Where is water being used in Melbourne households? Residential End Use Measurement Study (REUMS) insights

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ABSTRACT

To understand where and how water is used in homes, in July/August 2017 the three metropolitan Melbourne retail water corporations installed high resolution digital water meters and loggers for approximately 18 months. The data was collected at 10 seconds intervals and subsequently analysed using advanced disaggregation techniques and analysis procedures.

Information generated by these studies is used as input to Integrated Supply and Demand Planning modelling for a range of purposes, including pricing submissions, revenue budgets, water efficiency program planning and future demand forecasting. A previous REUMS study was completed in the 2010 - 2012 period. During the 2010 - 2012 period there were water restrictions and considerable promotion of water conservation through media and paid advertising. During the current study period, little to no promotion of water efficiency had occurred and the previous campaigns had largely escaped from the public's consciousness.

Analytical results indicate 'shower' to be the most significant residential end-use followed by 'toilet' and 'tap'. Some indoor water uses in households has increased compared to the previous study.
This paper provides an analysis of water usage data for 289 Melbourne based dwellings over a 12-month period. These results are compared to the REUMS 2010-12.

KEYWORDS

End uses, residential, water demand, forecasting models, demand analysis, Diurnal profiles, shower, household size.

INTRODUCTION

In recent years, Melbourne's population has been growing rapidly, and at a faster rate than the rest of Australia. It exceeds 5 million residents in 2020. From 2006 to 2012, despite high population growth, we saw a decrease in total water use. During this period, Melbourne was experiencing ongoing dry conditions, water restrictions were imposed and there was intensive spending on water conservation measures. Per capita water usage has since stabilised, and Melbourne's total water demand is now increasing rapidly in line with population growth. The

trend of Melburnians' water use is shown in Figure 1. Since 1997, Melbourne's water supply catchment areas have experienced drier and warmer weather conditions compared to the long-term average, and this trend is expected to continue. This has resulted in below average inflows to Melbourne's water supply reservoirs, and as a result have been augmented by desalination water orders, including 125 GL of desalinated water in 2019/20.

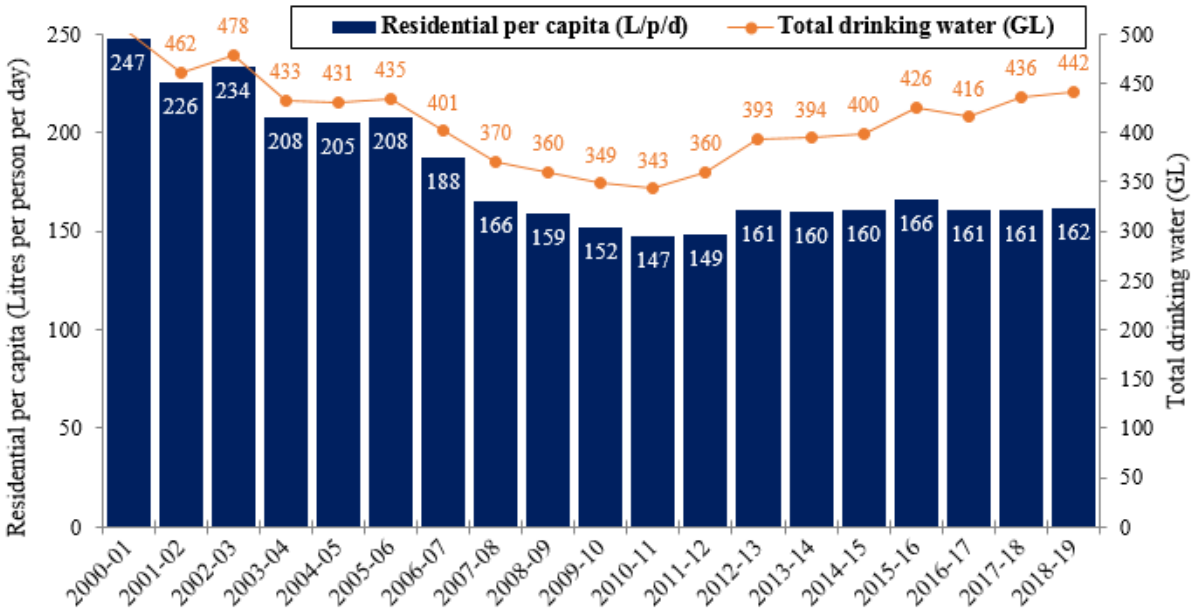

Figure 1. Melburnians' water use – per capita and total drinking water use

Melbourne is serviced by three metropolitan retail water corporations - City West Water (CWW) [1], South East Water (SEW) [2] and Yarra Valley Water (YVW) [3] – which source bulk drinking water from Melbourne Water. The boundaries of Melbourne's retail water corporations are shown in Figure 2.

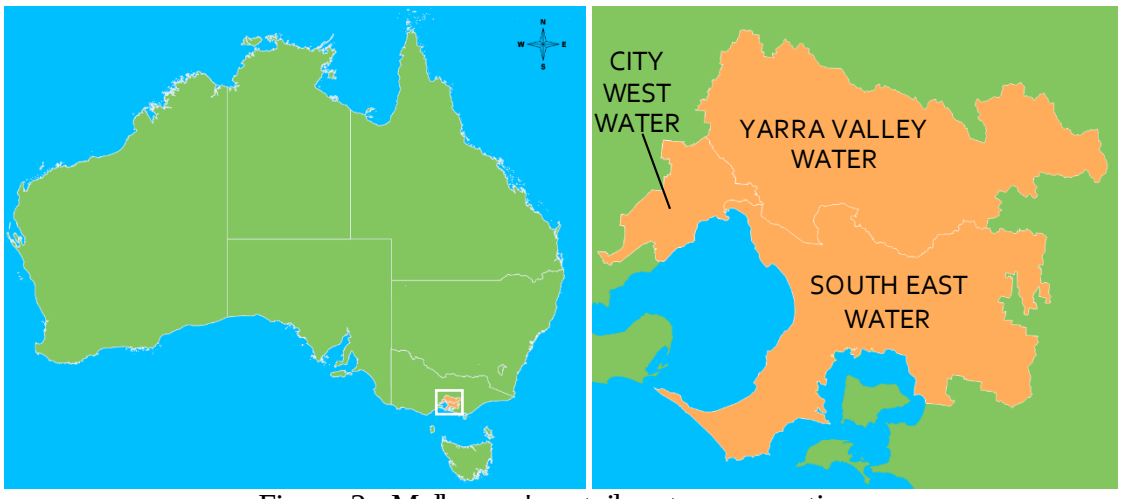

Figure 2. Melbourne's retail water corporations

The three retail water corporations use *bottom-up* end use modelling to forecast their future water demands. End use modelling is an important tool for the simulation of water supply and demand scenarios and as such, is a vital component of our water efficiency and business planning processes. An end use model is constructed using demographic information and data obtained from a detailed Residential End Use Study (REUMS).

REUMS are conducted periodically to gain insights into individual end uses of water, efficiency of appliances that use water and customer behaviours. These studies provide us with additional insights into residential customers' behaviours and practices and comparison between studies helps inform future demand forecasts.

THE REUMS 2017-18 STUDY

In July/August 2017, the three metropolitan Melbourne retail water corporations installed high resolution digital water meters and loggers for approximately 18 months of data collection. This is the second REUMS with comparable design undertaken concurrently by Melbourne's three retail water corporations.

This latest study involves investigating water use behaviour in 289 dwellings across Melbourne (110 in CWW's service area; 74 in SEW's service area; and 105 in YVW's service area) including 33 'dual supply' dwellings. Dual supply properties are those receiving both drinking and recycled (non-drinking) water in separate pipes.

Recruitment of participants for REUMS 2017-18 was carried out by a consultant and by calling for volunteers from three water corporations' staff.

Measurement technology

There were two parts to REUMS 2017-18:

1. The first was an Appliance Stock and Usage Pattern Survey (ASUPS) involving an online survey gathering information about the demographics and physical characteristics of the appliances and the dwellings.
2. The second involved the installation of a high-resolution meter and a data logger at participants' homes.

The ASUPS survey was designed to document water utilising appliances and fixtures, income range and other demographic features of participant and their homes.

The standard water meter at each participating dwelling was replaced with a high-resolution water meter (Aquiba A210 - Figure 3) and a logger after participants completed the online survey. 'Dual supply' properties also saw their standard recycled water meter replaced with a high-resolution recycled water meter and a logger in addition to the drinking water meter and logger.

Figure 3. High resolution water meter and logger (left) and this installed (right)

The high-resolution water meters were configured to measure flow at a resolution of 0.01 litres at ten second intervals – wireless data loggers encoded data directly from meter sensors, with encrypted/compressed data sent across the 3G network and forwarded to relevant water corporations. The wireless radio link between the meter and the logger can facilitate a wireless connection of up to 10 meters. This was useful in areas with poor 3G coverage at the meter location, which required the logger to be installed at a distance from the meter location to achieve the required signal strength.
Loggers were set up to upload data daily over the 18 months period, and each water corporation received weekly consolidated transfer data files.

Overview of data analysis

Detailed analysis was undertaken on a continuous 12 months of 10 second data (September 2017 to August 2018) to cover the expected range of water use fluctuations through Melbourne's seasons.
'Autoflow' software (a machine learning algorithm developed by Griffith University [4], [5]) trained with previous and current study data was used to enable the identification of water 'end-uses' (shower, toilet, tap, bath, washing-machine, dishwasher, leaks and drips, evaporative coolers and irrigation) derived from water meter trace data. Autoflow is also capable of identifying simultaneous events and provides a graphical representation of the data. The disaggregation of data using Autoflow was quantified by Griffith University at between 85% - 95% accuracy for the end-use categories using training data.
Following the Autoflow disaggregation analysis, a range of tools (Power BI, SQL, R, Python and Excel) was used to compile and analyse all end-use events. City West Water analysed data collected during REUMS 2010-12 for their customers within the study using the same methodology to compare the results with REUMS 2017-18 results [6]. The other water corporations have not completed this analysis at this time.

RESULTS

Sample characteristics

Analysis of the sample composition indicated that it was not wholly consistent with the 2016 Census.

In the REUMS 2017-18 sample, 81% of dwellings were detached houses, 17% were semi-detached or town house and the other 2% were units, flats or apartments. There was a higher concentration of participants from outer suburb areas as compared to the city and inner suburbs. The sample size was relatively small, particularly if conclusions are sought on or between sub-sample elements (e.g. flats vs detached dwellings).

The most common number of persons in the participant household was four (30%), followed by two persons (27%), three persons (20%), then single (11%) and five persons (10%). Compared to the 2016 Census, higher occupancy houses are over represented in this study sample, but the proportion of two-person households was comparable with census data. It is hypothesised that this sample composition corresponds with under representation of inner-city dwellings, which are more likely to be single occupancy.

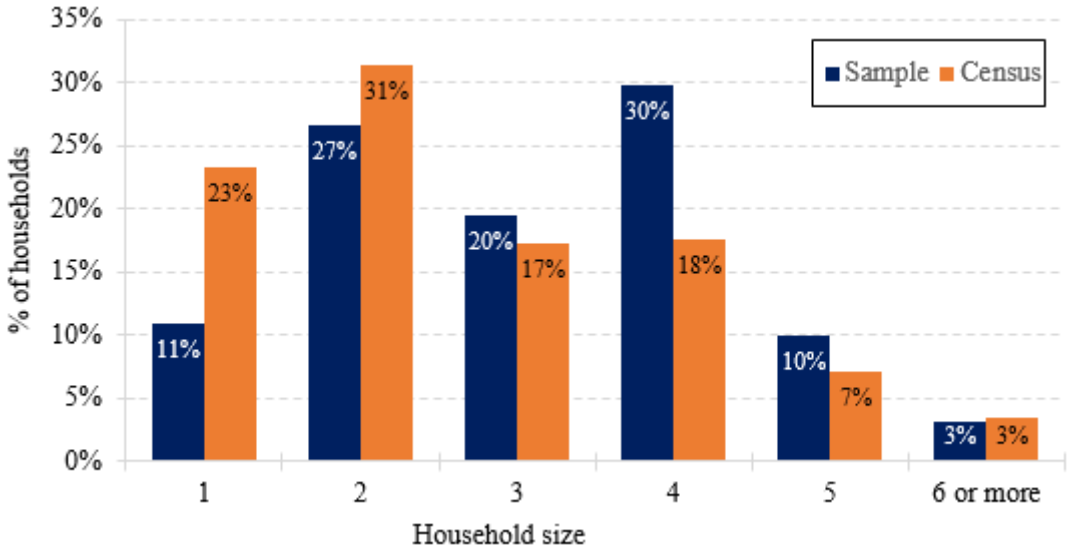

Figure 4. Number of persons usually resident – sample versus 2016 census

End-use portions

Based on the yearly water usage for both 'potable water only' and 'dual supply' properties, the highest water volume end-use was shower (31%), followed by toilet (19%), irrigation (15%) and tap (13%). Washing machines (clothes washers) accounted for 9% of total water usage. Tap use is the combined usage from bathroom basins, kitchen sinks, laundry troughs and outdoor tap use – this is not disaggregated, as it is not possible to determine which of these are being used for any given event. Household water usage for the study is summarised in Figure 5.

Figure 5. Household water usage by end-uses

Disaggregated monthly per capita usage by end-use is shown in Figure 6. Considerable seasonal variation is observed in irrigation and evaporative coolers with less variation or variation not correlated to weather conditions in the other end uses. Average daily per capita usage of the sample was 161.5 L/p/d (comparable to the overall Melbourne per capita - Figure 1).

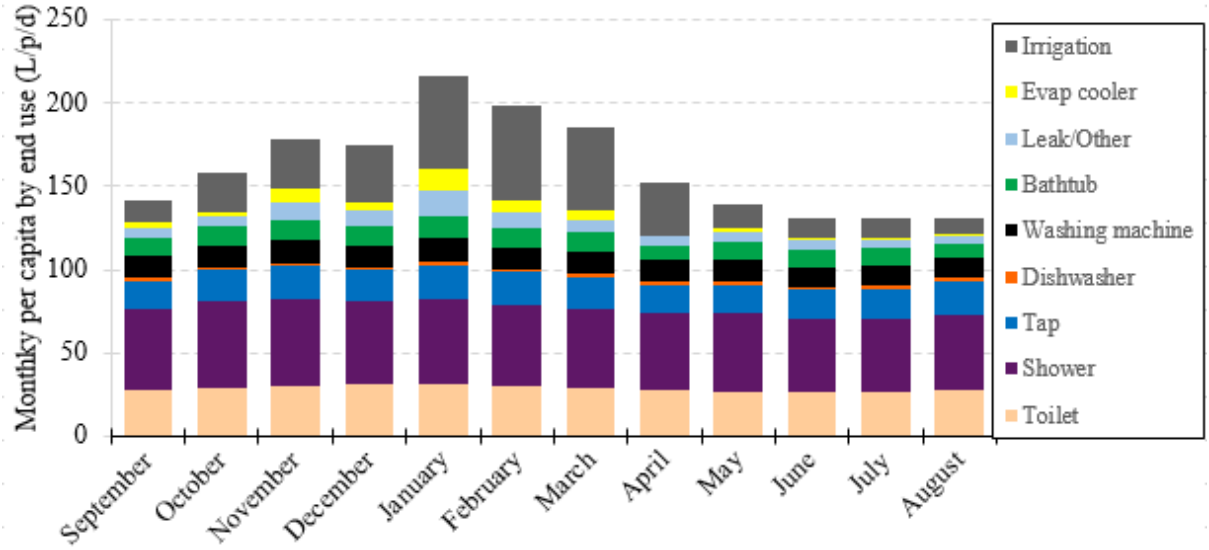

Figure 6. Monthly per capita usage by end use

Dual supply properties

Annually, 'dual supply' properties used about 33% recycled water and 67% potable water. Based on the total yearly recycled water usage, 43% of recycled water was used for irrigation followed by toilet (42%) and tap (includes outdoor use such as washing cars and cleaning - 10%). Washing machine use was only 1%. While in newer areas, laundries have been plumbed to recycled water, previously this had not been allowed. Further research into uptake of recycled water for clothes washing would be beneficial to understand the actual and potential reduction in drinking water use that could be achieved with recycled water.

Daily water use versus household size

Daily per capita water use is inversely correlated with household size. This is attributed to a baseline consumption for the household (irrigation, leakage, minimum frequency of clothes washing and dishwashing) regardless of how many persons are residents, and presence of more children under 11 with higher household sizes in the sample. The trend from this study is shown in Figure 7.

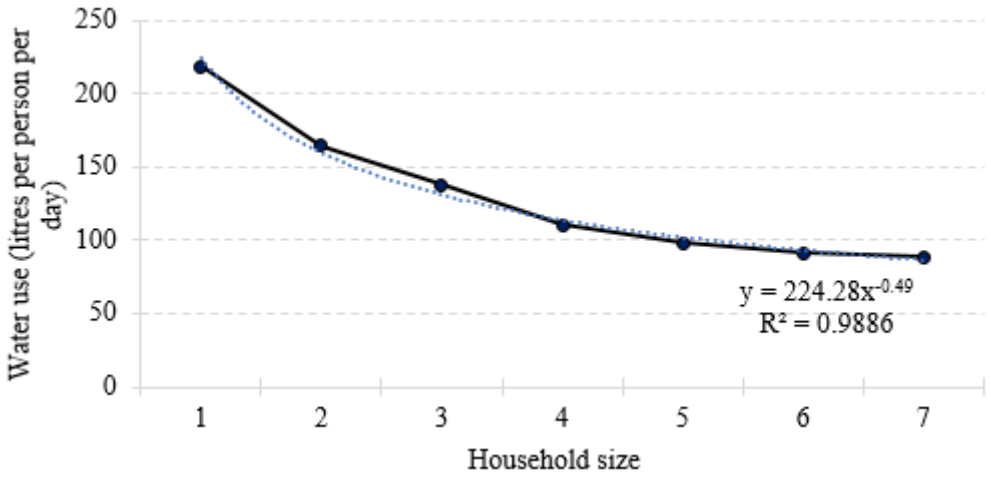

Figure 7. Water use by household size

Diurnal profiles

End use study analysis allows generation of diurnal profiles for different customers, including typical times that different end-uses occur. An example of a weekends and weekdays diurnal profile is included Figure 8. As expected, more water was used throughout the day on weekend in between morning and evening peak compared with the weekdays.

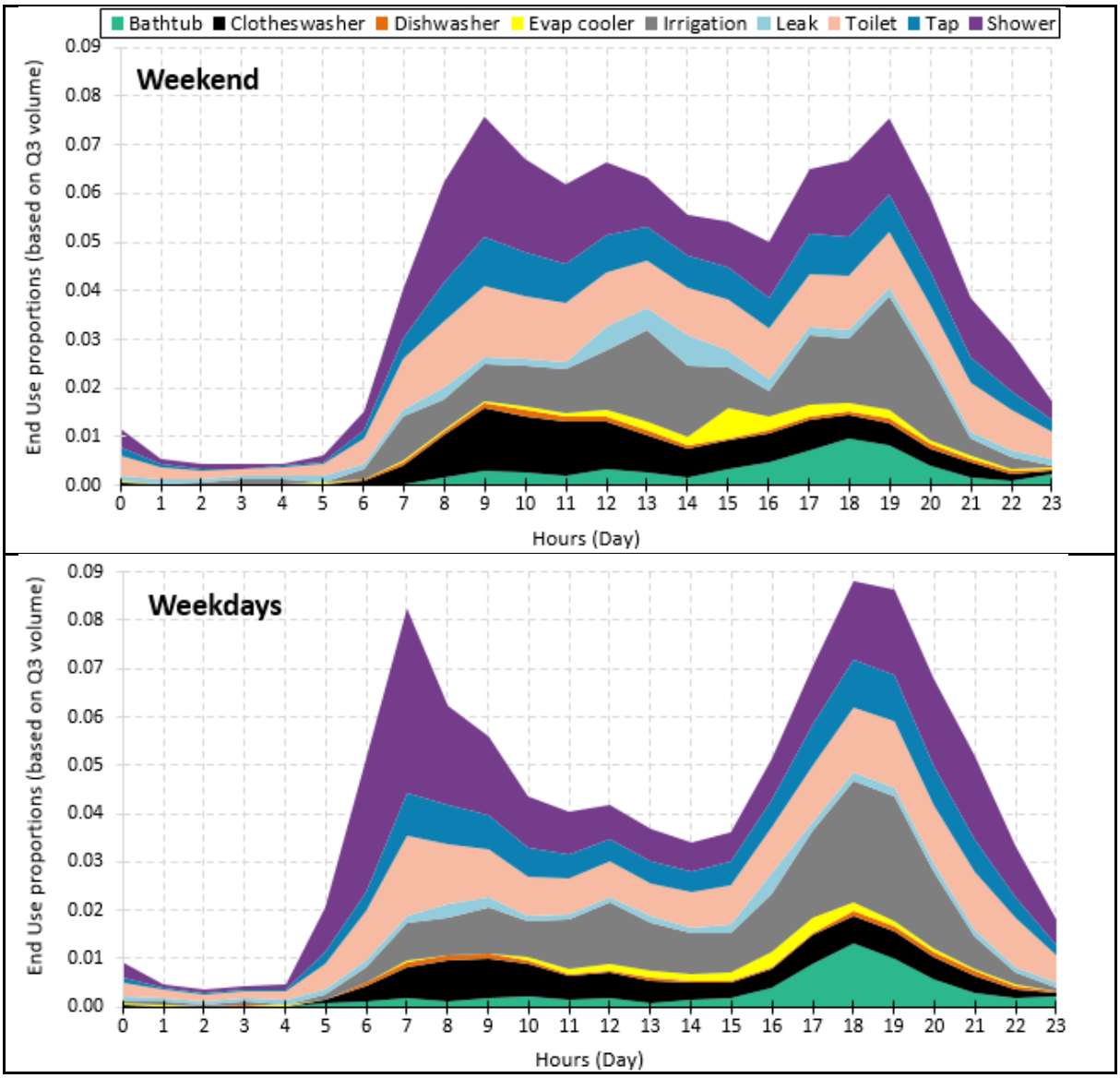

Figure 8. City West Water - Hourly diurnal profiles by end use for January to March (leaks include dripping taps as well [6]

Analysis of end uses

Shower. In line with the previous REUMS study [7], the shower is the end use responsible for the highest proportion of residential water use in Melbourne. This is despite an increasing penetration of 3 star or greater water-efficient showerheads (over 70% of shower events have a flow rate of less than 9 litres per minute versus less than 50% in the 2010-12 study). Average shower duration has been estimated at 6.8 minutes and frequency of showering is 0.9 showers per person per day, with marginally higher frequency and shorter duration in summer (1.0 shower per person per day and 6.6 minutes January to March) and lower frequency but longer duration in winter (0.9 showers per person per day and 7.1 minutes June to August). This is

relatively consistent across the three retail water corporations. While the average shower duration in Melbourne has been estimated at 7.1 minutes in previous research [7], [8], there is wide variation in duration. The spread of current study shower durations is shown in Figure 9. Based on the results of this study reducing the average shower duration across Melbourne by 1 minute could save 13 GL per annum.

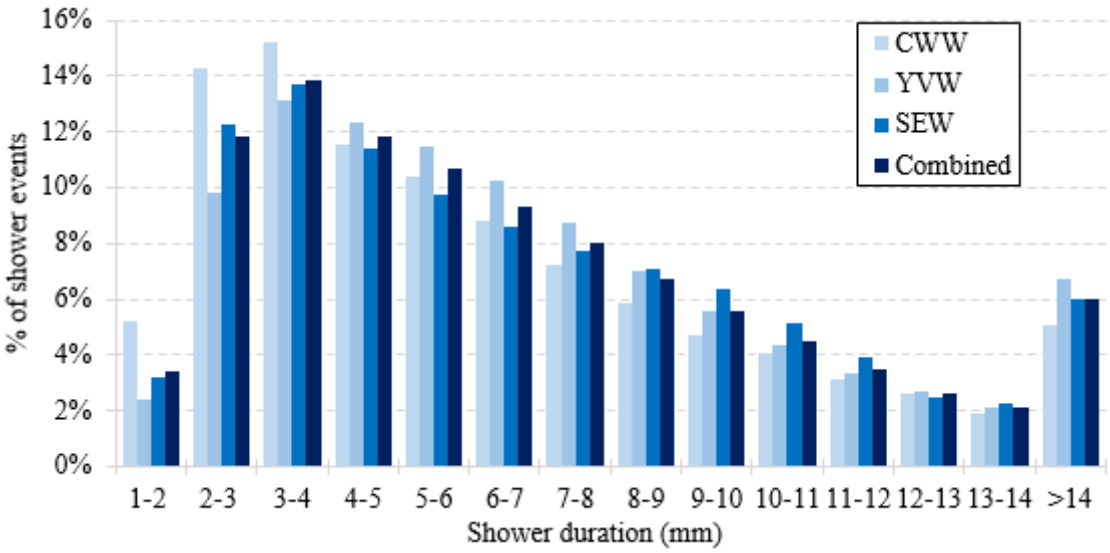

Figure 9. Spread of shower durations

Bathtub. The use of baths varies considerably across households. Households that indicated they have children younger than 10 years often had higher volumes of bathtub usage, in line with expectations that young children are more likely to have baths. Overall across the study bath frequency was around 2.1 events per household per week, and average bath volume was 86 litres per event. According to the ASUPS, 87% of households use their bathtub. Average daily bathtub water use is slightly higher in summer than winter.

Toilet. Average toilet flush frequency was estimated at 5.7 flushes per person per day. The sample includes some households where most residents are usually at work or school during the day, and other households where most residents are home most of the time. No analysis has been completed to confirm whether the sample is statistically representative in terms of how many hours people are typically at home each day. The average flush volume from the study was 5.0 litres. A 4-star toilet uses 4.5 litres per full flush and 3 litres per half flush with an expected average of 3.5 litres per flush. Reducing the average flush volume from 5.0 to 3.5 litres could save 15 GL per annum across Melbourne.

Washing machines (Clothes washers). Across Melbourne, 99% of households have a washing machine. Front-loading washing machines use around half the water of a top loading washing machine, per load (70 L vs 135 L). The penetration of front-loading washing machines is steadily increasing (61% in the current study), with an associated reduction in water use. On average, Melburnian households do 3 loads of washing per week. If all of Melbourne switched to front-loading washing machines, approximately 7.5 GL per annum of water could be saved. Clothes washing is an end use that varies by the day of the week. This impact is summarised in Figure 10.

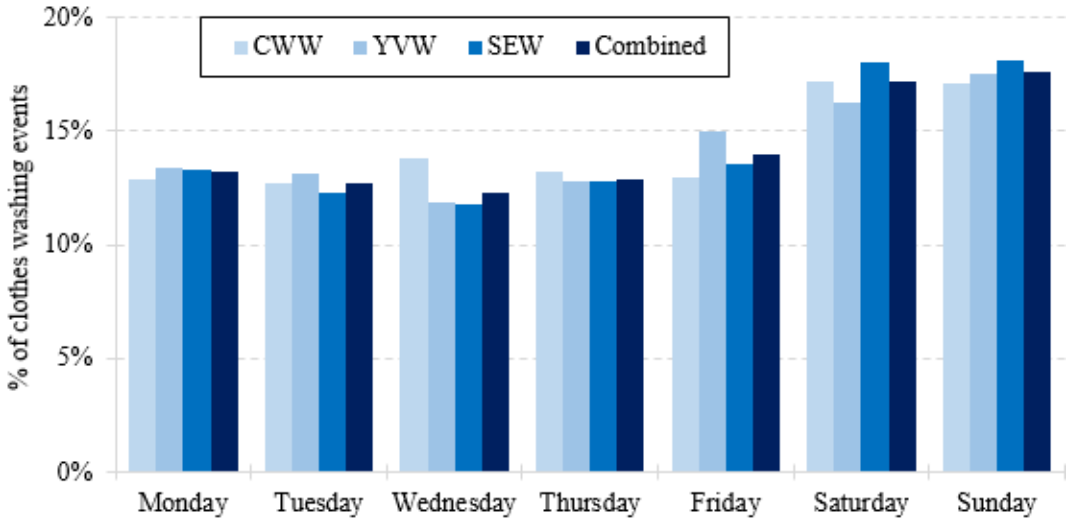

Figure 10. Clothes washing by day of week

Dishwashers. Dishwashers, while becoming even more efficient, only use an average volume of 15 litres per load and an average of 4.1 loads per week for households that have a dishwasher. They are not used consistently by all households that have them, and it is likely that their increased use could save water based on typical hand washing of dishes.

Taps. Hand basin, laundry trough, kitchen sink usage is characterised in taps and varies significantly across properties. Average flow rates of taps were recorded as 2.8 litres per minute. Average daily per capita volume was determined as 18.4 L/p/d.

Evaporative coolers. In Melbourne, evaporative coolers are quite prevalent with around 28% of households having one. For households that have them, they use around 16 litres per day on average. Overall, they contribute a very small proportion of total water use.

Leaks, dripping taps and other. A significant proportion of total household water use (around 21 litres per household per day) is thought to be leaks and dripping taps. Customers in the study that had significant leaks have been advised, however there is a significant number of small leaks and drips that may be uneconomical for customers to fix and may be difficult to locate. Bringing this issue to customers' attention could result in a material reduction in household usage across Melbourne.

Irrigation. Irrigation behaviour varies across Melbourne and is generally thought to be linked to garden size, affluence, species of plants and occupier preferences. The average frequency of irrigation per week across all households was 1.9 times per household with an average of 42 irrigating minutes per session. Irrigation has increased in recent years after remaining relatively flat for several years after water restrictions, which targeted irrigation in particular, were lifted and replaced with Permanent Water Saving Rules in December 2012. Other analysis into Melbourne's water use suggests that higher summer use has particularly been apparent since 2013, suggesting use of outdoor water with the lifting of water restrictions.

Comparison with 2010/12 end use study

A similar end use study was completed by the Melbourne water retail corporations from 2010 to 2012, which focussed on 2 weeks in summer and 2 weeks in winter rather than a whole year. Trace Wizard was used to segregate end used in the REUMS 2010-2012 [7]. Average daily household usage was higher in the current study sample than the REUMS 2010-12 (Table 1).

Significant increases appear to have occurred in shower, bath and irrigation volumes, and a decrease has occurred in washing machine volumes. Toilet volumes are also higher, however further analysis is required to determine whether this is related to differences in the sample and disaggregation technique. City West Water has completed more detailed analysis of the 2010-12 [6] data using the same Autoflow disaggregation methodology and this suggested a significantly higher toilet volume than published and a very similar volume to its 2017-18 result.

Table 1. Comparison of 2017-18 and 2010-12 end use study.

Parameters	**2017-18**	**2010-12**
Average volume per household per day (L/hh/d)	442	397
Shower (L/p/d)	48	36
Average volume per shower event (L)	52	48
Average frequency per person per day	0.9	0.8
Average shower duration (min)	6.8	7.1
Bathtub (L/p/d)	11	3
Average volume bath event (L)	86	125
Average frequency of bath per week	2.1	2.5
Toilet (L/p/d)	29	20
Average volume per flush	5.0	5.9
Average flush frequency	5.7	3.9
Washing machine (L/p/d)	13	21
Average volume per load (L)	95	90
Average loads per week	3.0	4.9
Dishwasher (L/p/d)	2.1	1
Average volume per load (L)	15.4	15.1
Average loads per week	4.1	3.2
Tap (L/p/d)	18.4	19.7
Average flow rate (L/minute)	2.8	2.8
Evaporative cooler (L/p/d)	4.2	6 (summer)
Leaks, dripping taps and other (L/p/d)	7	10
Irrigation (L/p/d)	28.6	21
Average duration (minutes/day)	42	61
Average frequency per week	1.9	2.0 (summer)

L/hh/d – litres per household per day; L/p/d – litres per person per day

Other factors affecting water use

There are many hypotheses that could be tested with the end use and survey data available that are areas for potential future investigation. These include:

- Income
- Rainwater tanks
- Lot size
- Evaporative coolers

- Age of dwelling
- Presence of young children, teenagers
- Dwelling structure type

Preliminary investigation into these factors suggests that:

- There is a hypothesis that affluent households use more water (larger houses and gardens, more irrigation, filling swimming pools etc). When correlating income and water use this is not necessarily apparent. Low income households are often retirees that are home for more hours per day and hence use more water at home. This would need to be normalised to test the hypothesis.
- Properties with rainwater tanks do not necessarily have lower drinking water usage than other properties. Many properties installed rainwater tanks during the millennium drought so they could water their large gardens, and in long periods of dry weather will revert to drinking water.
- Often larger lot sizes relate to larger gardens and hence higher water usage. Preliminary analysis of the study properties suggests that properties with lot sizes over 700 square metres generally have higher consumption than smaller lots and a higher proportion of irrigation consumption.
- While evaporative cooler water consumption across Melbourne is a relatively small proportion of total water use, properties with evaporative coolers have higher water consumption than those without.
- Average consumption of newer and older dwellings is similar but there is more variation in consumption of older dwellings.
- Households with young children have lower per capita consumption. Yarra Valley Water's analysis into its study participants suggests that average shower durations are higher in households with teenage children.
- There is a wide range of water consumption for each dwelling structure type. While average household usage is higher for detached dwellings, there are many townhouses and semi-detached dwellings that use as much or more water than detached dwellings.

DISCUSSION AND CONCLUSION

The information generated by end-use studies is invaluable as it provides an information source at the household level that allows Melbourne's three water corporations to quantify a range of variables that contribute to residential water use in their service area. However, as currently configured, this is a resource intensive effort, with a relatively modest sample size, and known limitations to the analysis software. Thus, the use of this valuable information needs to be tempered with an understanding of its limitations.

Key findings of REUMS 2017-18 were:

- There is a trend of higher per capita water usage where households have fewer occupants
- Showers continue to be the highest residential end-use by volume
- The increase in per capita water use since 2012 is likely to be due to higher levels of irrigation, slightly higher frequency and longer duration of showers and baths; and decreasing number of persons per household. This is despite the higher penetration of water efficient appliances – especially front-loading washing machines and new dwelling stock in growth areas generally having small gardens. This gradual drift in customer behaviour is perhaps attributable to the topic of water conservation moving

from being in the public spotlight following the end of the millennium drought and water restrictions no longer being in force.

- There remains significant potential for saving water through behaviour change, showerhead replacement, toilet replacement, changeover of washing machine stock, repair of dripping taps and toilet cisterns. By these measures there is a potential 45 GL per annum saving that could be made, equating to approximately 10% of Melbourne's total annual usage.

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