Identifying the Drivers of Water Consumption: a Summary of Results from the South East Queensland Residential End Use Study

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Summary

The aim of the South East Queensland Residential End Use Study (SEQREUS) was to address the research gap on water end usage by way of generating a high resolution data registry of water end uses and using such a database to explore the relationships and influences of residential water consumption from a bottom up approach. Such data can be used to optimise future demand management strategies. Mains water end uses in a sample of 252 residential dwellings located within South East Queensland (SEQ) were measured using a combination of high resolution smart meters and data loggers and a parallel social survey design comprising a questionnaire, a stock (appliance) audit and self-reported water diary for each household. An array of detailed analyses were conducted from the subsequent data registry based on three separate two-week monitoring periods (2 x winter and 1 x summer). Impacts on water consumption from water-efficient technology (eg, star rated washing machines, flow regulated taps and showers), socio-demographics (household composition, income and education and perceptions and attitudes towards of water conservation on household, per capita, diurnal and peak demand water consumption are presented, including the variation in water end uses on a daily and seasonal basis. We conclude with some policy considerations that evolved from our data analysis and that may assist in optimising future demand management strategies. For example, it is recommended to target households with large families with young children or teenagers, as these homes are often associated with high shower and tap usage.

Keywords
Water end uses, micro-components, water consumption behaviors, water-efficient technology, demand management, rebound effects, water restrictions, intervention strategies.

Background

In an attempt to improve water security, many government authorities in Australia have imposed water restrictions and water saving measures to manage demand and ensure the mindful use of water across the residential, commercial and industrial sectors. The combination of enforced water restrictions and State and local government rebate programmes for water efficient fixtures and rainwater tanks have resulted in a large reduction in household water use in South East Queensland (SEQ) (Walton and Hume, 2011). Residential water end use data can facilitate the identification of correlations between water behaviours and key demographical subsets within a population (eg, income, age, gender and family composition). Currently, there is a scarcity of measured water end use data for SEQ and Australia in general. The overarching aim of the SEQ Residential End Use Study (SEQREUS) was to address the research gap on water end usage by way of generating a high resolution data registry of water end uses and using such a database to explore the relationships and influences of residential water consumption from a bottom up approach. This paper provides a summary of the key findings arising from the SEQREUS which focussed on four local council authorities (Brisbane City, Gold Coast City, Ipswich City and Sunshine Coast Regional Council) located in the south-eastern corner of Queensland, Australia.

Methodology

The total number of homes monitored was 252 (winter 2010), 219 (summer 2010-11) and 110 (winter 2011). The breakdown of homes per region and some general characteristics of the participating households within each region are shown in Table 2. The SEQREUS used a mixed method, advanced water end use measurement approach to capture and analyse water use data. Upon completion of household recruitment, standard council residential water meters were replaced with modified Actaris CTS-5 water meters. These ‘smart’ meters measure flow to a resolution of 72 pulses/L or a pulse every 0.014 L. The meters were connected to Aegis Data Cell series R-CZ21002 data loggers.
Flow trace and water use analysis

Figure 1. Mixed method approach used in the SEQREUS.

The loggers were programmed to record pulse counts at five second intervals. Data was wirelessly transferred to a central computer and stored in a database for subsequent analysis (Figure 1). A representative sample of received data was extracted from the database and disaggregated into all end use events associated with the sampled residential households using the Trace Wizard® software (Aquacraft, 2010). Concomitantly with meter and logger installation, a water fixture/appliance stock survey and 7-day self-reported water use diary was conducted at each participating home in order to investigate how householders interact with such stock. Additionally, each homeowner completed the Household Water Use Survey. The aim of the survey was to capture attitudes and behaviours toward household water conservation. A detailed discussion on the research methods is provided in Beal et al., (2011) and Beal and Stewart (2012).

Table 1. Selected characteristics of households in the SEQREUS sample.

<table>
<thead>
<tr>
<th>Sample Characteristics¹</th>
<th>Gold Coast</th>
<th>Brisbane</th>
<th>Ipswich</th>
<th>Sunshine Coast</th>
<th>SEQ Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household occupancy</td>
<td>2.6</td>
<td>2.6</td>
<td>2.7</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>No. of people</td>
<td>230</td>
<td>164</td>
<td>96</td>
<td>171</td>
<td>661</td>
</tr>
<tr>
<td>No. homes</td>
<td>65</td>
<td>61</td>
<td>37</td>
<td>67</td>
<td>230</td>
</tr>
<tr>
<td>% Households with ≤ 2 people</td>
<td>58</td>
<td>41</td>
<td>51</td>
<td>69</td>
<td>55</td>
</tr>
<tr>
<td>% Households pensioners/retired</td>
<td>36</td>
<td>16</td>
<td>32</td>
<td>45</td>
<td>32</td>
</tr>
<tr>
<td>% Households with children (aged ≤ 17)</td>
<td>34</td>
<td>30</td>
<td>21</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>Average age of children (years)</td>
<td>8.8</td>
<td>2.7</td>
<td>4.4</td>
<td>10</td>
<td>6.5</td>
</tr>
<tr>
<td>Average household income (AUD)²</td>
<td>73,290</td>
<td>81,630</td>
<td>87,900</td>
<td>60,070</td>
<td>75,722</td>
</tr>
</tbody>
</table>

Notes: ¹ data presented are averages; ² Estimated from taking the average of the household income category that each respondents selected (Gregory and Di Leo, 2003), where categories were: 1 = <$30,000, 2 = $30,000 – $59,000, 3 = $60,000 – $89,999, 4 = $90,000 - $119,999, 5 = $120,000 - $149,999, 6 ≥ $150,000.

Results and Discussion

Water End Use Breakdowns

The water end use breakdown on a per capita basis indicated that, on average, shower, tap and clothes washer comprised the bulk of the water consumption. This trend was consistent both temporally and spatially throughout the SEQREUS with almost 70% (approximately 100 L/p/d) and 74% (approximately 106 L/p/d) of total consumption was attributed to these three activities in winter 2010 and winter 2011, respectively. Of note, irrigation made up less than 5% of average total consumption. Typically, the homes that used the most water had a disproportionately high contribution from irrigation. Dishwasher and bathtub use was also over-represented by a small number of homes,
with the latter end use being generally associated with young families. Although the sample size for the winter 2011 data was less than half that of the previous winter, the average total water consumption was very similar at 145.1 L/p/d, and compared well with the QWC reported per capita water use of 148 L/p/d for the same period. The larger household water consumption in winter 2011 is likely to be associated with the different household compositions for this smaller sample ie, the higher percentage of families with children in the winter 2011 dataset would effectively increase the household consumption, but reduce the per capita consumption. This is explored in more detail in later sections of the paper.

Table 2. Water end use breakdowns for SEQREUS sample.

<table>
<thead>
<tr>
<th>End Use</th>
<th>Winter¹ 2010</th>
<th>Summer² 2010-11</th>
<th>Winter³ 2011</th>
<th>Winter¹ 2010</th>
<th>Summer² 2010-11</th>
<th>Winter³ 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L/p/d</td>
<td>L/hh/d</td>
<td>% of Total</td>
<td>L/p/d</td>
<td>L/hh/d</td>
<td>% of Total</td>
</tr>
<tr>
<td>Leak</td>
<td>9.0</td>
<td>4.0</td>
<td>3.1</td>
<td>17.7</td>
<td>8.6</td>
<td>9.08</td>
</tr>
<tr>
<td>Toilet</td>
<td>23.7</td>
<td>23.2</td>
<td>24.4</td>
<td>58.6</td>
<td>56.2</td>
<td>70.1</td>
</tr>
<tr>
<td>Clothes washer</td>
<td>31.0</td>
<td>26.5</td>
<td>51.8</td>
<td>82.7</td>
<td>65.1</td>
<td>89.2</td>
</tr>
<tr>
<td>Shower</td>
<td>42.8</td>
<td>36.2</td>
<td>31.8</td>
<td>115.0</td>
<td>94.3</td>
<td>149.1</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>2.5</td>
<td>1.9</td>
<td>2.2</td>
<td>6.5</td>
<td>5.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Tap</td>
<td>27.5</td>
<td>27.4</td>
<td>25.1</td>
<td>68.6</td>
<td>67.1</td>
<td>70.1</td>
</tr>
<tr>
<td>Bathtub</td>
<td>1.8</td>
<td>1.5</td>
<td>1.9</td>
<td>5.8</td>
<td>4.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Irrigation</td>
<td>7.0</td>
<td>4.8</td>
<td>6.7</td>
<td>15.7</td>
<td>10.3</td>
<td>16.9</td>
</tr>
<tr>
<td>Total</td>
<td>145.3</td>
<td>125.3</td>
<td>145.1</td>
<td>370.7</td>
<td>311.3</td>
<td>415.6</td>
</tr>
</tbody>
</table>

Notes: ¹ n= 252 households, ² n= 219 households, ³ n= 110 households.

There are several explanations for the reduced summer usage observed in this study. Firstly, the above average rainfall experienced in 2010-11, Queensland’s 6th wettest summer on record, clearly resulted in very low outdoor use (irrigation) - the end use which is inherently higher in summer - thus it is the main end use which typically drives the increase in total consumption over summer (Willis et al., 2011a). Secondly, homes with high leakage rates were alerted to such, with resultant leakage rates reduction following maintenance. Additionally, as for the winter measurements, there will be some bias in the SEQREUS sample due to the smaller size of the sample compared with the QWC database and the possibility of a slight overrepresentation of low water consumers due to their involvement in this study. Due to these factors, greater care needs to be taken when applying the summer end use results towards water practice and policy actions.

Given the largest sample size and average rainfall and temperatures during the winter 2010 period of analysis, this dataset was considered the best representation of SEQ households with a strong mix of family types, income categories and household occupancies. Additionally, results suggest that the data obtained from this study compares well with other estimations of household consumption (ie, weekly reports from QWC). Consequently, detailed analysis presented is based on this winter 2010 dataset.

Regional Breakdowns

Looking at the regional breakdowns (Figure 2), it is clear that Gold Coast and Brisbane were mainly responsible for the upward shift in shower end use consumption. Collectively, for the winter 2011 analysis, households in these two regions had the highest percentage of families with children ≤ 17 years old. This may be reflected in the higher shower use and slightly higher bath end use also. Average end use breakdowns for Ipswich are very stable across the seasons, despite the reduced sample sizes, particularly for the final winter 2011 read (n=12). As there is very little irrigation for many of the Ipswich households, essentially it is the indoor end uses that are being compared in Figure 2. The Ipswich sample provides a good example of a low level of fluctuation between indoor end uses which have been reported elsewhere (eg, Willis et al., 2011a; Jacobs and Haarhoff, 2004). The homogeneity in indoor end uses further emphasises the strong influence that irrigation can have on total household demand and thus the value of supplementing irrigation water sources such as rainwater tanks and greywater systems.

The Sunshine Coast residents consumed the highest volumes of water for all regions, with the biggest indoor water usages attributed to showers, clothes washers and toilets. The Sunshine Coast sample had the oldest average age for children (10 years) and highest percentage of pensioners and retired residents (Table 1). There was more likely to be greater occupancy during the day in this region than compared to regions that had a lower daytime occupancy rate (eg, Brisbane demographic are more likely to be working and attending school). During the analysis, it was regularly observed that the homes that were occupied by older residents tended to use more water for showers and toilets. This
is confirmed by the high shower usage and elevated toilet usage observed in Figure 2. Water loss attributed to leaks was the highest of all the regions at 14.1 L/p/d in winter 2010, although after alerting these households, leakage was reduced substantially.

**Figure 2.** Regional water end use breakdown for winter and summer analyses. (Note: Total daily per capita use in parenthesis).

### Average Daily Diurnal Patterns

The winter average daily diurnal pattern for 2010 is shown in Figure 3. For each of the read periods, there were twin consumption peaks in the morning and afternoon water use events. Shower, clothes washer and taps contributed the bulk of the water use activity at these peak times. The morning peaks, were typically higher than evening peaks for both the winter and summer reads, although the summer peak use was more prolonged or ‘flattened’, particularly in the afternoon. Irrigation use appeared to occur throughout the day across both seasons, demonstrating a conflict with current water restrictions and awareness messages that recommend outdoor watering in early morning and late afternoon. As a result of the leak intervention programme after winter 2010, leaks have reduced significantly in all regions and were consistently low throughout the day, showing little diurnal variation.

**Figure 3.** Average daily diurnal pattern analysis.
Impacts of Household Stock Efficiency on Water Consumption

The impact of water efficient stock on water consumption was examined on the winter 2010 dataset. For clothes washing machines there was a clear trend for higher star rating and front loading machines to use less water and in terms of star ratings; ≥4 star machines used significantly less (p<0.05) water than ≤2 star machines (Figure 4). This equated to a potential savings of 8.8 kL/hh (or 29%) per year. The penetration of front loaders is likely to have increased sharply in the last three to five years due to the rebates offered in Queensland to install water efficient (typically front loading) machines. There was a significant reduction (p<0.05) in shower water demand from high (AAA star) efficiency heads compared to low (A star) or poor (standard/old) efficiency clusters (Figure 5). Replacing the old style showerhead with any star rated shower head would significantly (p<0.05) reduce water consumption by a minimum of 28 kL (or 75%) per year.

![Figure 4. Daily clothes washer efficiency comparisons.](image)

![Figure 5. Daily shower efficient cluster comparisons.](image)

There were significant differences (p<0.05) between all three tap efficiency clusters, and replacing an old style tap with a ≥ 3 star tap fitting can save 12.9 kL/hh or 65% annually. Efficient dishwashers (eg, 3.5+ star rating) used significantly less (p<0.05) water at a mean of 4.4 L/hh/d, compared to the average 9.2 L/hh/d from the inefficient dishwasher cluster. Homes with a rainwater tank (RWT) that was used exclusively for external events such as irrigation were found to have a statistically lower total household consumption than those homes without a RWT (Figure 6). Note that there were no homes that had internally plumbed RWT included in the study.

The study demonstrated that highly efficient water appliances and fixtures not only contribute to reduced use of potable water supplies but also lower the average day peak hour demand from which water supply infrastructure is designed. Data in Figure 7 compares the average daily diurnal patterns for the 50 least efficient and 50 most efficient homes in the sample. Water-efficient homes were found to have a reduced average peak hourly consumption of between 2.47 L/p/h/d (18.6%) and 3.52 L/p/h/d (19.3%). Both of these water demand reductions were statistically significant at p < 0.01).

![Figure 6. Water use for homes with and without a RWT.](image)

![Figure 7. Average day diurnal pattern efficiency clusters.](image)
Impacts of Household Socio-Demographics on Water Consumption

Higher income households consumed more water on average per day than lower income homes (Figure 8). The end uses that contributed most to the increased consumption were shower, clothes washer, dishwasher and bath. There was a trend for households with small families, with an older average age of residents and no children to consume less water per household on average. At an average total of 354 L/hh/d, households with either full and/or part-time residents consumed significantly more \((p>0.05)\) water than those homes with retired and/or pensioned residents (253 L/hh/d) (data not shown). Typically, water consumption will be higher for large homes with large families as the demand for water is obviously greater and there are a higher number of water fixtures and appliances, however, larger families are typically more water efficient on a per capita basis than single families (Figure 9). Homes with one or more teenagers consumed significantly more water for shower events compared to homes without teenagers (Figure 10). In terms of perceived water use clusters, a clear pattern emerged from the results which showed that self-reported high water users typically consumed less (130 L/p/d) than both the self reported medium (156 L/p/d) and low (143 L/p/d) water users on a per capita basis (Figure 11). Further discussion of this can be found in Beal et al., (2011b). Results also indicate a trend that higher income, larger, younger and more educated households tend to install efficiency appliances which may not always be sufficient in reducing water consumption if curtailment actions are not present. Therefore water consumption behaviours, as well as technology needs to be considered as part of a successful demand management strategy.

![Figure 8. Income category, age and occupancy.](image1)

![Figure 9. Family size and end use breakdown.](image2)

![Figure 10. Teenagers and shower usage.](image3)

![Figure 11. Perceived and actual household water use.](image4)
Conclusions

Some conclusions and water demand management key points for stakeholders have been drawn from the findings of the SEQREUS:

- There is still some degree of non-compliant irrigation during the 10 am to 4 pm period, particularly for homes in the Sunshine and Gold Coasts.
- Leaking toilets were more widespread than previously reported, however intervention programmes can be very effective at reducing these leaks as was shown in the summer and winter 2011 monitoring. Rapid post-meter leakage management is one of the key benefits of smart metering systems.
- Water efficient fittings for showers and taps are an excellent water demand management option for conserving water, confirming previous studies.
- Installing water efficient shower heads and clothes washers are significant areas for reducing average day peak hour demand.
- Changing to efficient washing machines and low-flow shower heads significantly reduces household consumption. Diurnal patterns indicate that by encouraging a shift in clothes washer operation from morning to evening, like the existing habit for dishwashers, would substantially reduce the average morning peak demand.
- Results strongly suggest the high importance of a sustained targeting of water consumption behaviour, particularly shower and tap use, as well as encouraging installation of water-efficient measures.
- Families with young children or teenagers are high water consumers on a household basis and this can be a target area for water conservation managers to consider, especially as these homes that have water-efficient technology, may not necessarily have low water consumption behaviours. Single person households, while having a high per capita consumption, typically do not contribute to the peak day demand periods.

References