatial variation in household water use, rainfall depths and frequency. Observed average household water demands for a local government area do not represent the average water use in the different dwellings and household sizes that are the components of the area. Continuous simulation of the performance of different household sizes in a variety of dwelling types can be used to deconstruct average water use into calibrated water use for different households.

Demographic, socioeconomic, climate and water use information was successfully transformed into surfaces of local data, and household and non-residential water balances. This structure was then used in a systems framework to reproduce the patterns and magnitudes of rainfall and water use throughout the regions. The bottom up structure of this method will enable more robust investigations of regional responses of local interventions including Water Sensitive Urban Design.

6 CONCLUSION

The Systems Framework processes utilises local rainfall and household water balances processes to satisfactorily reproduce observed daily, monthly, annual statistics of rainfall and water use at multiple sites. This demonstrates that the method is able to capture the inter-annual persistence and spatial variability of rainfall and water use that exists throughout the Greater Melbourne and Sydney regions. This demand method was able to adequately estimate regional water demand including the day to day variation and strong seasonal trends of water demand for the regions. This bottom up continuous simulation method provides an opportunity to understand the benefits of local solutions such as Water Sensitive Urban Design on regional systems.

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PLANNING FOR WATER SENSITIVE COMMUNITIES: THE NEED FOR A BOTTOM UP SYSTEMS APPROACH

Michael E Barry[1] and Peter J Coombes[2]

ABSTRACT: *The impacts of making average demand assumptions on water security predictions and distribution patterns is investigated using calibrated bottom up multi-scale numerical models of the Greater Melbourne and Sydney water networks. The calibrated models, which are highly spatially and temporally resolved, are progressively modified by removing their temporal and spatial granularity and replacing demands with various average assumptions. It is shown that average assumptions lead to material differences in model predictive behaviour, and that the directions of these differences are unpredictable and sometimes lead to counterintuitive outcomes. It is concluded that the application of average demand assumptions of any kind is difficult to support and that doing so has the potential to influence heavily infrastructure investment and, more broadly, policy direction.*

KEYWORDS: Water resource planning, systems analysis, bottom up, averaging, water security, resilience.

[1] Michael Barry, BMT, Brisbane, Australia. Email: michael.barry@bmtwbm.com.au
[2] Peter J Coombes, Urban Water Cycle Solutions, Newcastle, Australia. Email: peter@UWCS.com.au

ISBN: 978-1-925627-03-9

1 INTRODUCTION

The responsible and equitable social, fiscal and environmental management of Australia's water resources is central to planning for future water challenges across the world's second driest continent. Indeed, development of a robust understanding of the nonlinear interactions of all water streams in our urban settings is vital in laying out our visions and plans for future sustainable and resilient cities.

One way to come to this understanding is to construct and deploy numerical tools that consider the natural and anthropogenic water cycles and their interactions. There is, however, currently considerable variation across the domestic water industry as to the nature of assumptions adopted to underpin model construction. A specific example is the adoption of either top down (i.e. application of varying levels of spatial and temporal averaging) or bottom up (i.e. making no average assumptions and capturing local behaviours) analysis techniques using systems modelling.

In this investigation, we use advanced systems analysis (The Systems Framework is described by Coombes and Barry, 2015) [1] to assess the predictions of verified systems models - all of which initially use a bottom up approach and therefore include a high degree of spatial and temporal granularity - of the entire water cycles of Greater Melbourne and Sydney under varying input assumptions. This builds on the work of [2] and [7].

2 METHODS

2.1 MODELS

Both the Melbourne and Sydney systems models included the simulation of potable, wastewater and stormwater at three hierarchical and linked levels of spatial and temporal granularity: the local scale (individual dwellings); zone scale (approximately suburbs); and the whole of system scale (i.e. Greater Melbourne and Greater Sydney). This approach, which has been developed by the authors over two decades, ensures that the modelling system explicitly and properly accounts for both the spatial and temporal variability well-known to characterise water networks. This systems approach ensures that this variability is included as it manifests in reality, i.e. from the bottom (i.e. the smallest spatial and temporal scales at the individual lot or dwelling) upwards (i.e. to the whole of system scale via the intermediary zone scale).

2.1.1 Local scale

The local scale modelling of each system included the simulation of indoor and outdoor water use, wastewater and stormwater production across fifteen different residential dwelling possibilities (detached, semi-detached and units, each with occupancies of one to five people). Each simulation (depending on the options adopted) included the operation of rainwater tanks (down to timescales of seconds), water efficient appliances and local greywater reuse. Climate data from the Bureau of Meteorology (including pluviograph data, daily rainfall and daily maximum and minimum temperatures) were used to force the local model. Novel nearest neighbour spatial backfilling methods were devised and implemented to fill temporal gaps in these records and therefore support generation of one hundred year, six minute rainfall and temperature sequences to drive the local scale simulations.

Demographic data from the Australia Bureau of Statistics (ABS) and State Government departments were used in conjunction with the methods of Coombes and Barry (2015) to derive initial demographically based demand profiles for each local model.[1] These were then revised and calibrated to billing data from (the then) Department of Sustainability and Environment in Victoria and Sydney Water. An example of local scale calibration for Sydney is presented below.

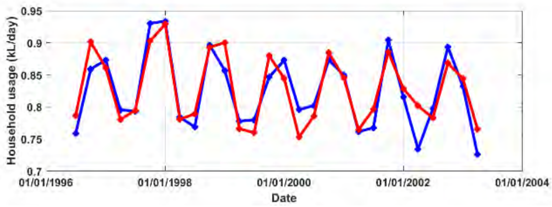

Figure 1: *Historical household water use for Fairfield, Sydney. Observed and predicted are blue and red, respectively*

The key outputs from this highest spatial and temporal granularity modelling were daily timestep local scale potable demands, wastewater generation and stormwater runoff. These daily quantities were computed as direct sums of the higher temporally resolved local computations, without recourse to averaging. These outputs served as resource files for subsequent execution of the zone scale model.

2.2 Zone scale

The zone scale model used ABS data to define its individual zones of simulation (Local Government areas), with each zone being assigned its own climatological data sequences (described above). The Melbourne and Sydney studies included thirty six and forty five zones, respectively. The Melbourne zone distribution is presented in **Figure 2**, noting that the Melbourne water supply area only includes parts of Geelong, Gippsland and East Gippsland.

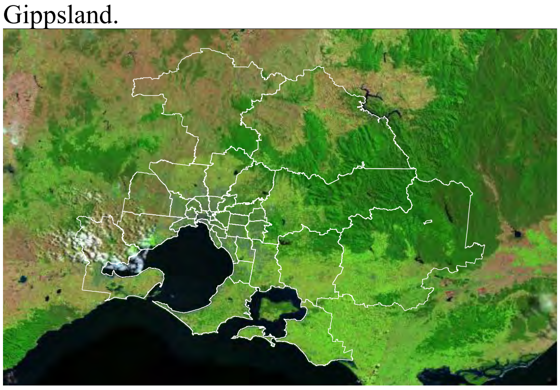

Figure 2: *Melbourne zones.*

For each zone, the zone model drew on household type and occupancy distributions reported by ABS, projected growth and renovation rate statistics out to 2050, climatological data, the local scale model reference files and other related data sets to develop sequences of household indoor and outdoor demand from 2010 to the simulation horizon.

To preserve the climatic correlation between the urban and water supply catchments, one hundred equally likely replicates of streamflow and climate in water supply catchments and zones were simultaneously generated for the simulation period using a multi-site lag-one Markov model to generate annual values that were then disaggregated into daily values using the method of fragments as described by Kuczera (1992).[3] Replicates of daily climate sequences (rainfall, temperature and evaporation) were used to generate water demands within each zone (see Coombes, 2005).[4] One hundred replicates, at a daily timestep spanning forty years (2010 to 2050) were therefore produced for each zone.

Non-residential demand was simulated on a per unit hectare basis, with land use maps being used to scale these demand, wastewater and stormwater predictions to the correct current and future profiles, per zone.

In this study, previous methods of the authors were upgraded through the inclusion of known distributions of water savings devices already in place over the validation period. The statistics for the historical installation of rainwater tanks and water efficient appliances was sourced from the ABS Environmental series publications, and from the detailed data underpinning these publications. Moreover, more recent population growth statistics available through Planning Departments in each state were used to drive the zone scale model in this study, which represents a significant departure from previous studies.[2].

2.3 Whole of system scale

The Systems Framework utilised the WATHNET network model.[3] In each case, the model included the complete water supply (i.e. demand sequences developed by the zone scale model), wastewater and stormwater networks. These demand, stormwater and wastewater networks were developed within the network scale model to represent on ground pathways and connections. They included sources such as reservoirs and desalination plants, sinks such as wastewater treatment plants, and all major relevant waterways. Where appropriate, these networks were constructed to reflect potential interactions, such as stormwater infiltration to sewerage networks and supply of demand from rivers.

For the Melbourne system it was assumed that water from the current desalination plant was utilised when dam levels are less than 65% and water from the north south pipeline is used when dam levels are less than 30%. Desalination was used in the Sydney system when total storages in dams were less than 80%.

The predictions of the system scale models were validated against available data, such as water treatment plant flows or reservoir levels and volumes. Sydney and Melbourne validations are presented in **Figure 3**.

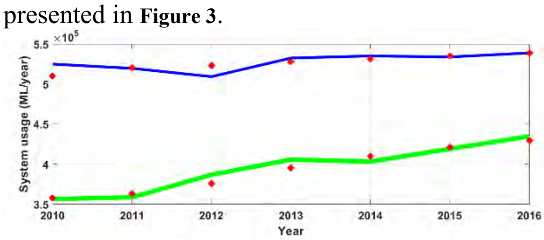

Figure 3: *Historical system demand for Sydney (blue) and Melbourne (green). Observations for each are red points.*

2.4 SCENARIOS

Two scenarios were considered in this study, where different scenarios were created by driving the zone scale model with different demographic and socioeconomic data and projections (the impact of averaging is examined equally on both as a separate matter below, and is not related to the definition of a scenario). The two scenarios reported here are referred to as Business as Usual (BAU) and Alternative (ALT). In broad terms, BAU represented the continuance of existing planning and other water related measures to the simulation horizon, whilst ALT was BAU but with more aggressive implementation of water saving measures in Melbourne. The ALT scenario was created to test the impact of averaging on different mixes of dwelling characteristics in a regional water supply scenario, and in particular, each of Sydney and Melbourne's ALT scenarios were deliberately chosen to be mirror images. That is, the ALT scenario in Melbourne was set to reflect current and future planning and policy initiatives in Sydney, and vice versa.

Details of both BAU and ALT for each of Melbourne and Sydney are as follows. They are presented as typical parameters across the system model, noting that each zone has different parameters (see Coombes et al., 2018 for further details).[5]

2.4.1 Melbourne – BAU

At approximately 2010:

- Water efficient (6/3 dual flush) toilets in 88.5% of dwellings
- Low flow showers in 67.4% of dwellings
- Water efficient clothes washer in 29.7% of dwellings
- Rainwater tanks in 21.5% of dwellings

From 2010:

- 60% of renovated dwellings install low flow showers and water efficient clothes washers
- 100% of new dwellings install dual flush toilet toilets with higher efficiency (4.5/3 litre flush), low flow showers and water efficient clothes washers
- 8% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank, supply toilet, laundry and outdoor)
- 9% of new (detached and semi-detached) dwellings install rainwater tanks
- 5% of new units install rainwater tanks

2.4.2 Sydney - BAU

At approximately 2010:

- Water efficient (6/3 dual flush) toilets in 81.9% of dwellings
- Low flow showers in 64.9% of dwellings
- Water efficient clothes washer in 23.9% of dwellings
- Rainwater tanks in 16.4% of dwellings

From 2010:

- 60% of renovated dwellings install low flow showers and water efficient clothes washers.
- 100% of new dwellings install dual flush toilet toilets with higher efficiency (4.5/3 litre flush), low flow showers and water efficient clothes washers
- 30% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank, supply toilet, laundry and outdoor)
- 80% of new (detached and semi-detached) dwellings install rainwater tanks
- 10% of new units install rainwater tanks

2.4.3 Melbourne – ALT

ALT is the same as BAU, except:

- 30% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank, supply toilet, laundry and outdoor)
- 80% of new (detached and semi-detached) dwellings install rainwater tanks
- 10% of new units install rainwater tanks

2.4.4 Sydney – ALT

ALT is the same as BAU, except:

- 8% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank, supply toilet, laundry and outdoor)
- 90% of new (detached and semi-detached) dwellings install rainwater tanks
- 50% of new units install rainwater tanks

2.5 MODEL ASSUMPTIONS

This study developed a multi-tiered modelling suite that that employed daily time steps based on long sequences of spatially and temporally consistent climate, stream flows and spatially calibrated water use behaviours. These models were dependent on climate and demographic inputs. This detailed bottom up analysis is a departure from the practice of using average water demands for the entire system that are varied by population or dwelling count and water use sectors (such as residential, industry, commerce and other).

In order to investigate the impact on water resource assessments of making these temporal and/or spatial averaging assumptions, the high spatial and temporal detail included in models developed in this investigation was progressively eroded through an exploratory averaging process. Specifically, the validated modelling framework developed here was subjected to averaging in the specification of residential demands via execution of a suite of additional simulations as follows:

- Global temporal and spatial average indoor and outdoor residential demand (GA). The global (i.e. whole of model) average residential demands were computed from the fully resolved systems model, and applied to each zone based purely on numbers of dwellings in each
- Zone based temporal average indoor and outdoor residential demand (ZA). Individual zone temporal averages were computed and then assigned back as a constant to each zone, and
- Zone based temporal average indoor and outdoor residential demand, climatically adjusted (ZC). Individual zone temporal averages were computed (not a global Melbourne-wide or Sydney-wide average), adjusted to reflect the climatic impacts on the daily zonal demand sequences, and then assigned back as time varying series to each zone. This climate seasonality was applied on a monthly basis

All of the above assumptions averaged the spatial and temporal demand patterns generated by the full systems analysis with the exception of the third approach which allowed for seasonal variability. Importantly, this approach of assessing the impact of making average assumptions ensured that nothing in the fully resolved systems models was altered, except the means by which residential indoor and outdoor demand was specified at each node. All other simulation parameters and boundaries were left unaltered (and at their fully resolved time variant daily timesteps, e.g. hydrology), thus allowing the various simulation predictions to reveal impacts associated only with making average assumptions.

Of note is that these average demands were computed directly from the high granularity (bottom up) demands generated by the local and zone scale models, and thus are a reflection of well resolved demands. In other words, the averages above are the purest averages calculable in that they are derived from highly resolved model predictions rather than from external average data or similar.

In total, there were eight system model simulations for each of Melbourne and Sydney as presented in Table 1, with abbreviations.

Table 1: *Simulation matrix with abbreviations*

	BAU	ALT
System analysis	BAU_S	ALT_S
GA	BAU_GA	ALT_GA
ZA	BAU_ZA	ALT_ZA
ZC	BAU_ZC	ALT_ZC

3 RESULTS

The modelling described above generated a very rich data set that has been interrogated in a variety of ways, of which only a small selection is able to be presented here. The focus of this manuscript therefore is to assess the potential impacts that making average assumptions (i.e. not using a bottom up approach) may have on:

- forecasting future system-wide residential water security, and
- predicting potable water distribution patterns within bulk infrastructure

Changes in potable water distribution patterns under different averaging assumptions has been captured by examination of probability density functions (pdf) of predicted water flows (not demands) through key major infrastructure assets.

3.1 RESIDENTIAL WATER SECURITY

3.1.1 BAU

In examining predictions of future water security, the metric adopted for assessment is the percentage likelihood within each forecast year of water restrictions needing to be applied. Given that 100 replicates were executed for each scenario, this likelihood has a distribution for each calendar year, and the average of these is presented here. As a guide, it has been assumed that if the average likelihood of water restrictions being imposed exceeds 10%, then augmentation of regional infrastructure is required.

Figure 4 and **Figure 5** present indoor and outdoor water security predictions for Sydney and Melbourne, respectively, under different averaging assumptions. There are clear variations in predictions of water security between the four BAU cases (BAU_S, BAU_GA, BAU_ZA, BAU_ZC) for both Sydney and Melbourne. For example, in Sydney, BAU_GA generally predicts worse residential water security than BAU_S, at times up to a factor of two worse than BAU_S.

Contrastingly, the corresponding Melbourne simulations show the opposite response in that BAU_GA predicts greater residential water security over the period of interest, and in this case this underprediction is by up to a factor of three compared to BAU_S.

Figure 4 and **Figure 5** also reveal that the type of averaging adopted (i.e. global, zonal or zonal with climatic trends) influences model predictive ability. For example, whilst the Sydney outdoor demand curves show that both BAU_ZA and BAU_ZC fall mostly within the envelope formed by BAU_S and BAU_GA, the figure also shows that BAU_ZA oscillates between being sometimes equal to either BAU_S or BAU_GA for extended periods. This oscillatory behaviour is not regular or smooth, and presents the BAU_ZA predictions as being somewhat of a hybrid of two substantially different forecasts. BAU_ZC for Sydney demonstrates a similarly unpredictable hybrid behaviour.

The Melbourne model shows a different response to averaging in that whilst the BAU_ZA and BAU_ZC predictions of water security sometimes fall within the envelope drawn by BAU_S and BAU_GA, for the majority of the period of interest, both zonal averaging predictions lie above (poorer water security) BAU_S.

This behaviour of BAU_ZA and BAU_ZC is noteworthy in that it demonstrates that adopting zonal averaging produces a water security profile worse than BAU_S, but that using global averaging results in a security profile substantially better than BAU_S. This contradictory behaviour points to the potential difficulty in interpreting average demand model predictions.

3.1.2 ALT

Coming to an understanding of how a complex urban system such as an Australian capital city responds to implementation of a range of water policy and planning initiatives is a critical question surrounding Australia's water future. One such option was considered in this study (ALT) and the water security predictions of the fully resolved and average assumptions models under the measures applied by ALT were examined. Water security results for Melbourne indoor demand are presented in the top pane of **Figure 6** as BAU_S and ALT_S. The pane shows, as expected, that the ALT_S scenario provides Melbourne with greater indoor water security, consistent with previous findings (Coombes and Barry, 2014)[6]. This increase is substantial at times, with ALT_S delivering up to four times greater water security than BAU_S.

Whilst the consequences of this type of outcome are potentially significant (see Coombes et al., 2018[5]), of more interest to this study is investigation of the impact on predicted water security of using average assumptions to drive demand. To support this, the bottom pane of **Figure 6** presents BAU_S and ALT_S together with the corresponding BAU_GA and ALT_GA model predictions. The figure shows the same result already presented in **Figure 4** with regard to BAU_S and BAU_GA, i.e. BAU_GA predicts an increased

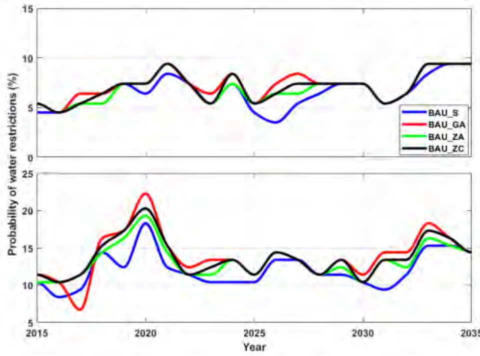

Figure 4: *Predictions of the likelihood of water restrictions being imposed for Sydney indoor (top panel) and outdoor (bottom panel) water demand between 2015 and 2035, under different averaging assumptions, BAU scenario.*

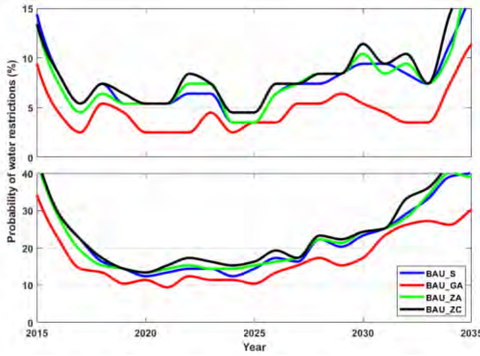

Figure 5: *Predictions of the likelihood of water restrictions being imposed for Melbourne indoor (top panel) and outdoor (bottom panel) water demand between 2015 and 2035, under different averaging assumptions, BAU scenario.*

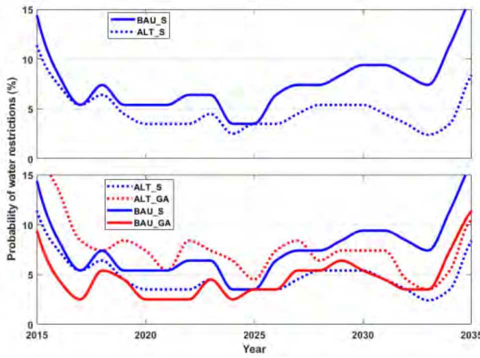

Figure 6: *Predictions of the likelihood of water restrictions under BAU and ALT conditions for Melbourne indoor demand between 2015 and 2035, under bottom up (top pane) and global averaging assumptions (bottom pane).*

ISBN: 978-1-925627-03-9

security over BAU_S, by up to a factor of two to three. Critically however, the influence of applying global averages to the ALT_S scenario for Melbourne residential demands is to predict (ALT_GA) as a deterioration in water security – the precise opposite of the behaviour observed in the corresponding comparison of BAU_S to BAU_GA in the same figure pane. The key result here is that global averaging skews BAU results in one direction, but ALT results in the other, underlining the unpredictability of implementing average assumptions in such analyses.

Perhaps the most striking aspect of the bottom pane of **Figure 6** is its demonstration that using global average demands in the BAU_GA and ALT_GA scenarios has the network model predicting a deterioration in water security over the simulation period by application of the measures in ALT. This is precisely contradictory to the forecasts of the fully temporally and spatially resolved models (BAU_S and ALT_S) which together predict that application of the ALT measures improves water security.

To support the above, the impact of selecting different averaging methods on indoor water security predictions for the suite of Melbourne ALT simulations was investigated. **Figure 7** presents these outcomes.

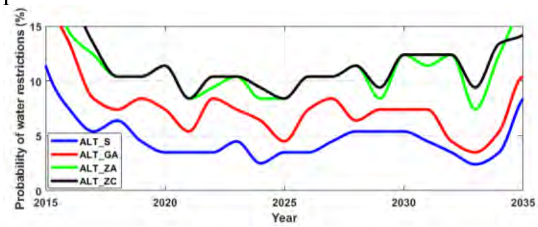

Figure 7: *Predictions of the likelihood of water restrictions under ALT conditions for Melbourne indoor demand between 2015 and 2035, under all averaging assumptions.*

The figure demonstrates clearly that, for an otherwise unchanged network model, the manner in which average demands are specified can have significant impacts on model predictions. This result is not related to the differences observed in predictions derived from models using fully resolved versus averaged demands: it has revealed that even the nature of averaging adopted can in itself have significant impacts on predictions of water security. For example, the ALT_GA and ALT_ZA predicted water securities are at times up to a factor of two different.

3.2 WATER DISTRIBUTION PATTERNS

In order to assess the impacts on water distribution patterns of making average assumptions in the Sydney and Melbourne models, key potable supply infrastructure components (model arcs) were identified in each and their predicted daily flows extracted. Examination of this issue is important because these flow quantities are used to design and augment major infrastructure such as pipelines, pumps, pressure reservoirs and water treatment plants. To affect this analysis. each arc output consisted of approximately 1.5 million daily data points, which spanned all years and replicates. These were processed to prepare a probability density function for each arc flow, averaging assumption and scenario. A subset of these analyses is presented here for Melbourne (flows through the Cardinia-Dandenong main) and Sydney (flows from Prospect Reservoir to Potts Hill). The standard definition of a probability density was adopted for this analysis, which has that for any sample X (in this case X is the daily flow through a water supply line), the probability that it lies between two values (flows) a and b is the area under the probability density function between a and b. Formally, this is given by:

$$\Pr[a \le X \le b] = \int_a^b f_X(x)dx$$

Where Pr is the probability of X being between a and b, and $f_X(x)$ is the probability density function. The ordinate and abscissa axes in all figures below are probability density and daily flow in megalitres per day (ML/d), respectively. The ordinate's probability density can be interpreted as providing a relative likelihood that the value of a randomly chosen flow from the respective arc's total sample space would equal that flow. The units of the ordinate are therefore only relative, and are not absolute probabilities. As an example, the flow corresponding to the peak of a given probability density function is the flow appearing most often within the arcs total sample space, and therefore the one most likely to occur in the network.

Probability density functions are presented in the following figures. **Figure 8** through **Figure 11** are a series of four-paned figures, where each pane presents one to one comparisons between either BAU_S or ALT_S, with all other corresponding averaging outcomes (_GA, _ZA and _ZC). The top left pane is always BAU_S or ALT_S in isolation to assist with subsequent visual inspection of the remaining three panes in each figure. Note that Melbourne and Sydney have different ordinate and abscissa scales for presentation purposes.

ISBN: 978-1-925627-03-9

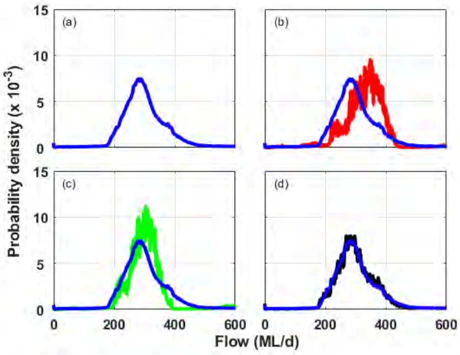

Figure 8: *Probability density functions for flows through the Cardinia Dandenong mains under all BAU averaging assumptions. (a) BAU_S, (b) BAU_S and BAU_GA, (c) BAU_S and BAU_ZA, and (d) BAU_S and BAU_ZC. BAU_S is blue in all panes.*

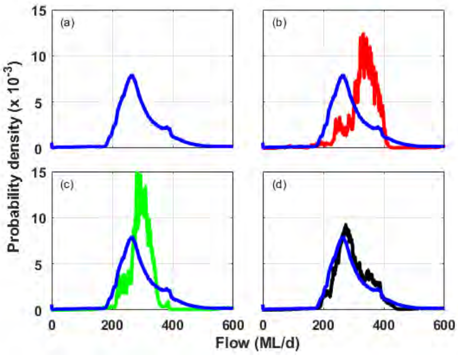

Figure 9: *Probability density functions for flows through the Cardinia Dandenong main under all ALT averaging assumptions. (a) ALT_S, (b) ALT_S and ALT_GA, (c) ALT_S and ALT_ZA, and (d) ALT_S and ALT_ZC. ALT_S is blue in all panes.*

The figures presented above demonstrate again that the application of different types of averages (global, zonal or zonal with climate variations) produces different results. Regardless of the relationship of the average to properly resolved predictions, the figures underscore that the type of averaging adopted in any investigation of this type has the potential to materially influence model outcomes and therefore decisions made using these predictions. Comparing, therefore, global average predictions with zonal (or any other) type of average prediction is fraught: there exists no common point of comparison.

This aside, perhaps the most striking result across the figures is that all BAU_GA, BAU_ZA, ALT_GA and ALT_ZA average assumption probability density functions from both Melbourne and Sydney vary markedly in shape from those of their respective fully resolved, BAU/ALT_S, predictions. Importantly, all of these averaged

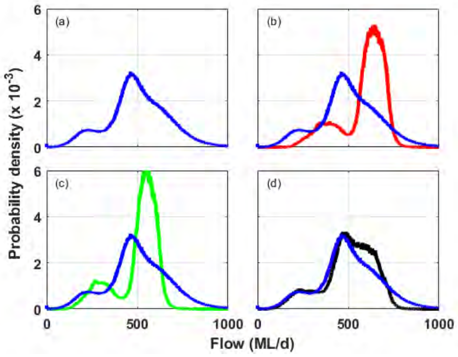

Figure 10: *Probability density functions for flows to Potts Hill Reservoir under all BAU averaging assumptions. (a) BAU_S, (b) BAU_S and BAU_GA, (c) BAU_S and BAU_ZA, and (d) BAU_S and BAU_ZC. BAU_S is blue in all panes.*

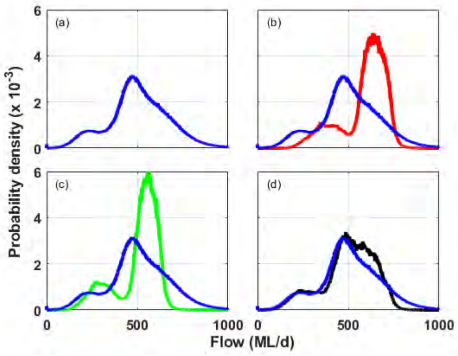

Figure 11: *Probability density functions for flows to Potts Hill Reservoir under all ALT averaging assumptions. (a) ALT_S, (b) ALT_S and ALT_GA, (c) ALT_S and ALT_ZA, and (d) ALT _S and ALT _ZC. ALT _S is blue in all panes.*

probability density functions predict a marked upwards shift in the probability of peak daily flows, compared to their respective fully resolved cases. For instance, the Potts Hill distributions presented in **Figure 10** (b) show the peak probability flow shifts from 460 ML/d in BAU_S to 645 ML/d in the case of BAU_GA. This is an increase of 40%.

A key result of this investigation is therefore, that the impact of adopting global and non-seasonal zone averaging in all Melbourne and Sydney simulations is to generate a significant over-prediction of the magnitude of the most frequent flows at key distribution points within the network. Using averages to inform infrastructure sizing is therefore clearly problematic.

In addition to this upwards shift in peak probability flows under averaging assumptions other than _ZC, all Melbourne and (especially) Sydney _GA and _ZA distributions are also markedly sharpened, i.e. they display both a significant contraction of the region spanned by non-zero probability densities and also (by definition) higher probability density peaks, compared to the fully resolved cases. This is consistent with a sample space characterised by a greater frequency of occurrence of a smaller number (subset) of daily flows – i.e. a less varied sample space. This is particularly obvious in the case of the Potts Hill mains distributions (**Figure 10** and **Figure 11**, panes (b) and (c)). Again, this outcome may well have strong implications for infrastructure sizing decisions.

This modification (caused by the application of average water demands) to the fundamental statistical profile of water network flows is especially evident in the Melbourne ALT scenario. **Figure 12** presents this analysis in more detail, with three panes of probability density functions (for Melbourne) included: ALT_GA (upper pane), ALT_S (middle pane) and ALT_S with ALT_ZC (lower pane).

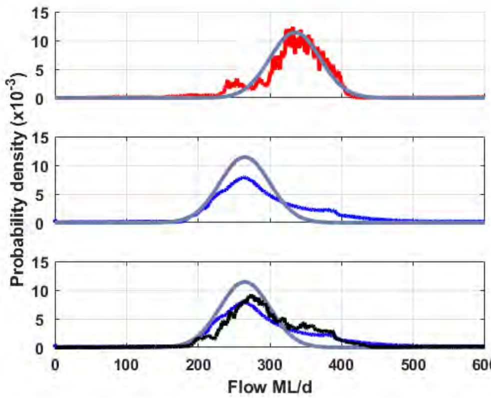

Figure 12: *Probability density functions for flows through the Cardinia Dandenong mains. (a) ALT_GA) (b) ALT_S (c) ALT_S (blue) and ALT_ZC (black). A computed normal probability density function is shown in all in grey: (a) μ = 335, σ = 35, (b)(c) μ = 265, σ = 35.*

The upper pane reveals that the ALT_GA distribution is well approximated by a normal distribution with μ = 335, and σ = 35 ML/d. This same normal distribution (with reduced mean to account for the shift in peak probabilities discussed above) is replotted in the middle pane over the ALT_S distribution. This pane shows that when applying temporally and spatially resolved demands, the shape of the probability density function is clearly not well approximated by a normal distribution. Notably, the ALT_S distribution has a significant non-normal tail between approximately 300 and 500 ML/d. This tail is not evident in the ALT_GA distribution and is a clear point of departure between ALT_S and ALT_GA, underlining again the very different statistical profiles of the two analysis approaches, and the transformative impact that making global average assumptions can have. Finally, the lower panel is the same as the middle panel, but with the ALT_ZC distribution overlain. This comparison reveals that the addition of (even crude monthly) climatic variability to the Melbourne simulation has a significant impact on the corresponding probability density function and therefore prediction of water flows through the network. The same is also true for the Melbourne BAU case (see **Figure 8** (d)) and the Sydney results (see **Figure 10** (d) and **Figure 11**(d)). All these outcomes point clearly to the need to include climatic variability on a per zone (not global average) basis in water systems analysis. Notably, this apparently good performance of the averaged conditions is illusory, as investigation of the corresponding water security predictions speaks to the contrary, as shown in **Figure 4** through to **Figure 7** in Section 3.1.

Figure 13 (Melbourne) and **Figure 14** (Sydney) present the respective BAU_S, ALT_S, BAU_GA and ALT_GA probability density functions for each city.

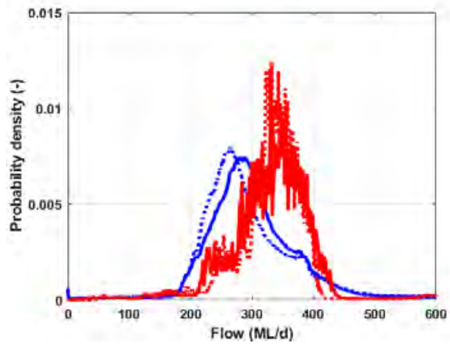

Figure 13: *Probability density functions for flows through the Cardinia Dandenong main for BAU_S (solid blue), ALT_S (dotted blue), BAU_GA (solid red) and ALT_GA (dotted red).*

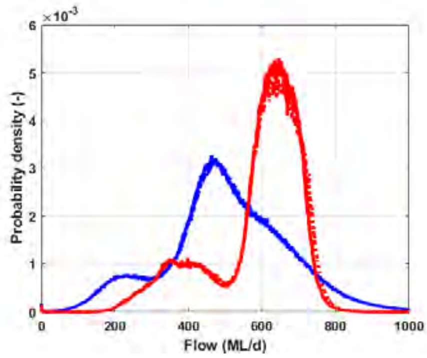

Figure 14: *Probability density functions for flows to Potts Hill Reservoir for BAU_S (solid blue), ALT_S (dotted blue), BAU_GA (solid red) and ALT_GA (dotted red). The solid and dotted lines are indistinguishable.*

The overprediction of peak probability flows is again, of course, evident. In the case of Melbourne, the relationship between the BAU_S and ALT_S distributions is as expected – applying more

aggressive water savings to the city does indeed derive benefit in terms of reducing peak probability flows (and demands) in the network. The reverse is supported in the Sydney case, as expected, because that model's ALT scenario employed less aggressive measures than are currently in place. Contrastingly however, both the Melbourne and Sydney BAU_GA and ALT_GA distributions are not materially different. Notwithstanding the quasi-discontinuous (and therefore most likely unreliable) nature of the _GA distributions, the fact that the BAU_GA and ALT_GA density functions are essentially indistinguishable, may have consequences for the setting of future water policy: applying global averaging (and even zone averaging in the case of Sydney) to options analysis of water systems potentially masks opportunities offered by measures such as those in this investigation's ALT scenario. Specifically, this investigation has shown that averaging provides a perspective that alternative solutions do not provide a benefit. In some ways therefore, the average analysis supports a 'do nothing' approach in this instance, which is clearly a counterintuitive outcome for Melbourne.

4 DISCUSSION

The intent of this investigation was to establish, across Australia's two largest cities, the impact or otherwise of adopting various degrees of average demand assumptions in numerical studies.

In terms of water security predictions, different demand averaging methods produced different outcomes, with water security predictions varying by up to a factor of three between averaged cases and properly resolved model inputs. Further, the application of average assumptions in Melbourne saw apparently improved water security, but the reverse was true for Sydney – all average assumptions predicted worse water security than did the temporally and spatially resolved model. Even within the Melbourne model, average demand assumptions saw, counterintuitively, BAU and ALT scenarios' predictions of water security biased in opposite directions.

Probability density function analysis also revealed that average assumptions can lead to significant over-prediction of peak probability flows, and narrowing of flow distributions. Distribution shapes were also markedly altered by averaging processes, pointing to a fundamental change in statistical profiles of flow networks brought about by the imposition of average assumptions. More significantly, however, average assumptions consistently led to the over-prediction of peak probability flows in all cases considered. The implications of this for potential over-investment in exaggerated infrastructure are therefore real. Use of average inputs also produced a false impression that alterative options, such as WSUD, were not beneficial for water security or reducing flows in water networks.

There is therefore little, if any, evidence from this investigation that the use of average demands in systems analysis is acceptable or beneficial. This investigation has shown that doing so is fraught and leads to unpredictable, variable and therefore unreliable modelling responses. This outcome points to the imperative to move away from using top down average assumptions and to move towards a bottom up (no downwards averaging) approach to water resource planning. The tools exist to support this bottom up approach, so at least in Australia where data is relatively accessible, there seems no compelling reason to use top down average demand assumptions moving forwards.

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[2] Coombes P.J., and Barry M. *Impact of spatial and temporal averages on prediction of water security using systems analysis*. Proceedings of the 37th Hydrology and Water Resources Symposium, Queenstown New Zealand, 2016.

[3] Kuczera, G., *Water supply headworks simulation using network linear programming*, Advances in Eng. Software, 14, 55-60., 1992.

[4] Coombes P. J., *Integrated water cycle management: analysis of resource security*, Water, 32: 21-26., 2005

[5] Coombes P.J., Barry M.E., and Smit M., *Systems analysis and big data reveals benefit of new economy solutions at multiple scales*. WSUD 2018 & Hydropolis 2018, Perth. 2018

[6] Coombes P.J. and Barry M.E., *A systems framework of big data driving policy making Melbourne's water future*, OzWater14 Conference, AWA, Brisbane. 2014.

[7] Coombes P.J., Smit M. & MacDonald G., *Resolving boundary conditions in economic analysis of distributed solutions for water cycle management.* Australian Journal of Water Resources, DOI: 10.1080/13241583.2016.1162762

ISBN: 978-1-925627-03-9

Impact of water law on urban monopoly power and consumer expenses

Peter Coombes

Urban WaterCycle Solutions
Independent research and consulting

1 December 2017

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Introduction

This essay discusses recent water reforms with associated legislative frameworks that apply to urban water supplies. The structure of reforms, governance and legal arrangements is examined for Melbourne to demonstrate impacts on consumers.

Discussion

There is substantial recent history of decisions about allocation of scarce water resources, mainly focused on the Murray Darling Basin, using objectives for environmental, social and economic outcomes.[1] These processes mostly originated from the Council of Australian Governments (COAG) 1994 agreement to implement a framework for an efficient and sustainable water industry. This reform of water law aimed to transform water governance to include environmental sustainability and economic efficiency.[2]

In 2004, COAG agreed to a National Water Initiative (NWI) as a national

[1] Kelly, R., Getting the balance right: why the Murray Darling Basin Plan can implement the triple bottom line approach, (Canberra Law Review, 10(178), 2011), 182-183

[2] Godden L., and Foerster A., International transitions and water law governance, (Water Law, 53, 22(2/3), 2011), 54

plan for water reform which included urban water.[3,4] The Australian Constitution does not discuss Commonwealth regulation of water and it was assumed that state governments retained power to manage water.[5] The Commonwealth also cannot regulate trade or commerce to restrict a state or residents of the reasonable use of waters from rivers for conservation or irrigation.[6] Nevertheless, other constitutional powers, such as external affairs powers, were utilised to provide the Water Act 2007 (Cth).[7]

These processes influenced urban water reforms in the states. The economic efficiency of urban water supplies has declined since 2003.[8] Total national consumer expense for water services has increased by 95% ($6.7 b) for a 3% (88 GL) increase in water use. Households paid a majority of increased expenses (74%, $5.5 b) whilst reducing water use. Water operating costs of urban water utilities have increased by 15% to 167% in real terms.

Evidence from the millennium drought demonstrated that water conservation and local sources of water ensured that cities did not run out

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[3] Connell D., Dovers S., and Grafton R. Q., *A critical analysis of the national water policy initiative,* (Australasian Journal of National Resources, Law and Policy, 10(1), 2005)
[4]Council of Australian Governments, *Intergovernmental agreement on a national water initiative*, (24 June, 2014), s24(vi)
[5] Ibid n1, 180-181
[6] Commonwealth of Australia Constitution Act 1900 (Cth), s100
[7] Ibid n1, 181
[8] Coombes P.J., Barry M.E., and Smit M., *Systems analysis and big data reveals benefit of new economy solutions at multiple scales.* (In press, WSUD 2018 & Hydropolis 2018, Engineers Australia, Perth. 2018).

of water.[9] But water bureaucracies argue that only centralised solutions provided by government monopolies are viable and legislation requiring water efficiency was repealed using these assumptions.[10] In 2011, the Productivity Commission argued for reduced focus on urban water restrictions, water efficiency and conservation.[11] It was claimed that water efficient behaviours reduce revenue earned by government monopolies which was economically inefficient. This prevailing view is inconsistent with objectives of the NWI to efficiently allocate scarce resources across society.

A Senate inquiry heard that dominance of state owned water monopolies distorts policy settings leading to inefficient investments which impact on sustainable stormwater and catchment management.[12] Increasing centralisation associated with government monopoly response to drought led to construction of a water grid in South East Queensland resulting in persistent debt.[13] The water bureaucracy has called for reduced water

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[9] Turner, A., White, S., Chong, J., Dickinson, M.A., Cooley, H. and Donnelly, K., *Managing drought: Learning from Australia,* (Prepared by the Alliance for Water Efficiency, the Institute for Sustainable Futures, University of Technology Sydney and the Pacific Institute for the Metropolitan Water District of Southern California, the San Francisco Public Utilities Commission and the Water Research Foundation, 2016)

[10] Coombes P.J., Smit M., and MacDonald G., *Resolving boundary conditions in economic analysis of distributed solutions for water cycle management.* (Australian Journal of Water Resources, Vol 20, 2015). 11-29

[11] Productivity Commission, *Australia's urban water sector,* (Final Inquiry Report No. 55, Canberra, 2011)

[12] Commonwealth of Australia, *Stormwater management in Australia*, (The Senate, Environment and Communications References Committee, 2015)

[13] Queensland Government, *Water: 2015-16 results of financial audits*, (Queensland Audit Office, 2016).

efficiency and sustainability to increase water use, and for higher water prices, to increase revenue to pay debt.

The Productivity Commission's 2017 draft report remains focused on government water monopolies, but acknowledge that urban water management needs clearer roles and responsibilities for augmentation planning to enable decentralised solutions and more outcomes-focused environmental regulation.[14] The dominance of monopoly water bureaucracy and influence over research consortiums could be a driver increasing centralisation and narrowing of stormwater solutions leading to toxic pollution of waterways.[15]

The process of urban water reform has generated challenges that need examination. Godden and Foerster nominate these problems as successive attempts to implement generic models of water law based on state centric institutions or corporations that have evolved into deregulated institutional structures with free market objectives.[16] Different views of water as a common property resource, essential service or private commodity earning economic rent are unresolved. The NWI is a significant national reform program that incorporates COAG policies of national competition policy, and protection of environments that reduces economic protectionism and

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[14] Productivity Commission, *National Water Reform,* (draft report, September 2017)
[15] Sharley D.J., Sharp S.M., Marshall S., Jeppe K., and Pettigrove V.J., *Linking urban land use to pollutants in constructed wetlands: Implications for stormwater and urban planning* (Landscape and Urban Planning, 162, 2017) 80–91
[16] Ibid n2, 54

associated legal frameworks.[17] Nevertheless urban water institutions are a paradox of retaining protectionism of government monopolies and guaranteed revenue from fixed tariffs with objectives of economic efficiency and competition as outlined below for Melbourne.

The Water Act 1989 (Vic) provides the governance framework and institutional structures for management of water resources in Victoria.[18] Melbourne Water Corporation (MWC) was created in 1991 to ultimately replace the powerful Melbourne Metropolitan Board of Works (MMBW).[19] Legislation was passed in 1992 to corporatize Victorian water boards as part of a privatisation agenda. This change in water governance influenced law reforms in other states.[20] Melbourne's water and sewerage services were geographically separated into three retail water corporations (City West Water, South East Water and Yarra Valley Water) and MWC retained bulk supply, treatment and some stormwater management responsibilities. The government monopolies have planning and approval powers and operational responsibilities which is a barrier to acceptance of alternative solutions.[21]

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[17] Ibid n3, 85-86
[18] Water Act 1989 (Vic)
[19] Reinhardt W., Guérin-Schneider L., *Governance and Regulation of the Urban Water Sector: Quoi de Neuf?.* (In: Grafton Q., Daniell K., Nauges C., Rinaudo JD., Chan N. (eds) Understanding and Managing Urban Water in Transition. Global Issues in Water Policy, vol 15. Springer, Dordrecht, 2015), 426-428
[20] Ibid n19
[21] Daniell K.A, Coombes P. J., and White I., Politics of innovation in multi-level water governance systems, (Journal of Hydrology, 519(C), 2014), 2415-2435: Government monopolies combine with supporting bureaucracy to block alternative solutions, strategies or policies that are perceived to complete with

The Water Minister, in consultation with the Essential Services Commission (ESC) and Treasurer, is empowered by the Water Industry Act 1994 to issue Statements of Obligation (SOO) that govern water corporations.[22] The Victorian ESC describes state owned water monopolies as government business enterprises that are the responsibility of the Water Minister.[23] The ESC was established by the Essential Services Act 2001 (Vic) to provide incentives for economic efficiency of the water industry, and to promote long term interests of Victorian consumers.[24] This governance objective is enacted by consideration of price, quantity and reliability of essential services.[25] Actions to meet consumer interest objectives must consider economic efficiency, incentives for investment, and financial viability of the industry.[26] Arguably, these objectives are more consistent with securing economic returns from state government business enterprises which are the responsibility of a Treasurer who is also responsible for the ESC Act.

The ESC assesses the performance of water monopolies by benchmarking against other government water monopolies, described as competition by comparison. Given the national decline in economic efficiency of urban water supplies discussed above, comparison to similar government water

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established power structures around existing solutions. Control of planning, approval and operations with partnership on governance permits this outcome.

[22] Water Industry Act 1994 (Vic), s41

[23] Essential Services Commission, About the Victorian water industry, (https://www.esc.vic.gov.au/water/, Accessed on 24/11/2017)

[24] Essential Services Act 2001 (Vic), s1

[25] Ibid n2, s8(1),(2)

[26] Ibid n2, s8A(1)

monopolies may not be adequate replacement for competition and targets to promote long term welfare of consumers. This view was also expressed by the Consumer Action Law Centre.[27] The improved economic efficiency of utility water supply and diminished impact on consumers associated with household water saving targets in NSW BASIX legislation supports this perspective.[28] Planning legislation operating independently of water bureaucracy created competition that drives improved economic efficiency and highlights a need for structural separation of institutions with legal responsibilities for water services.

The ESC Act mostly concerned with economic viability of a water industry defined as government monopolies. If objectives of the Act and legislation are in conflict, the ESC is permitted to choose the best response. The ESC considers that government water monopolies best represent the interests of consumers – this assumption effectively removes citizens from the decision making process.[29] The objectives of the ESC are conflicted. It is acknowledged that variable charges permit customers control over water bills. But fixed charges are consistent with assumptions that most costs of water businesses are fixed - water monopolies must propose different tariff structures.[30] The ESC responds to revenue preferences of water

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[27] Consumer Action Law Centre, *Water reform in Victoria, independent pricing regulation and its outcomes for consumers*, (Consumer Action Law Centre, March, 2007), 2

[28] Ibid n8, 7-8; State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004 (NSW).

[29] Ibid n22

[30] Ibid n22

monopolies. Fixed tariffs are guaranteed revenue but do not provide incentives economic efficient behaviours of customers or firms.[31] A key economic principle is the all medium to long run costs are variable.[32] The tariff structure may not be consistent with objective to promote long run interests of customers in the ESC Act.

Section 3(e) of the Essential Services Act explains that the ESC is empowered by Water Industry Regulatory Orders (WIRO) under the Water Industry Act 1994 (Vic) (WIA).[33] The ESC advises, responds to and recommends to the Minister on essential services (s10), but is not subject to direction or control by the Minister (s12).[34] In accordance with WIA and WIRO, water monopolies provide Water Plans of expected capital and operating expenses that underpin proposals for prices and service levels. The ESC considers these proposals in determining prices and service levels.

The Department of Environment, Land, Water and Planning (DELWP) administers the WIA and the Water Act 1989 (Vic).[35] The Water Minister is responsible for these Acts and DELWP provides liaison with water monopolies. The Victorian government is sole shareholder of water

[31] Coase R.H., *The economics of uniform pricing systems* (The Manchester School, 15, 1947) 139–156
[32] Hubbard R.G., Garnett A.M., Lewis P., and O'Brien A.P., *Microeconomics*, (Pearson Education, 3rd Ed, 2013), 204-207
[33] Ibid n2, s3(e)
[34] Ibid n2, s10 (b),(c),(e),(m),s12
[35] Department of Environment, Land, Water and Planning, *Water Industry Structure* (Governing the Victorian Water Industry, 2017), 15-22

monopolies and appoints board members based on recommendations by DELWP. Water monopolies and DELWP select consultants for consultant panels and people for citizen juries or community consultation panels to assist with decisions about water strategies.

Conclusion

There are overlapping interests of urban water monopolies, their water bureaucracy partners and government owners in water law frameworks and associated institutional protocols. The boundaries of planning, governance, approval and operational responsibility are also not well defined. This results in excessive focus on economic interests of water monopolies at increased consumer expense. The Victorian Ombudsman highlights that the accepted practice of Departmental Secretaries contributing to governance by water monopoly boards in inconsistent with enabling legislation.[36] The Consumer Action Law Centre recommends amending regulatory frameworks to more actively account for social and environmental considerations in pricing decisions.[37] It is proposed that the structural separation of powers principles demonstrated in the Australian Constitution be applied to water law frameworks to separate the operation of government water monopolies from their bureaucratic partners, regulators and government owners. Planning and approval powers must

[36] Victorian Ombudsman, *A review of the governance of public sector boards in Victoria,* (Victorian Ombudsman, December, 2013), 6
[37] Ibid n26, 2

also be separated from operational functions to better protect the long term interests of consumers and environment.

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Conservation Limits Rate Increases for a Colorado Utility

Demand Reductions Over 30 Years Have Dramatically Reduced Capital Costs

NOVEMBER, 2013

Alliance *for* Water Efficiency

Authors

Stuart Feinglas
Water Resources Analyst
City of Westminster

Christine Gray
Management Analyst
City of Westminster

Peter Mayer, P.E.
Principal
Water Demand Management

Why are my rates going up again?

“Why do you ask me to conserve and then raise my rates?” asked a concerned citizen at a public meeting in Westminster, Colorado in 2011.

“Very good question,” pondered Westminster Utilities’ staff as they struggled with only limited success for a compelling answer. They knew water conservation has had a profound impact on the city by reducing demand, the amount of additional water needed to purchase and eliminating the need for expansion of facilities, but they didn’t have a good way to quantify the impacts and respond to the citizen’s question.

Similar tough questions have been posed to water utilities across the country as water and wastewater rates have increased faster than the Consumer Price Index (CPI) over the past 15 years, (Beecher 2013), (Craley and Noyes 2013). Managing the public response to and understanding of rate increases has taken on increasing significance in recent years as utilities grapple with the double edged sword of rising infrastructure costs and decreasing demands (Goetz M. 2013).

Rather than leaving the question of customer conservation and rates hanging without a satisfactory response, the Westminster staff decided to do some research to try and come up with some answers using data from their own system. The timing of the question was significant as the City is working towards completing a series of identified projects designed to meet the City’s needs at a projected buildout date of 2050 (using current and projected demands which include conservation).

To examine the impact of conservation on rates, the City looked at marginal costs due to the buildout requirements by removing conservation from the equation. The results of the City’s research were startling: Reduced water use in Westminster since 1980 has resulted in significant savings in both water resource and infrastructure costs, saving residents and businesses 80% in tap fees and 91% in rates compared to what they would have been without conservation.

The City’s research on water demands and rates since 1980 provided a useful response to the citizen’s question and revealed previously unexplored and under-appreciated benefits of long-term water conservation in reducing rate increases. Water rates in Westminster are much lower today than they would have been in the absence of demand reductions from conservation. Here’s how the City was able to reach this important conclusion.

Change in Water Use

To explore the impacts of demand management on water rates and tap fees, Westminster staff examined water demand records, water rates, tap fees[1], and capital project costs from 1980 through 2010 with the following question in mind: "What would our water rates and tap fees be today if per customer water demands remained unchanged since 1980?". 1980 was chosen because it predated City related conservation programs and two levels of plumbing code related changes.

The first step was to examine water use patterns. To do this, Westminster staff examined water use patterns from 1980 – 2010 by taking total demand (all customer classes) and dividing by the best estimate of the service area population for each year. Westminster has a reclaimed water system that reuses treated wastewater for irrigation thus lowering the City's impact on water resources. To be conservative, reclaimed water was assumed to be a conservation measure. This consumption was added back into potable water use to reflect the full use of water without conservation. As shown in Figure 1 average gpcd, based on total City water use, was 21% higher 30 years ago, starting at 180 gpcd in 1980 and ending at 149 gpcd in 2010. Westminster attributes these changes in demand to three primary management factors:

1. Utility sponsored water conservation programs
2. The City's inclining block and seasonal rate water billing structure
3. National plumbing codes implemented as part of the Energy Policy Act of 1992 (EP Act)

1 Tap fees, also called connection fees or development fees, are the costs paid by new customers to join the water system.

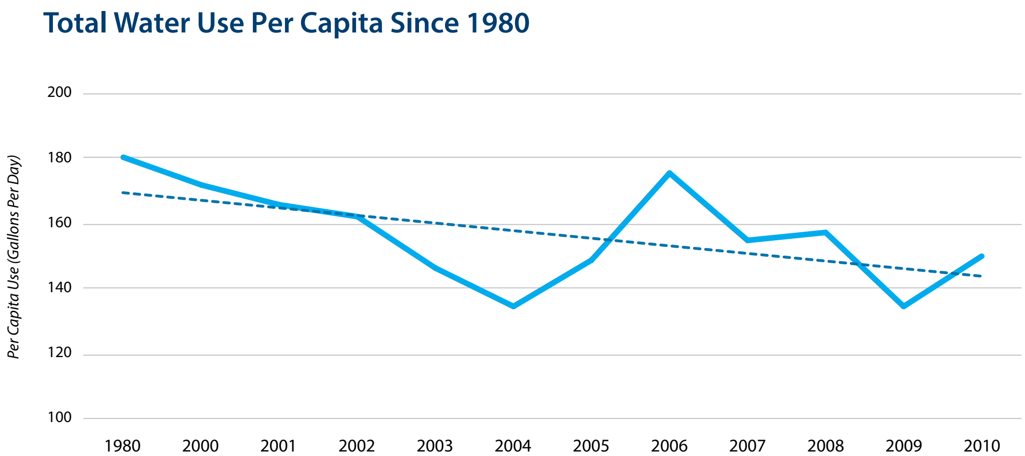


Figure 1: Average gpcd in Westminster, based on total water use 1980 – 2010

New Supply Requirements and Cost

Once the changes in water demand were quantified, the Westminster staff were able to estimate what water use in 2010 would have been without the enactment of water conservation programs and policies. Through this analysis it was concluded that if per capita water use had not decreased by 21%, Westminster would have been required to secure an additional 7,295 acre-feet (AF) of additional water supply order to meet the customer demand while satisfying the City's reliability requirements.

If per capita water use had not decreased by 21%, Westminster would have been required to secure an additional 7,295 acre-feet (AF) of additional water supply order to meet the customer demand.

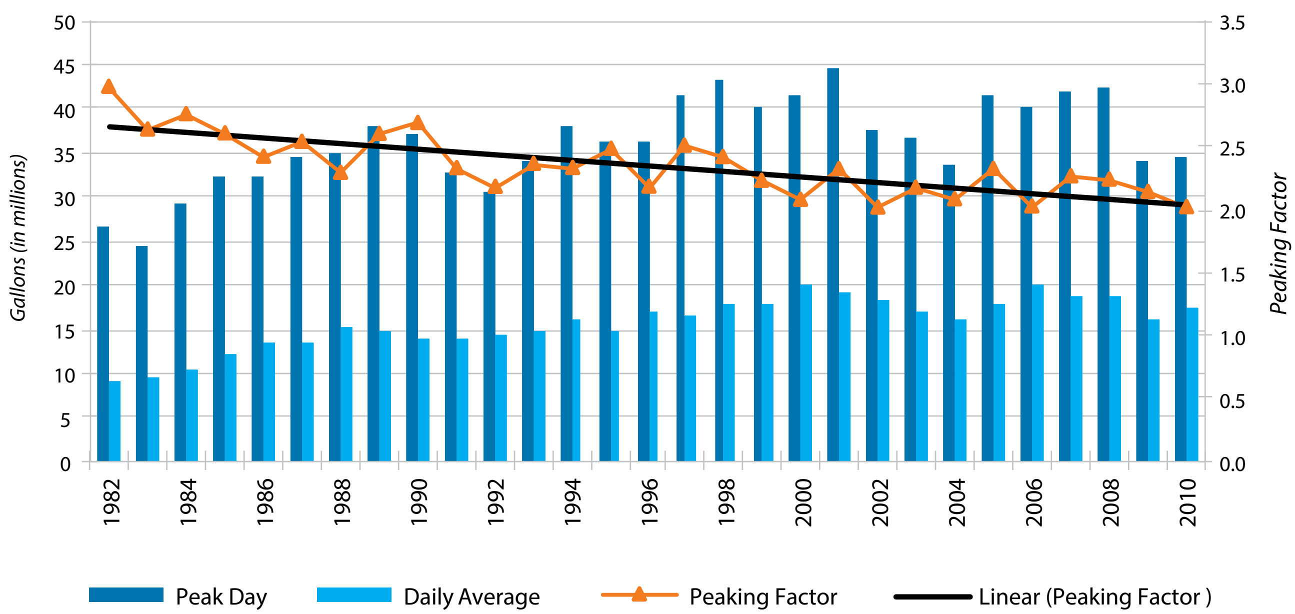
New water supply in Colorado's Front Range does not come cheap. Current market costs for new water supply average $30,000 per acre-foot on Colorado's Front Range. Westminster pays close attention to the cost of new supply as it builds these costs into the tap fees of new customers so that the City can fully recover the expense of serving new customers without burdening existing customers with the cost of growth. The staff also concluded that had conservation from 1980 – 2010 not occurred, the City would have been competing with other water providers in the region to acquire more raw water, further tightening the market and making new water supply even more expensive. At this average price, the estimated cost of obtaining and delivering the required additional 7,295 AF of water would have required a capital investment of $218,850,000. With this simple analysis alone, the cost savings associated with reduced water use became obvious, but staff realized this was only part of the story.

Additional Peak Demands and Infrastructure Costs

Peak demand in 2010 would also have been considerably higher had conservation not been implemented in Westminster over the past 30 years. The City has found that water conservation programs have altered irrigation patterns thus reducing the system's peak day factor. In 1980 the peak to average day factor in Westminster was 3.0, but by 2010 changes in irrigation practices and reduced water demand cut the peak factor to 2.1 — a 30% reduction.

Potable Water Production

Peak Day, Daily Average, Peaking Factor



If 1980 demand levels had been perpetuated along with the 1980 peaking factor of 3, then the City's peak requirement at buildout was estimated to be 52 MGD *higher* than the current planned maximum capacity. This level of peak demand would require the City to add an additional 52 MGD of treatment capacity at an estimated finished and installed cost of $2,500,000 per MGD[2]. Developing the additional water treatment infrastructure to meet these higher demands would have required a capital investment by the City of approximately $130,000,000.

2 Based on recent projects and engineering estimates

Additional Wastewater Treatment Infrastructure Costs

If conservation were not taken and water demands had stayed at 1980 levels, staff determined that Westminster would have needed to add an additional 4 MGD of wastewater treatment capacity to their system. Adding wastewater treatment capacity costs the City an estimated $5,000,000 per MGD[3]. Thus the additional 4 MGD of wastewater would have required a capital investment by the City of approximately $20,000,000.

Total Estimated Costs of Increased Demand

All estimated costs associated with the hypothetical increased demand were assembled into a single table and then the City added in the costs of debt financing charges which would certainly have been part of these capital construction projects, had they been implemented. As shown in Table 1, had the citizens of Westminster not reduced their water use, the estimated total cost to the City of the increased demand came to $591,850,000 – more than half a billion dollars.

Table 1: Estimated new infrastructure costs of increased demand

Additional water treatment capacity	52 MGD total ($2,500,000/MG)	$130,000,000
Additional wastewater treatment capacity	4 MGD total ($5,000,000/MG)	$20,000,000
Additional water resources	7,295 AF total ($30,000/AF)	$218,850,000
Interest (on debt funding for all projects)*		$223,000,000
Total Costs		**$591,850,000**

** For the purposes of this analysis it is assumed that debt would have been issued, and the resulting debt service would have been paid through rates. Those costs were included in the impacts to rates.*

3 Based on recent projects and engineering estimates

Next the staff examined the increases in operating costs that the City estimates it would have incurred to handle the increased demand and associated additional infrastructure. While no additional staff personnel were assumed to be necessary, it was assumed that operating costs (power, chemicals, and other annual costs related to water and wastewater treatment, distribution and collection) would increase proportionally to the demand increases as shown in Table 2. From this analysis, it was estimated that Westminster would have incurred an additional $1,238,000 per year on average in operating costs associated with the additional demand.

Table 2: Estimated additional operating costs of new demand*

Additional annual operating cost of water treatment facilities	21% increase	$480,400
Additional annual operating cost of wastewater treatment facilities	20% increase	$757,600
Total estimated additional operating costs		**$1,238,000 per year**

**No additional staff personnel were added*

Impact to Water and Wastewater Rates and Tap Fees

Once the cost estimates were completed, the question of how to recover the additional costs through rates and fees was examined. Westminster Utilities has just two sources of revenue that it must use to pay for all costs associated with running the water and wastewater systems: (1) Water and wastewater rates; and (2) Tap fees. In theory, water and wastewater rates are set by the City so that the revenue generated covers operations and maintenance of the system as well as some of the repair and replacement costs, and debt service. Tap fees are set to cover the costs of buying into the existing system based on current value plus any new infrastructure (capital projects), and water resources required by growth.

In practice, existing customers build the City's water and wastewater systems before new customers arrive so that growth can occur. Infrastructure must be planned for future demands and not constructed as needed. When new customers connect and pay their tap fees, current customers are reimbursed for their investment in the City's existing systems. Those funds pay for capital improvement projects including repair and replacement, thus reducing the costs to existing customers. Therefore, both rates and tap fees are impacted by the same projects.

Working from this basic division of costs between rates and tap fees, Westminster developed an estimate of what 2012 water and wastewater rates and tap fees for single-family customers would need to be to cover the additional costs incurred as a result of the hypothetical additional supply requirements. In 2012, the average single-family customer in Westminster paid a total of $410 for water and $245 for wastewater service. To cover the single-family sector's share of the additional annual costs associated with the increased demand considered in this analysis, the average single-family customer would have to pay an additional $553 per year for water service and $43 per year for wastewater service. The weighted average of these additional costs means that the average single-family customer would pay combined water and wastewater rates that are 91% higher than they are today if 1980-level water demands were perpetuated over the past 30 years. These results are shown in Table 3.

Table 3: New single-family rates and fees required to pay for additional demand

	Total Avg. Per Customer Charges in 2012	Additional Charges Required to Cover New Costs	New 2012 Annual SF Water/Sewer Bill	% Increase in Charges from Additional Demands
Water	$410	$553	$963	135%
Sewer	$245	$43	$288	17%
Total	$655	$596	$1,251	91%

A similar analysis was conducted to examine the impact of increased demands on tap fees for new customers in Westminster. In 2012 the average tap fee for a new customer (residential and non-residential combined) was $21,229, of which 77% was for water and 23% was for wastewater components. The combined cost of new infrastructure, new water resources, and repair and replacement associated with the increased demand modeled in this analysis would require an 80% increase in the average tap fee, up to $38,181 as shown in Table 4.

Table 4: New tap fees required to pay for additional demand

	Avg. Per Customer Tap Fee in 2012	Additional Tap Fee Charges Required to Cover New Costs	New 2012 Avg. Tap Fee	% Increase in Charges from Additional Demands
Water	$16,325	$16,086	$32,411	99%
Sewer	$4,904	$866	$5,770	18%
Total	$21,229	$16,952	$38,181	80%

With Conservation Rates Go Up, But Not Nearly as Much

There is a commonly held belief in the water industry that declining per capita usage due to water conservation has "forced an increase to rates to account for fewer units of volume billed" (Craley and Noyes 2013). But the rate increases necessitated by conservation are actually much smaller than the rate increases that would be necessary to account for population growth in the absence of conservation. The 21% reduction in average per capita water demand that Westminster has experienced over the past 30 years has resulted in significant benefit to its customers and reduced the rate of increase in water and wastewater rates. While water and wastewater rates and tap fees have increased over that 30 year time period, they have increased much less than they would have. Customers in Westminster have avoided increasing their water rates by 99% and their wastewater rates by 18% had this level of water conservation not been achieved. New customers in Westminster have also avoided an 80% increase in water and sewer tap fees. Yes rates have gone up, but because of the costs associated with new water supply and infrastructure, they have gone up much less than they would have.

An answer to the citizen's question about water conservation and rates had been found and the result was far more dramatic than the staff had anticipated. The next time a question was posed about the relationship between conservation and water rates, the Westminster staff was prepared with an answer: Water rates are going to increase with or without water conservation because the costs of operating and maintaining the water system continue to increase. However, water rates increase at a much slower rate if citizens conserve because the city does not need to purchase expensive new water supply and construct expensive new infrastructure. The net results of water conservation is a significant cost savings to the customer in water and wastewater rates and in tap fees.

Each water system is unique, so the results from Westminster may not be applicable to everyone. Utilities could perform a similar analysis to see the real value of conservation. However, the over $590 million dollar cost associated with the additional 7,295 AF of demand reveals the significant hardship associated with expanding water resources supply and wastewater treatment infrastructure in today's environment. The high cost also highlights the tremendous value that is inherent in a utility's water treatment, wastewater treatment and delivery infrastructure. Imagine the cost of obtaining water rights and constructing an entire water supply system today. The cheapest water (by far) is the water we already have and the best way to keep rates and tap fees low is to conserve the water we already have. The cost of water to providers may vary by region but the cost of infrastructure remains more consistent. The least expensive infrastructure to build, operate and maintain is the infrastructure that isn't needed in the first place. Conserve water or don't conserve water – your rates will go up – but if conservation is the lowest cost source of new supply (and it almost always is) then your rates will go up less than they would have without conservation.

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Alliance for Water Efficiency
300 W. Adams Street, Suite 601
Chicago, Illinois 60606

www.allianceforwaterefficiency.org