CONFERENCE PAPER

CP136 (2009)

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Presented at the SB07 NZ Conference: Transforming our Built Environment, 14-16 November 2007, Auckland, New Zealand.

Funded by BRANZ from the Building Research Levy

The work reported here was funded by BRANZ from the Building Research Levy.

ISSN: 1178-4946

SB07 Conference
Paper number: 058

WATER END-USE AND EFFICIENCY PROJECT (WEEP) – A CASE STUDY

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Abstract

Twelve homes on the Kapiti Coast (New Zealand) have been monitored for eight months to find out where the water is used. Reporting includes monitoring data and analysis of the winter and summer period, as well as a summary of the methods and tests that have been conducted in order to derive an end-use monitoring technique. By analysing water use at an end-use level, it is possible to identify the areas which would yield the greatest results when conducting a retrofit. The largest water savings could be achieved by installing low-flow shower heads and water-efficient washing machines. High savings in mains water use can be accomplished by installing a greywater system or rain tank. This conference paper highlights the findings of the study.

1. INTRODUCTION

Water is a significant issue at present in many parts of New Zealand and water shortages threaten to spread. In 2005 BRANZ started to look at ways to measure water end-uses in a sample of residential homes of varying age and occupant demographics. In July 2006 monitoring equipment was installed in 12 homes on the Kapiti Coast to investigate where the water is actually used. To reduce human impact on the water supply, alternative water sources are required.

The use of rainwater in rural areas has a long history, but using rainwater in urban areas for uses around the house and stormwater retention at a decentralised scale still has a long way to go. This conference paper shows a summary of some of the findings from the monitoring. The full report (Study Report 159) is available from www.branz.co.nz.

2. MONITORING

Following a detailed water audit and questionnaire, the 12 homes were equipped with high resolution water meters and modified BRANZ data loggers, which were capable of storing 35 days of data at a 10 second interval. Flow trace analysis software was then used to disaggregate the flow profile of the home into its end-use components. Monitoring equipment was in place for eight months to capture the seasonal variations.

3. DAILY PER CAPITA USE

During summer the average daily use per person was 204 litres (L) and during winter 168 L. The average per person use over the whole monitoring period was 184 L per person per day (L/p/d). In the summer months (November–March) the maximum water use per person is higher than the maximum use in winter. This is mainly due to outside uses in a small number of houses. On average 36 L are used additionally in summer by each person per day. The house which had the highest outdoor use during winter also had the highest outdoor use during summer. The water usage figures represented here differ from published council data, as the Kapiti Coast District Council (KCDC) does not meter its residents and hence it is difficult to get a picture of accurate residential use. Residential usage is basically calculated by taking the total water use and dividing it by the total population and leaks within the water supply system are also not always accounted for.

4. YEARLY USAGE

On average a household would use 177,000 L of mains water per year. This equates to about 67,000 L per person per year. When looking at the projected yearly consumptions from similar size households in Table 1, it can be seen that there are a wide range of volumes used. The average use for a four person household (two adults and two children) was 210,000 L, with a maximum of 304,000 L and a minimum of 137,000 L. A reason for the difference in this particular case was that the home with the minimum volume used about a 10th of the water for the washing machine than the house with the maximum volume. Only full loads were being washed in a water-efficient front loader, as opposed to smaller loads in a top-loading machine. 96% of washing machines in New Zealand are top-loaders (Pollard 2007).

Table 1: Yearly usage for similar size household

	Volume year (000s litres)	
	4 people	**2 people**
Max	309.3	207.8
Average	210	145
Min	136.5	83.4
St dev.	72	53.8

5. END-USES

Table 2 shows a summary of end-uses and the average volumes used per person during summer and winter. The indoor use for summer is nearly identical with the winter indoor use, suggesting that indoor use keeps constant throughout the year, with a few exceptions. In winter, bathtub usage is double to summer usage. This is not significant, since bathtub usage is only a small proportion of indoor use. The main difference as expected between summer and winter is the outside usage. During summer outdoor usage accounted for 22% of the total usage, which is three times the amount used during the winter period.

Table 2: Summer/winter end-uses comparison (average over all houses)

	Total use (%)		**Indoor use (%)**		**Average (L/p/d)**	
	Summer	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**
Tap	11.9	13.5	15.6	15.5	24.3	22.7
Shower	22.2	26.7	29.8	30.5	45.3	44.9
Washing machine	20.5	23.7	27.4	27.1	41.8	39.9
Toilet	17.4	18.6	22.9	21.3	35.5	31.3
Dishwasher	1.3	1.2	1.8	1.4	2.7	2.1
Bathtub	1.5	3.3	2.0	3.8	3.1	5.5
Miscellaneous	0	0.4	0.0	0.5	0	0.8
TOTAL INDOOR	**74.22**	**87.5**	**100**	**100**	**151.3**	**147.1**
Outdoor	21.7	8.3			44.2	13.9
Leaks	3.3	4.2			6.7	7
TOTAL USE	**100**	**100**			**203.9**	**168.1**

6. END-USES SUPPLEMENTED BY RAINWATER

Not all end-uses require mains water. The toilet, washing machine and outdoor uses can be supplemented by rainwater without major concerns, especially in New Zealand with a higher-than-average amount of rainfall (1200 mm average for Kapiti). Those three uses alone account for 60% (122 L/p/d) of the total uses in summer and 51% (86 L/p/d) in winter. To use rainwater for the supply of hot water is also an option, but not covered within this paper.

6.1 Washing machine

The washing machine represented 27% (41 L/p/d) of the indoor uses in both winter and summer. Over the whole two monitoring periods a total of 1,464 loads of washing were recorded from all households, which equates to 0.3 loads per person per day. The average annual volume of water used per person was 14,500 L when a top-loader was used and 6,000 L with a front-loading machine. At present this water gets discharged into the wastewater system in the majority of houses. The use of rainwater for this appliance could eliminate the mains water required for this purpose and also reduce the irrigation water requirement even further if the greywater was to be discharged in the garden.

The savings here are average savings, and the range of volumes used for this purpose in the households differs not only by household size, but also by appliance type and behaviour.

6.1.1 Effect of household size on washing machine use

There were substantial differences in the number of loads washed and the amount of water used by households with similar demographics. (The example below is based on four person households, two adults and two children).

- **Extreme case** – one house washing 2.2 loads per house per day on average, using 297 L per house per day (74 L/p/d) using a top-loading machine. When talking to the occupant it was found that only half-loads were being washed. The increased number of half-loads meant the washing machine was not used in its most efficient way.
- **Medium case** – 0.9 loads per day using a top loader (33 L/p/d).
- **Low case** – 0.5 loads per day using a front-loading machine at 60 L per load (8 L/p/d). An interview with the occupants confirmed the speculation that only full loads are washed in the house (most efficient use of washing machine).

During the same time period, the family using the front-loading machine used about a 10^{th} of the water than the extreme case (3,300 L and 30,900 L respectively).

6.2 Toilets

When comparing the number of toilet flushes per person on a household level there is only 4% variation between summer and winter. The daily per capita uses were found to be 35.5 L and 31 L for summer and winter respectively. As an approximation the toilet is flushed about five times per person per day throughout the year, using an average volume of 11,300 L per person annually (6.2 L/flush). The toilet systems were also responsible for a majority of the leaks. In the first month of monitoring, the leaks in one home represented 56% of the total uses. This was due to an old seal in the toilet cistern, which was then replaced. Rainwater could eliminate about 22% of mains water used for indoor uses, not including any leaks. Before installing a rainwater system for toilet flushing, water-efficient models or flush mechanisms need to be installed.

6.2.1 Toilet retrofit

The majority of houses in the study group already had dual-flush toilets installed. The average flush volume over the whole study group was 7.9 L per full flush and 4.1 L per half-flush. Two homes had 12 L single-flush toilets. By substituting the 12 L toilet for a 4.5/3 L model (four star rating), approximately two-thirds of the water used by the toilet could be saved. Potentially 86 L/day could be saved, which translates to an annual saving of 31,300 L of water. A three star 6/3 L toilet could achieve a saving of 28,500 L annually in this particular case.

6.3 Irrigation and outdoor use

Outdoor use and irrigation were the major factors for differences in water use between the different seasons. During the winter outdoor use accounted for 8% of the total uses and during the summer it was 22% (14 and 44 L/p/d respectively). The majority of outdoor uses were found in a small number of homes throughout both periods. These tended to be the same houses. The majority of outdoor uses were for irrigation purposes. Some houses used no water for irrigation. The largest irrigation event recorded had a duration of 11 hours, using nearly 12,000 L of mains water. In the summer period there were a relatively high proportion of irrigation events using more than 2,000 L per event. A rainwater or greywater system would be the most water-wise investment for high irrigation users to cut down on their water use. To cope for large-scale garden irrigation large storage capacity for rainwater or greywater is required. This is not always feasible, as larger irrigation events tend to occur during dry periods where tank levels are generally lower.

For the highest irrigation user during the summer period, 57% of their total uses were due to irrigation averaging 642 L per day. During the winter period the highest irrigation proportion of any one house was 34% of the total uses (146 L per day).

6.4 Rainwater and stormwater conclusion

The average annual rainfall on the Kapiti Coast is 1200 mm (low: 825 mm; high: 1,500 mm). The 12 case study homes have a combined roof area of 2,085 m^2 (average: 173 m^2; low: 100 m^2; high: 320 m^2) and could potentially harvest 1,462,000 L of rainwater annually (4,000 L daily) in a lower-than-average rainfall year and 2,658,000 L (7,200 L daily) in a higher-than-average rainfall (1,500 mm) year.

During the winter period captured rainfall would cover the demand for irrigation, toilet flushing and the washing machine in all the homes requiring no mains top-up supply during a year with above-average rainfall. Two homes would require mains back-up in a year with low rainfall. During the summer mains top-up would be required in 40% of the homes during a low rainfall year and in 10% of the homes in a high rainfall year. High irrigation users would require mains top-up during dry periods.

Using rainwater in the home would not only reduce mains water demand in the study homes, but would also reduce the stormwater discharge and peak discharge from the site, hence reducing the environmental footprint. This is especially important in areas where the infrastructure is reaching a maximum capacity.

7. SOURCES OF GREYWATER

About 50% of water used in summer and 60% of water used in winter ends up as greywater, which gets discharged to the sewer as wastewater if no greywater system is present. Greywater is defined as the wastewater from the shower, bath, washing machine and taps (not incl. kitchen). Irrigation demand could be fully covered by greywater in the majority of homes in the study group, except for days with high irrigation demand. By using rainwater as well, irrigation demand would be reduced to a minimum.

One of the study homes had a greywater system installed. On average 125 L of greywater was produced by the house per day during the monitoring period. This equates to about 46,000 L of greywater annually. The greywater system reduces the cost and associated energy use for wastewater disposal and the irrigation demand. There are no financial benefits for the owner at present, since the water supply is not metered. This home also had a very low per capita consumption of 110 L per day (in winter), considering they had the most vegetated and greenest garden of the whole study group. In addition to their greywater system, a 2,700 L rain tank was in place to harvest rainwater for irrigation from a total roof area of 140 m^2.

On average 106,000 L of greywater is produced annually from each of the homes. The annual volumes range from 38,000 L to 220,000 L (104 L per day and 603 L per day respectively). The home producing the highest amount of greywater had the highest washing machine use and the highest shower flow rate of 18 L per minute (Lpm). At the same time the irrigation requirement over the summer for this home was 201 L per day. This irrigation demand could easily be supplemented by greywater alone.

7.1 Shower

The shower accounted for around 30% of indoor use in both summer and winter. When looking at shower consumption on a household level there is very little variation between shower time, flow rate and number of showers taken across the two seasons. For all monitored showers, the average shower time was 7.8 minutes throughout the year with an average of 0.7 showers per person per day, at an average flow rate of 11 Lpm (one star). The highest observed flow rate was 18 Lpm in one of the newer homes. Generally, newly constructed homes had showers capable of higher flow rates, but the sample size is too small to verify these assumptions.

Homes with small children have a lower shower usage than homes without, but the bath usage tends to be higher.

7.1.1 Shower retrofit

In the study group there is a large potential for reducing mains water demand by installing a low flow shower head. A maximum efficient shower head (three star) in houses 3 and 5 would yield an annual water saving of 50,000 L and 42,000 L respectively. This equates to 47% and 54% savings in water used for showers alone. The estimated annual consumption of house 3 is 219,000 L. By installing a three star shower head, the consumption would be reduced to 169,000 L (23% savings). For house 5 the estimated annual consumption would be reduced by 13%.

7.2 Indoor taps

Over the monitoring period, 59,181 individual indoor tap usages (30,781 in summer and 28,400 in winter) were recorded. On average a person from the study group used a tap 11.6 times per day during the summer and 11.9 times during winter, using an average volume of 1.6 L per event. Tap usage represents around 16% of total usage over both summer and winter.

The end-use monitoring methodology adopted did not allow the differentiation between the different taps i.e. kitchen, bathroom. The greywater proportion of total tap use (excluding kitchen taps) is assumed to be 50%. Hence the greywater proportion from taps would be around 8% of indoor uses (kitchen tap not used as greywater).

7.2.1 Tap retrofit

There is no major variation between the data measured in the two separate periods. Only 1.4 L of water was used additionally by each person per day during the summer. The average duration, volume and flow rates of the separate events stayed the same. The average flow rate of 3.8 Lpm is below a six star WELS rating, which specifies flows of less than 4.5 Lpm. By retrofitting water-efficient tapware to the case study homes on average no significant water reduction would be achieved.

8. EMISSION AND POLLUTANTS

For some regions the water and wastewater sector produces a substantial part of the local areas greenhouse gas emissions. For example, the Kapiti Coast District Councils water and sewage treatment produced 57% (CO_2 equivalent) of their total greenhouse gas emissions in 2001, which corresponds to 2,318 tonnes of CO_2 equivalent (1,030 tonnes, 40% in 2006) (Parsons 2001).

In 2001, 4.8 million m^3 of water was supplied in the district in total which equates to greenhouse gas emissions of 0.23 kg of CO_2/m^3 for mains water supply (collection, distribution and treatment) alone. In the same year 1.83 million m^3 of sewage was treated, which equates to 0.64 kg of CO_2/m^3 of sewage (collection, disposal and treatment).

By reducing mains water demand (rainwater harvesting and greywater) and reducing the amount of wastewater (greywater discharge), substantial cost reductions and CO_2 reductions can be achieved.

9. CONCLUSION

By obtaining accurate end-use information, areas in which water can be used more efficiently are able to be identified. Eliminating leaks and taking basic demand management steps (e.g. low flow shower heads, low-flush toilets and water-efficient washing machines) should be the first action. Dual-plumbed rainwater and greywater systems can be the next step in reducing mains water demand.

To reduce demand, the most impact could be made by installing low flow shower heads, front-loading washing machines and dual-flush toilets. In addition, the reduction in the amount of hot water used reduces the energy required to heat it and hence the direct costs involved. Water and wastewater treatments are energy-intensive processes and a reduction in water demand translates into energy savings. A reduction in energy use reduces the amount of greenhouse gases, especially CO_2, which contribute to global warming.

The key findings from the study which have the greatest impact on water consumption and conservation include the following:

1. reducing leakage
2. retrofitting opportunities (including WELS)
3. on-site rainwater
4. on-site greywater.

The homes in the study group leaked an average of 7 L/p/d. In the first weeks of monitoring one house was found to leak at a rate of nearly 200 L per day, which made up 56% of its total uses.

On average a house from the study group would use 39,000 L of water annually (14,500 L per person) for laundry use alone. This potable water could easily have been supplemented by collected rainwater and then be reused as greywater. Average annual water savings of 23,000 L per house could be achieved by replacing a top-loader with a front-loading machine.

By installing a WELS three star low flow shower head and a front-loading washing machine, 33% of the total water used in house 5 (Table 3) could be saved. Even a basic modern low flow shower head, which requires modest investment, can reduce total consumption by 19% in this particular case.

Table 3: Potential retrofit savings (house 5)

Present annual consumption (000s litres)			Potential annual savings after retrofit (000s litres)				
			Shower head				
Total	Shower	Washing machine	*	**	***	Front-loader	Front-loader & ***SH
309.2	70.6	109.2	16.9	32.1	41.9	60.1	102
Consumption after retrofit			**292.3**	**277.1**	**267.3**	**249.1**	**207.2**
% saving of total			**6%**	**10%**	**14%**	**19%**	**33%**

9.1 Direct and indirect costs

Additional CO_2 is released into the atmosphere by an increasing water demand. Demand is not likely to decrease, as the population grows continuously. However, the rate at which the demand for water increases can be slowed down if water is used more wisely and efficiently. By increasing demand, it gets to a point when the infrastructure to supply and treat the water and stormwater has reached a saturation point. Additional infrastructure (treatment plants, pipes, reservoirs, dams etc) and water sources are required. In most cases this is a very costly undertaking. By reducing demand the future investment costs can be reduced and delayed.

9.2 Recommendations

From questionnaire data and discussions with the occupants it became apparent that the incentive to save water is not very high, since there are no direct costs involved for the occupant in most residential homes. If metering were to be introduced by the councils, this perception might change and water might be used more efficiently. Most people have no idea about how much water they are using and they generally tend to underestimate their use. Only when there is a price and the individual knows their consumption are there incentives to save water and use it more efficiently.

It should be noted that this is a small study and it cannot be assumed that these results are correct for either all of Kapiti or the whole of New Zealand. A larger-scale study is required to obtain higher accuracy. However, the evidence presented here suggests real opportunities in reducing water demand in the residential sector.

10. REFERENCES

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