AUCKLAND WATER USE STUDY – MONITORING OF RESIDENTIAL WATER END USES

ABSTRACT
There is a continuing increase in water demand in New Zealand's main urban centres. Significant investments in urban water infrastructure are going to be needed to keep up with demand. In many regions water allocation is a hot issue, where urban water demand is competing with the demand for irrigation water for agriculture especially in periods of drought. Yet water is still inexpensive compared to other resources. Prevention of water shortages can come from infrastructure investments, reduced demand, or a combination of both. Water suppliers want to be able to address both options, however they are unlikely to effectively manage demand for water because most water suppliers lack crucial information on actual water use for the range of uses within New Zealand homes. In order to address this problem, Auckland's bulk water supplier and local councils commissioned BRANZ to quantitatively assess how residential water users use water in their region. In the Auckland Water Use Study (AWUS), water end use was monitored in detail in 51 residential buildings. Identification and benchmarking of prime targets in water-saving fixtures for buildings is now possible, and using the Water Efficiency Labelling Scheme (WELS), it can be demonstrated what modifications are feasible for more water efficient buildings. The AWUS project provided essential information for effective management of water demand in the greater Auckland area.

KEYWORDS: Water, end use, monitoring, demand, appliance.

INTRODUCTION
Auckland's population has grown at approximately double the national average over the last five years. As a result, water demand has increased along with the amount of wastewater that needs to be treated. During the 2007 financial year, more than 136 billion litres of A-grade drinking water was supplied and over 104 billion litres of wastewater was treated by WaterCare Services Limited, which supplies bulk water and wastewater services to the Auckland region. Water Care draws the water from 12 sources, treats it to A-grade drinking water, and supplies it to six Local Network Operators (LNOs). It is then on-sold to more than 1.2 million consumers (WaterCare 2006). About 62% of Auckland's reticulated water is used in residential buildings.

Annually, WaterCare produces an estimate, based on population growth predictions and current per capita water use, for the future demand requirements for the water networks in the Auckland region, and to plan for future investments in the infrastructure. The current prospect is that eventually a point is reached where the available water sources become fully allocated, and the necessary amount of water cannot be supplied. Either a new source needs to be found and connected to the infrastructure system, or the total amount of water used needs be reduced, ideally without compromising living standards.

By rationally reducing water use, expensive infrastructure investments can be shifted further into the future. This is where residential end use analysis comes in, since the more that is known about a specific sector, the more accurate the forecasts can become. Also by getting a better understanding of where the water is used in the homes, opportunities for improving water efficiency can be identified and monitored for their effectiveness.

BRANZ was commissioned by WaterCare to conduct an end use study on their behalf to find out where and how water is used in Auckland homes.

METHODOLOGY

BRANZ could build upon expertise gained in the Water End Use and Efficiency Project (WEEP) (Heinrich 2007), which piloted monitoring water end uses in a sample of 12 houses on the Kapiti Coast. The conceptual basis for end use monitoring also dates back to experience gained in the Household Energy End Use Project (HEEP) (Isaacs et al 2006), a 10 year energy study looking at energy usage in over 400 New Zealand homes.

Sample selection

Initially it was decided to monitor about 50 houses spread across the six LNO regions to obtain a balanced sample distribution to represent the Auckland region. Each region was weighted according to the number of connected houses, the population and water volumes used. After the sample was weighted the number was set to 51 houses, which were distributed over the regions as shown in Table 1. Houses were then selected at random from the metering databases of the individual LNOs. A 10% reply rate was assumed, so 10 times as many homes were initially selected as required from each of the districts.

Table 1: Sample distribution and response rate over local network regions

Area	*Local Network Operator (LNO)*	*Monitored homes*	*Mailing*	*Response rate*	
			Total	*Positive*	*Negative*
Manukau	Manukau Water	12	120	14	18
Central AUK	Metrowater	18	200	30	44
North Shore	North Shore CC	9	94	14	14
Rodney	Rodney DC	2	25	3	10
Papakura	United Water	2	25	2	6
Waitakere	Ecowater	8	82	11	19
Total	–	*51*	*546*	*74*	*111*

Information packs were sent out to the 546 randomly selected customers. These packs were customised to suit the needs of each of the six LNOs, and included the following documents:

- covering letter – explaining the study and its aims
- reply form with a short questionnaire
- information on frequently asked questions about the survey and study
- document explaining the data collection procedure in more detail.

The overall response rate to the mailing was 34%, of which 40% were positive. In every region there were enough positive responses to draw the sample using the original order of the random drawing, plus some practical criteria to get to the final numbers needed for the study.

The average occupancy of the study group was found to be 2.7 occupants per home, which is slightly lower than census figures published by Statistics NZ (Statistics NZ 2006) of 2.9 people per dwelling. The largest group were the two person households, which represents 47% of the total sample. The largest number in any household was found to be eight people. Single occupancy households represented 14% of the group.

The study group includes houses from varying demographic groups and household sizes. Some houses had no outside water uses, whereas others used water for irrigation or filling swimming and spa pools. Two houses in the selection had swimming pools. One home had a broken pipe through the majority of the summer monitoring period, which made up most of this home's total uses. Some water end uses were found in every house (such as toilets, showers and taps), whereas washing machines, dishwashers, baths and other end uses were not.

Measurement methodology

To monitor the water end use of individual appliances in each house, a method called Flow Trace Analysis was utilised. This technique required logging of high frequency data from only one single high resolution water meter at the water supply entry to house. This approach was piloted with success in the WEEP study (Heinrich 2007). A calibration procedure was required to optimally tune the data analysis software package, "Trace Wizard" from Aquacraft, to recognise the temporal fingerprint of the specific appliance in the household.

After the installation of a dedicated high resolution water meter with pulse output (MES 25 – Neptune – 34.2 pulses per litre) by the LNO to a selected house, BRANZ performed a house visit with the following outputs:

- Installation and activation of a BRANZ pulse data logger to collect the signal from the water meter
- Physical description of the dwelling with numbers of specific water-using appliances
- Fingerprint procedure by timed activation of appliances in the house
- Interview of the occupants to obtain background information on appliance use and additional demographic material.

Flow profiles at 10 second intervals were collected with a BRANZ data logger. Given its storage capacity, up to 35 days of data could be obtained before replacement was required. From each data record the individual end use would be disaggregated using the Trace Wizard software calibrated for that specific dwelling.

The records of all dwellings were stored in an MS-Access database. For the data analysis a combination of MS-Excel, MS Access and Visual Basics programming was used.

Household data

For in-depth interpretation of the measured water end use data, understanding of the household context proved to be essential. This information was acquired through the household questionnaire and interviews. Careful consideration of the required background information from each household proved to be vital for understanding the patterns of usage that occur. However there were some details in the dataset that required going back to occupants for an additional interview.

The following topics were covered in the questionnaire:

- Characteristics of the household (including number of occupants)
- Water use and living patterns (including types and numbers of end use appliances)
- Background details on occupants.

All household information was acquired under an appropriate confidentiality agreement.

RESULTS

The field survey took place over two main monitoring periods – one in summer and one in winter – to assess seasonal differences in water use. In the summer period (February and March) two sequential data series per dwelling were collected with each series being around four weeks long. In the winter period (during the months June and July) only a single data series per dwelling was collected with up to five weeks of end use data.

Daily water use

The data analysis of the summer monitoring period was split into two separate months, February and March respectively, to see if significant variations in water use would occur within the same season. This data of one house was affected by a major leak. In this article most data presented excludes the contribution of this major leak, although the occurrence of this leak of 2,300 litre/day (89% of water use of that property) illustrates a reality in water supply that needs to be accounted for in estimates of water network performance. Due to the limited number of houses this estimation has not been done as part of this study. A group average daily water use profile can be constructed from the measured flow data (see Figure 1).

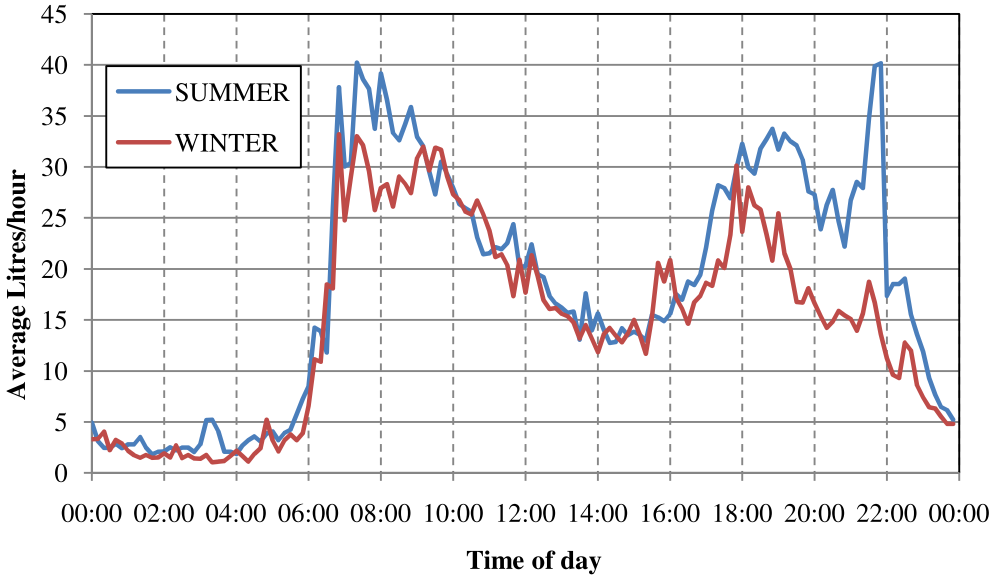

Figure 1: Average daily flow profile summer / winter (10 min averages)

The average volume used per day per property can be found by integration over this daily flow profile. A selection of the resulting aggregated daily water use figures in the summer and winter period is given in Table 2 for dwellings and in Table 3 per capita. The peak in daily water use is the maximum volume in daily water use that was detected over the monitoring period for a specific property. Averaging the peak values of all properties gives the average peak volume. As can be expected longer monitoring periods will result in larger average peak volume due to the increased probability of a high use event. This expectation is confirmed by the data. The two-month (Feb & Mar) summer average peak value is higher than respective one-month average peak values for February and March. Per dwelling average summer water use was slightly lower than winter water use. However, more significant changes in water use were found when comparing February water use, which was 15% higher than March.

Per capita summer water use was slightly higher than values found in water. Average peak volume used in summer was significantly higher than the average peak in winter. However the lowest peak values were found in the March period. The monthly variations in peak water use were therefore found to be comparable in magnitude to the seasonal variations.

Table 2: Daily water use per household in summer and winter period

Daily water use per dwelling	*Summer 2008*			*Winter 2008*
	Feb 1-month	*Mar 1-month*	*Feb & Mar 2-month*	*Jun/Jul 1-month*
Average daily water use per dwelling (litre/day)	456	394	422	425
Average over peaks in daily water use per dwelling over period (litre/day)	1416	1038	1649	1102

Table 3: Daily water use per capita in summer and winter period

Daily water use per capita	*Summer 2008*			*Winter 2008*
	Feb 1-month	*Mar 1-month*	*Feb & Mar 2-month*	*Jun/Jul 1-month*

Average daily water use per capita (litre/day)	188	172	179	175
Average over peaks in daily water use per capita over period (litre/day)	620	453	683	465

Average water end use per appliance

In Figure 2 the pie-charts show end use distribution of water over the main appliances over the summer period per household and per capita, while the pie-charts in Figure 3 show the winter period. Looking at the end uses of water for households, the largest measured indoor event during summer was the shower, which accounted for 26% of all end uses, followed by the washing machine and the toilet with 21% and 17% respectively, while outdoor water use was 18%. The tap was also a significant end use at 12%.

The contribution of other appliances was considerably smaller. The winter end use distribution was almost identical. The water end use per capita distribution shows that outdoor water use was much lower at only 6%, which indicates that outdoor water use is not very sensitive to the number of occupants. The proportionality of the main indoor uses has not changed with respect to each other.

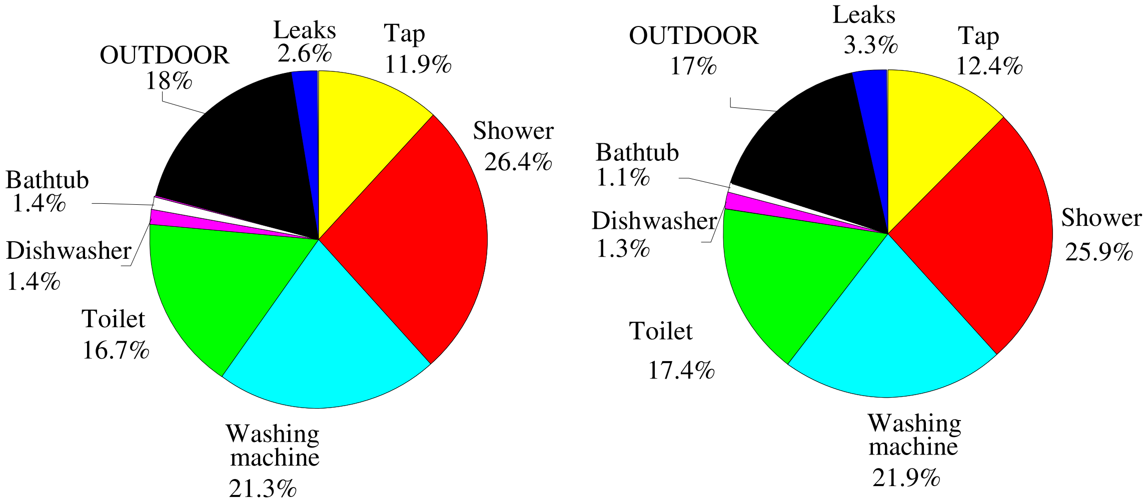

Figure 2: Household (left) and per capita (right) end use distribution in summer

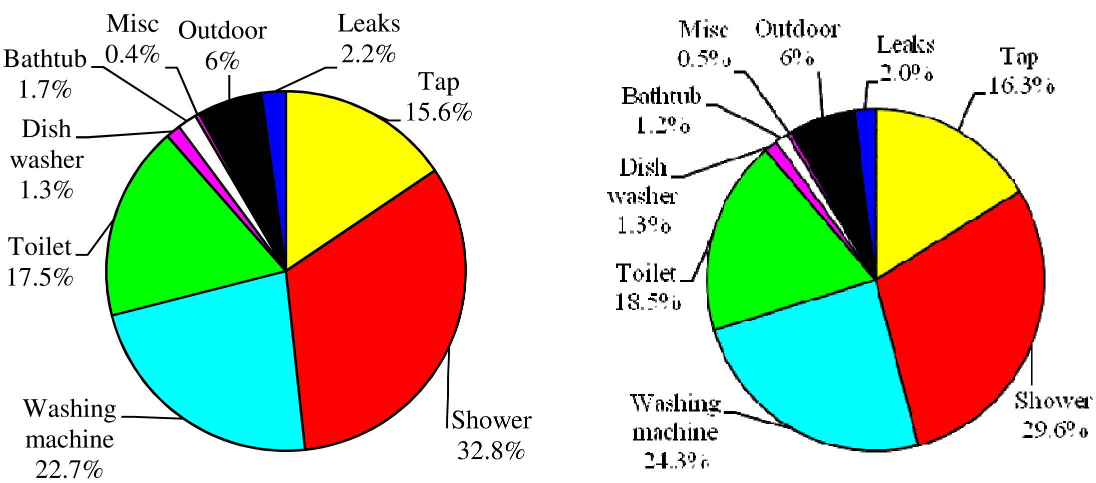

Figure 3: Total end uses per household (left) and per capita (right) in winter

The associated end use volumes per appliance are presented in Table 4. The average number of occupants (2.7 persons per dwelling) gives a first appreciation of differences between the water use per dwelling and per capita. Seasonal differences are found for tap, shower and outdoor end use volumes per day.

Table 4: Average volume per specific water end use appliance

Water End Use	*Summer 2008 Feb 1-month*		*Winter 2008 Jun/Jul 1-month*	
	Per household	*Per person*	*Per household*	*Per person*
	litre/day	*litre/day*	*litre/day*	*litre/day*
Tap	51.9	21.5	66.3	28.5
Shower	112.6	45.9	139.4	51.8
Washing machine	97.9	42.2	96.5	42.5
Toilet	75.8	33.0	74.4	32.4
Dishwasher	5.7	2.3	5.5	2.3
Bathtub	8.9	2.8	7.2	2.1
Misc	2.9	0.8	1.7	0.9
TOTAL INDOOR	*358*	*149*	*391*	*161*
Outdoor	83.2	10.5	25.5	10.5
Leaks	14.7	3.5	9.4	3.5
TOTAL USE	*456*	*188*	*425*	*175*

Detailed water use per appliance in household context

The data of washing machines is presented as an example of detailed appliance analysis. Table 5 gives a summary of average washing machine use over the two seasonal periods showing that washing machine use remained fairly constant.

Table 5: Summary of washing machine water use

	Summer 08 Feb & Mar 2-month		*Winter 08 Jun/Jul 1-month*	
	Average	*Standard Deviation*	*Average*	*Standard Deviation*
Volume/load	122	27	123	29
Loads/day	0.80	0.50	0.78	0.44
Loads/person/day	0.35	0.22	0.36	0.25
Litres/house/day	99	61	94	55
Volume/person/day	43	29	43	32

The washing machine is the second highest indoor use, representing around 27% of indoor use during both summer and winter. Overall 2,910 unique washing machine events have been observed over the two separate monitoring periods.

As only three machines (6%) were front-loading, it is not statistically relevant to distinguish between the two types of systems, even though front-loading machines generally use less water than top-loading. Ninety-four percent of machines in the study group were top-loading, which corresponds to data collected in the HEEP study (Pollard 2007).

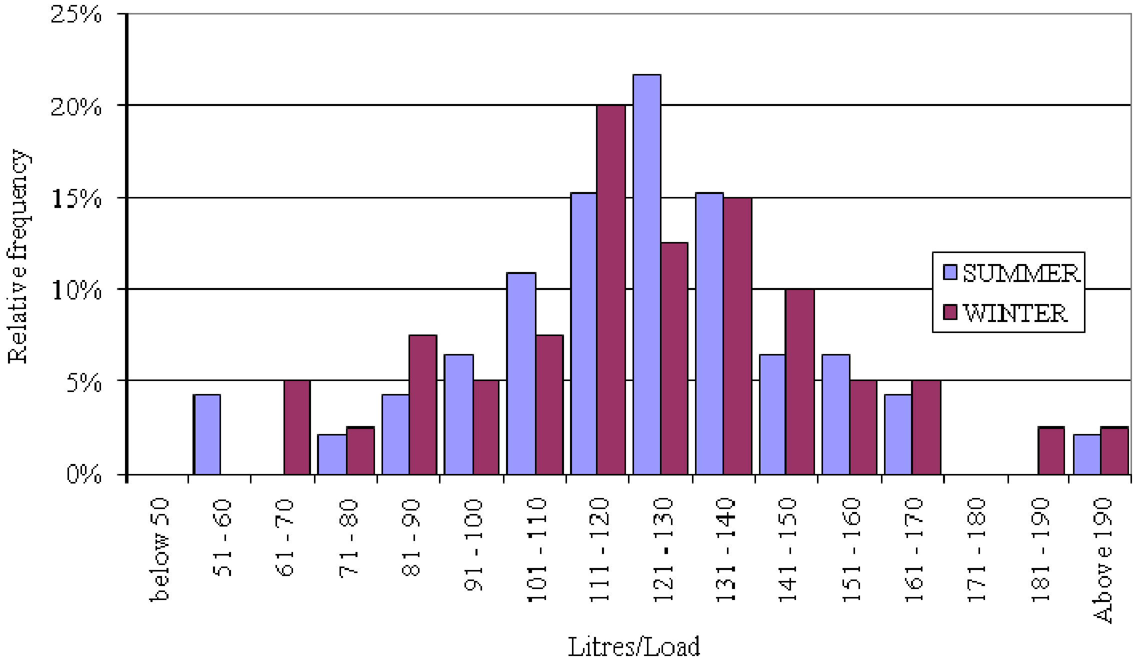

Figure 4: Average washing machine water use per load

Figure 4 shows the distribution of average washing machine load volumes for each of the houses. On average a load of washing used 122 litres/load during the summer and 123 litres/load over winter. The highest volume for any load was 190 litres in the summer and 196 litres during winter. The lowest average load size was 51 litres and 67 litres during summer and winter respectively.

Other appliances

Also, for the other appliances similar detailed data was recorded. As an indication of the richness of the dataset, a listing of the total number of registered end use events for three other appliances is given here:

- Toilets 28,701 events (summer) 13,589 events (winter)
- Showers 5,709 events (summer) 3,136 events (winter)
- Taps 143,000 events (summer) 70,633 events (winter).

DISCUSSION

The results from this study give a unique and useful insight into how water is used in Auckland households. Obtaining accurate end use information allows the identification of areas in which water can be used more efficiently. For the clients (WaterCare and the LNOs) a detailed end report (Heinrich 2008a) with all results and detailed analysis of all appliances was produced. This discussion reflects the main findings of the complete analysis performed in the end use study for the clients. A variety of options for water savings in buildings were assessed.

Water saving by appliance upgrade

According to the results in this study, savings can be achieved in households primarily by installing more water efficient toilets and washing machines. Installation of low flow shower heads would reduce water consumption in only a few houses, as the majority of homes already have relatively low shower flows due to the prevalent use of low pressure electric domestic hot water. Reducing the flow of taps (i.e. tap aerators) would have a small effect on reducing water use, as 81% of tap uses in summer and 88% in winter already have flows of less than 4.5 litres/minute, which is equivalent to a 6 star WELS rating (maximum efficiency). Even though taps are capable of higher flows, the data suggests that they are not used to their full capacity. This could be due to the fact that some basins are not designed for high flows as water would spray onto the surroundings.

Seasonal water use behaviour

Indoor usage: The proportion of indoor usage remained fairly constant throughout both summer and winter periods, with a slightly higher volumetric indoor usage during winter. This difference is only small, and when looking at the individual end use components similar results were observed over the two seasonal periods.

Outdoor usage: Seasonal variation is the main driver for outside usage. During summer, outdoor use represented 17% of the total uses (32 litres/person/day), whereas during winter this proportion dropped to 6% (11 litres/person/day). Similar to leaks, only a small number of households were responsible for the majority of outdoor water uses in both summer and winter. The highest outdoor water users in the study group were the two houses that had swimming pools and spa pools. Irrigation was the highest single outdoor usage, and these events had a large effect in increasing a household's daily peak demand. The houses with a high outdoor usage during summer also had high outdoor usage during winter.

Addressing leaks

Leakage can have a major effect on household water consumption, especially if the leak is unnoticed or left ignored. During February 2008, leaks made up 13% of the total water usage (on a household basis – 24% on a per person basis) across all the study homes. This was mainly due to one large leak, which wasted 2,300 litres/day.

Winter measurements showed that leaks represent only 2% of the total water usage across all the study homes throughout this period. The tendency is that only a small number of houses are responsible for the majority of leaks. Leaks still need to be addressed as sometimes it is just a matter of changing a 50 cent seal. It is not always easy for a homeowner to detect a leak. Night-time metering of water usage is often the first indication. Education programmes about water efficiency and leakage control may be effective.

Extrapolation of toilet data to accumulated water savings for Auckland

If each toilet in Auckland was brought to the standard of a 6 star WELS rated toilet (average of 2.3 litres/flush) from the current 0 star average model, the accumulated water savings would be over 9.5 billion litres of water/year (7.1% of total yearly supply of 135 billion litres), and over 7.6 billion litres of wastewater/year, which is around 6.8% of the total wastewater discharge (116 billion litres). On average each person uses 11,500 litres/year for flushing the toilet alone, which is over 14 billion litres/year (≈11% of total water supplied) when looking at the whole population that is served by WaterCare.

CONCLUSION

Sixty-two percent of Auckland's water usage occurs in residential buildings. This study delivered a unique dataset and analysis that provides a detailed picture of how water is used by occupants in residential buildings in this area. This insight was transformed into directly relevant information and advice for network operators, which helped them to better understand the usage patterns and rationalise choices between feasible options for improvements and upgrades inside residential buildings that could improve buildings' water use performance and reduce consumer demand for water. Incorporation of this information and knowledge of water end use in long-term planning will enable water demand management to be a more effective tool in water supply management and infrastructure development, thereby optimising the overall functionality of the local water infrastructure. The high quality dataset can be used to better calibrate and further develop water demand management models in this region. For other regions, local water end use data should be collected to inform water demand management, because while there can be similarities, water use patterns vary from place to place. However in the context of water demand management, an accurate local picture of water use is considered to be essential in the debate with the end users.

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