INSTITUTE FOR SUSTAINABLE FUTURES

THINK.
CHANGE.
DO

ISF: RESEARCH

THINK WATER, ACT WATER:

EVALUATION OF THE ACT GOVERNMENT'S WATER

Institute for Sustainable Futures

UNIVERSITY OF TECHNOLOGY SYDNEY

THINK WATER, ACT WATER

Evaluation of the ACT Government's Water Demand Management Program

Final Report

For Territory and Municipal Services

Authors

Lisa Lee, Roel Plant and Stuart White

Institute for Sustainable Futures

Disclaimer

Please cite this report as:

Lee, L., Plant, R., and White S., 2008, Think Water, Act Water: evaluation of ACT Government's water demand management program. [prepared for Territory and Municipal Services (TAMS)], Institute for Sustainable Futures, UTS, Sydney.

Acknowledgements

The authors would like to thank Tony Maher and Mike Lake from the Computational Research Centre of Expertise for programming support, and Mick O'Neill from the Statistical Advisory & Training Service for his statistical advice. We would also like to acknowledge Arifur Rahman from the ACT Territory and Municipal Services for providing data and information.

Executive Summary

In April 2004, the ACT Government released *Think Water, Act Water*, a strategy for sustainable water resource management in the ACT. The strategy outlined key targets and objectives to ensure sustainable management of ACT water resources, including water efficiency targets:

> *"achieve a 12 per cent reduction in per person use of mains water by 2013, and a 25 per cent reduction by 2023"*

As part of the *Think Water, Act Water* program, the ACT Government's Territory and Municipal Services (TAMS) has implemented a suite of water efficiency measures (hereafter called 'programs'):

- **WaterSmart Homes** – a residential indoor water tune-up program that involves subsidising the cost of a plumber's visit to install a water efficient shower head, up to two tap valves or flow regulators, fix leaks and install cistern flush arrestors;

- **GardenSmart** – a free residential outdoor water efficiency program for all ACT residents. A specialist visits the household, assesses watering needs, and provides advice on how to be water-efficient through plant choice and/or garden design. Participating households also qualify for a rebate on selected water saving products;

- **Rainwater Tank Rebate** – subsidises the cost of purchasing and installing rainwater tanks with an internal connection. The rainwater tank rebate has been continuing since 1997 and, until August 2005, did not require connections to internal end-uses, such as toilets, to be made;

- **Dual Flush** – this is a joint program with the *WaterSmart Homes*, meaning all households that participated in the Dual Flush toilet program (i.e., received a rebated toilet retrofit) were also participants in the *WaterSmart Homes* program*.* Participants in *WaterSmart Homes* can choose between 1) receiving a further rebate for replacing single-flush toilets with 6/3 litre dual flush toilets; or 2) a free cistern weight for single flush toilets.

TAMS has commissioned the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney, to conduct an independent statistical evaluation of the water savings achieved through these four water efficiency programs. This report summarises the results of this research project.

ISF's methodology to estimate water savings consisted of first isolating the effect of the *Think Water, Act Water* programs from other factors that may affect water use behaviour, and subsequently comparing water consumption patterns of program participants with those of non-participants through a process of "pair-matching". Water consumption between the paired households is compared on a monthly basis before and after the 'intervention', with the divergence in consumption during the 'after-intervention period' representing the water savings from the water efficiency program.

Key results:

- The *Think Water, Act Water* program that achieved the greatest water savings was the *Dual Flush*[1] program, which reduced residential household water use by 29.2±16.7 kL per household per year (kL/hh/yr) on average over 24 months.
- *WaterSmart Homes*[2] produced the second largest savings of 20.4±5.9 kL/hh/yr over 24 months. An evaluation of Sydney Water's retrofit program (the WaterFix Program), which has similar elements, indicated savings of 20.9±2.5 kL/hh/yr (Turner *et al.*, 2005:4). This compares favourably with the results for ACT's indoor tune-up program and indicates that the savings assumptions used were well founded.

Due to small sample size, it was not possible to discern statistically significant water savings for the other programs. However, *Rainwater Tank (Outdoor)* participants did show statistically significant savings in the second year of participation (12.1±9.8 kL per household in 2005).

The outdoor program, *GardenSmart*, did not show statistically significant savings for either 2005 or 2006, or for the 24-month period. There is some indication that this program did not save water, or even increased water use amongst participants. While this result, that is, an *increase* in water demand, has been seen in one example in the past, in Kalgoorlie-Boulder, this was with a very differently designed program (Sarac and White, 2003). The Sydney Water outdoor water efficiency program has greater similarity to the design of the ACT's *GardenSmart* program and was rolled out based on the results of an evaluation of a pilot program, in which water savings were measured (Andre Boerema, pers. comm. 2 April 2008).

It is highly likely that the restrictions in place at the time of the program have confounded the results for the GardenSmart programs. Some garden watering by participants following the program implementation is likely to have occurred, relative to the control group. This does not mean that efficiency levels would not be higher relative to the control households once restrictions are lifted. It is recommended that a long term time series analysis be undertaken after restrictions have been lifted for over 12 months.

[1] Note that the *Dual Flush* program is a conjoined program with *WaterSmart Homes*. Participants in *WaterSmart Homes* have the option of participating in *Dual Flush* (i.e., receiving a rebated dual flush toilet retrofit) as an extra service. The savings figure for *Dual Flush* is therefore a combined saving from the *WaterSmart Homes* and *Dual Flush* programs.

[2] *WaterSmart Home* participants who did not participate in *Dual Flush.*

Table of Contents

List of Tables

List of Figures

Abbreviations / Glossary

ACT	Australian Capital Territory
ActewAGL	Joint venture between Australian Gas Light and ACTEW Corporation, an ACT government owned enterprise
Control	Non-participant household (baseline consumption)
GENTRACK	ActewAGL’s customer/billing database
Intervention	Household uptake of water efficiency programs
ISF	Institute for Sustainable Futures
Net savings	Water savings achieved through water efficiency programs net of the difference in consumption before intervention
Pair	Matched control-participant households to compare water savings
Participant	Participant household in water efficiency programs
Population	Every participant household in the database
Sample	Group of participant households selected from the database
SQL Server	Database management program
TAMS	Territory and Municipal Services
Valid Pair	Matched pair which passed statistical filtering

1 Introduction

The Department of Territory and Municipal Services (TAMS) is the branch of the ACT Government responsible for delivering a range of municipal services for people of the ACT. As part of the Sustainability Policy and Programs within TAMS is the delivery of the *Think Water, Act Water* program, which forms part of the ACT Government's water resource management objectives. The implementation of the program was carried out by ActewAGL on behalf of the ACT Government.

Think Water, Act Water began in April 2004, providing long-term guidance for the management of ACT water resources. There are six key objectives, one of which is to "increase the efficiency of water usage", with reduction targets of 12 percent for mains water consumption by 2013 and 25 percent by 2023, relative to 2003 levels of consumption (ACT Government 2006, p.31). This is to be achieved through a combination of water efficiency and recycling measures, including residential water efficiency programs. Residential detached homes represent 54% of total water use in the ACT, equivalent to 32.3 GL/yr (ACT Government 2006).

The Institute for Sustainable Futures (ISF) was commissioned by the ACT Government and ACTEW Corporation in 2003 to provide a least cost planning assessment, and in 2005 to assist with the development of an end-use model, to help achieve water savings targets. The research summarised in this report provides an empirical evaluation of the actual savings – based on actual consumption data - achieved through the ACT's various residential water efficiency programs.

The objective of the research reported here was to perform a statistical evaluation of the water savings achieved through various programs under the umbrella of *Think Water, Act Water*, based on actual water consumption data from ActewAGL's customer database (GENTRACK). The estimated savings reported here, combined with the costs associated with the programs, provide an indication of the effectiveness of the water efficiency measures in achieving water use reductions in the residential sector. The findings in this report may also be used to inform the development of future water conservation projects.

This report is organised as follows. A summary of *Think Water, Act Water* and brief information on associated sub-programs is provided in Section 2. This is followed by a detailed description of ISF's methodology in Section 3. This section details the pair-matching approach used to find the participant/control pairs, and further quality testing. The results of the analysis are provided in Section 4. In Section 5, conclusions and recommendations drawn from the program assessment are presented.

2 ACT Government's *Think Water, Act Water* Program

The following suite of water efficiency measures were implemented as part of the *Think Water, Act Water* program which began in April 2004:

- **WaterSmart Homes** – this is a residential indoor water tune-up program for ActewAGL customers, which involves subsidising the cost of a plumber's visit. Households pay $30 to have a 3-star showerhead installed, up to two tap valves or flow regulators, and up to two tap washers installed. Registration for this program ceased in July 2007 because other private companies accredited in the ACT under the ACT/NSW Greenhouse Gas Abatement Scheme can provide the same services – installing water-efficient showerheads and energy-efficient light bulbs – free of charge. However between 2004 and July 2007 indoor retrofits were funded by the ACT Government.

- **GardenSmart** – this is a free residential outdoor water efficiency program for all ACT residents. A qualified horticulturist visits the household's garden to assess watering needs, then demonstrates practical ways for using less water in the garden, for example through clever plant choice and garden design and practical maintenance and watering advice. Taking part in GardenSmart also makes households eligible for a rebate of up to $50 when selected water-saving products are bought (e.g., garden mulch, drip irrigation systems or components, weeping hoses, tap timers, soil additives for moisture retention, etc.).

- **Rainwater Tank Rebate** – subsidises the cost of purchasing and installing rainwater tanks which have an internal connection for ActewAGL customers. The rain tank rebate has been continuing since 1997 and, until August 2005, did not require internal connections to be made. It was only in August 2005 that the rules of eligibility changed so only households with rain tanks connected indoors could receive rebates (Rahman 2008, pers comm.). The subsidised amount subsequently increased to cover the additional plumbing costs, which depend on the size of the tank. Currently the minimum rebate is $550 for a 2000L tank with internal connections.

- **Dual Flush** – this is a joint program with the WaterSmart Homes. Participants in WaterSmart Homes are given the choice to receive a further rebate of $100 for replacing single-flush toilets with a 6/3 litre dual flush toilet. Alternatively, the plumber may simply install for free a cistern weight into single flush toilets to reduce toilet water use as part of Water Wise Homes (ACT Government 2007).

The roles of the *Rainwater Tank Rebate*, *GardenSmart*, *WaterSmart Homes* and *Dual Flush* programs in moving towards the ACT's water efficiency targets is assessed in this report. The focus is on the residential sector.

3 METHODOLOGY

In this section, a summary of the methodological approach used to evaluate the water savings from *Think Water, Act Water* is presented. Details of the data manipulation process involved as well as the approach undertaken for the evaluation of savings are also presented.

In brief, ISF's methodology to estimate water savings consists of first isolating the effect of the *Think Water, Act Water* programs from other factors such as regulations affecting the water use behaviour, and subsequently comparing water consumption patterns of program participants with those of non-participants through a process of "pair-matching". Water consumption between the paired households is compared on a monthly basis before and after the 'intervention' period, with the divergence in consumption during the 'after-intervention period' representing the water savings resulting from the water efficiency program.

A key assumption of the pair matching approach is that the behaviour of the controls constitutes the baseline against which savings are measured. Another way to put this is that during the evaluation period over which the savings are calculated, the controls are assumed, on average, to take the same actions that the participants would have taken in the absence of the intervention.

In general, the methodology consists of the following steps:

- Data preparation;
- Identifying participant households and control households;
- Pair-matching;
- Quality testing of pair matches;
- Savings calculation and null hypothesis testing with a paired t-test.

3.1 Data Preparation

The analysis was based on customer water meter data from ActewAGL's customer/billing data base (GENTRACK) as provided by TAMS; hence the scope of the evaluation was limited to ACT residents serviced by ActewAGL.

Of these households, only single dwellings (i.e., free-standing houses without common walls) that have individual water meters were included for analysis. This is because multi-dwellings (such as apartments) do not usually have separate water meters.

TAMS provided the data in the form of MS-Access database tables containing the following fields:

- Unique customer reference numbers – 'UniqueID';
- Intervention dates for each participant's uptake of water efficiency programs;
- Meter reading dates for the analysis period;
- Consumption for the meter read period;

Data cleaning was required to ensure the robustness of the analysis. The cleaning criteria included:

- No duplicate readings;
- No negative readings;
- No null (as opposed to zero) readings or any other spurious values such as extremely high readings or incorrectly entered dates;
- Only include properties with full readings available for the analysis period (as a time series);
- Include readings for only the relevant analysis period (earliest reading - latest reading);
- Include only data that is relevant in the fields specified;
- Exact intervention dates for each participant household;
- Include only relevant dwelling types (single-residential);
- Unique identifier for each dwelling.

The record for any properties with a null or negative reading was deleted - without a continuous set of ‘normal’ readings these properties cannot be used for pair matching. Only records with a complete, continuous reading for the period of analysis were kept.

This means the analysis was confined to households whose consumption behaviour remained relatively unchanged.

Any households with incomplete meter readings (gaps in the analysis period) were excluded because it was necessary to have continuous water consumption data in the matching period. Doing this would have excluded properties that were newly constructed in 2005, which needed to be eliminated from analysis because new regulation required water efficient fittings to be installed in new dwellings (compliant with 5-star rating homes). Properties which had a change of occupants were also eliminated, so only the same households were compared to reduce bias.

TAMS provided ISF with two separate sets of tables for the 'Participant' and 'Non-participant' groups.

In the original tables provided by TAMS, there were 6,563 residential ‘participant’ households and 88,886 ‘non-participant’ households. After cleaning, there were 6,440 residential participants and 82,126 non-participating households remaining.

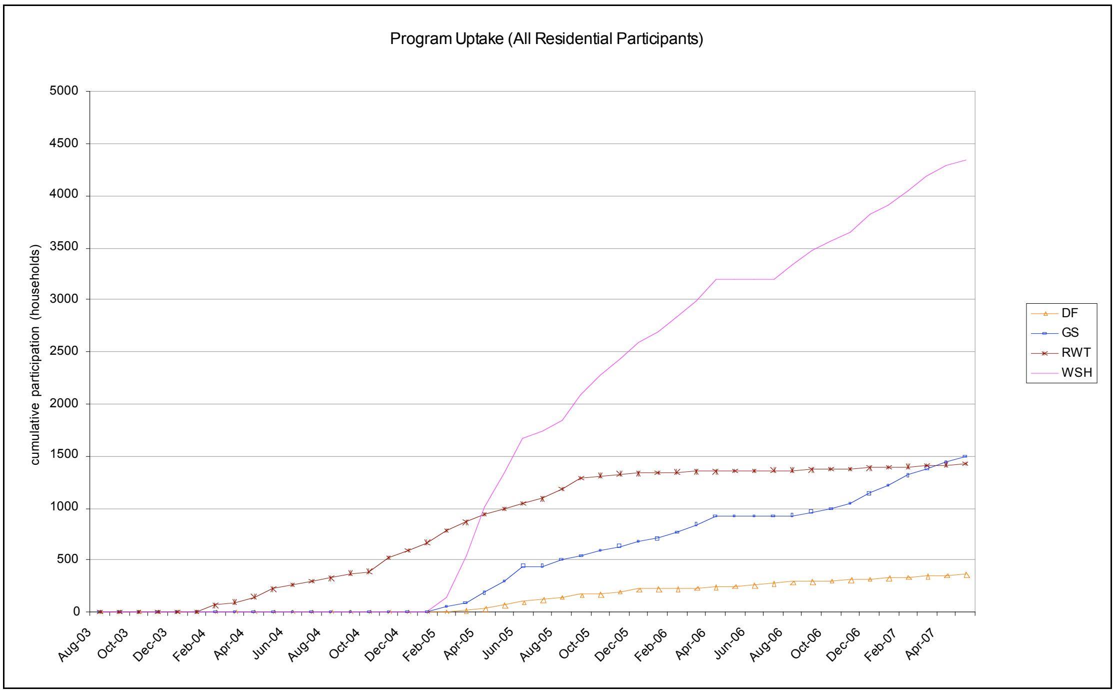
Only residential households were included in the analysis. The program participation of residential households is as follows:

Table 1 Total number of residential participants in *Think Water, Act Water* sub-programs.

Program	Number of Participant Households
WaterSmart Homes with Dual Flush	365
GardenSmart	1,489
Rainwater Tank	1,426
WaterSmart Homes	4,327

There are 1,070 households that participated in more than one program. The uptake rate is shown in the figure below:

Figure 1 Customer Uptake rate of the *Think Water, Act Water* programs.



The number of households which participated in only one program is as follows:

Table 2 Number of once-only participants in each program.

Program	Number of Participant Households (one program only)
Dual Flush + WaterSmart Homes[3]	245
GardenSmart	751
Rainwater Tank	1,286
WaterSmart Homes	3,291

[3] *Dual Flush* participants must have participated in *WaterSmart Homes* in order to receive rebate.

Note the *Rainwater Tank* participants consist of households with internal connections or outdoor connections only. These groups have been separated and are shown in Figure 1. Note also that *Dual Flush* is a sub-program of *WaterSmart Homes*, such that participants who took up *Dual Flush* must also participate in *WaterSmart Homes*.

There was no strategic targeting of households by ActewAGL for participation in the water efficiency programs, so the participants are considered to be representative of the ACT population as they were selected randomly.

3.2 Selecting a Matching Period

To incorporate seasonal variations in consumption, a minimum 12-month period *prior* to the commencement of the programs is required for the pair matching process.

The earlier rainwater tank subsidy program ran from 1997 to 2004. The rainwater tank subsidy was then updated as part of the suite of water efficiency programs under *Think Water, Act Water*. The earliest date of participation in rainwater rebate in the database provided to ISF was October 2000. However this was a single household, with the next uptake being August 2003 followed by a steady rate of rainwater rebate uptake from January 2004. The *GardenSmart*, *WaterSmart Homes*, and *Dual Flush* rebates had begun in 2004-05, with the earliest participation date in the database being January 2005.

Two approaches to the match period were taken. The first approach is as follows. The cut-off date between before and after periods was taken to be the earliest participation date for any program. This was set to August 2003, being the earliest rainwater tank rebate uptake. This leaves periods prior to August 2003 for matching participants in *all* programs, having deleted the sole participant in 2000 from the participant group. Taking all participants in all programs in aggregate, the match period was set to Aug-2002 to Jul-2003. It did not matter if the participant took up more than one rebate. The objective was to obtain the cumulative impact of the *Think Water, Act Water* program on residential water consumption.

The second approach was to match program participants separately and analysing the program's savings individually. This involved matching periods for participants based on the earliest uptake date for the program. For the rainwater tank rebate, match period was initially set to August 2002 to July 2003, prior to any program participation. However, results indicated that a better savings estimate may be found by setting the match period to January 2003 to December 2003, since the bulk of participants are in 2004 onwards (only one uptake was in the 2003 year). The earliest start date for other programs was January 2005, so the match dates were set to January 2003 to December 2004. Program start dates are shown in Figures 2a and 2b below.

The entire timeframe, however, is affected by various stages of water restrictions. While it would have been ideal to match pairs under circumstances of no restrictions, which would enable the natural consumption behaviour to be paired, it is assumed that similar households' response to restrictions would remain the same and should not affect the matching significantly. Other variations in water use changes would be captured by random error.

The data available for analysis is from April 2001 to May 2007, with program participation dates from August 2003 onwards (although in this project participation after January 2004 is of interest). While the programs have run for at least two years, as can be seen from the above figures participation was steadily increasing for the entire period (with the exception of rainwater tanks with outdoor connections only –

as the rules for rebate has changed to be available for only internally linked rainwater tanks). Some programs have fairly low participation, which may cause the estimated savings produced in this analysis to be less significant than hoped. However, if the analysis was repeated when more participants take up the program then some significant changes could be observed.

Figures 2a and 2b (below) show the average consumption for all ‘participants’ and ‘non participants’, program start dates, water restriction levels, and rainfall from November 1999 to May 2007.

Figure 2a : Water consumption of participant and control groups.

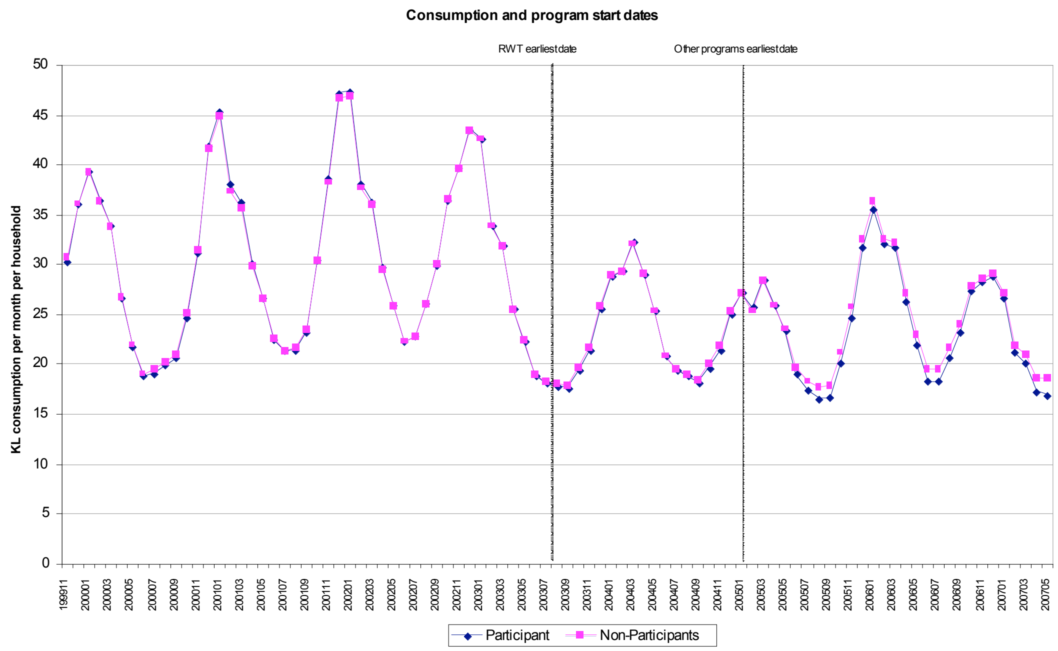
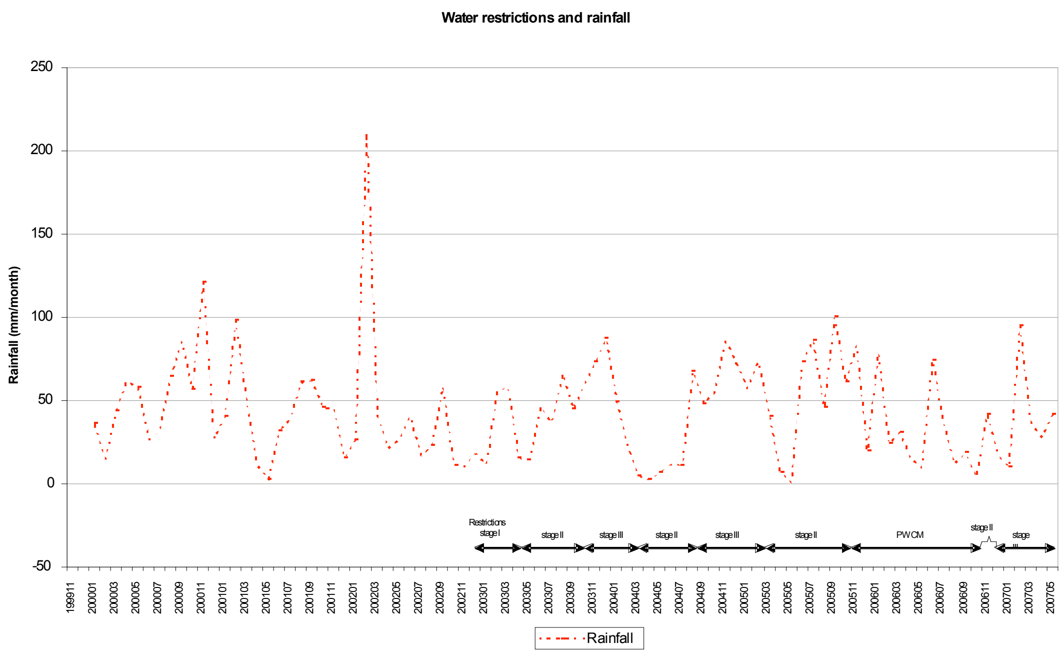


Figure 2b: Water restrictions and rainfall.



Through visual inspection of the consumption curves there appears to be some reduction in water consumption in the participant group post water efficiency programs. There is an overall trend, however, of reduced consumption in both groups, most likely in response to water restrictions.

3.3 Data standardisation of consumption records

The consumption across the period of the meter readings, which were taken quarterly, was converted into a monthly consumption basis. This ‘monthly binning’ allows for an improved sense of the seasonality in household water use. This process was done entirely in SQL Server, although the queries were managed through Python scripting. The water consumption recorded for the meter read periods were converted into estimated consumption for each calendar month. A weighted consumption for each month was calculated by taking the average daily consumption for each meter read period, then standardising into monthly consumption.

3.4 Pair Matching

This section describes the core of the methodology, consisting of matching each single-residence household (‘participant’) with a single-residence household (‘control’). Household demand is driven by many factors such as:

- External factors: restrictions and climate;
- Internal factors: household occupancy, household type, technology, behaviour, type of end use (e.g. garden or not – type, size, maintenance, pool or not, etc.)

Two single-residence households with similar internal factors would be influenced in the same manner by external factors. If a change to one variable is applied at a point in time to only one household, then this household will show a different profile reflecting the impact of this parameter. This approach identifies for each participant a control household based on their demand over a fixed period of time. When a household takes part in a water efficiency program, we expect only the participant to be affected by this change; we expect a clear water demand reduction.

This change or demand reduction is measured by calculating the difference between the demands of the participant and the control over a fixed period of time. This assumes the demand levels of the participant and control were affected identically by all other external parameters before and after the water efficiency measure. The following sections describe the identification of a matching period, in which each participant’s demand profile was compared to all available control households to find the best match, and the use of the least square equation in that process.

3.5 Matching Pair Equation

Once the matching period was decided, we then processed the data for the participants in each program and for all available controls using a Visual Basic for Applications (VBA) script to identify the best suitable control household for each participant.

Matching is done based on an exhaustive comparison between one participant and all controls (i.e., no sampling is used) using a linear search algorithm, with the optimal control having the smallest square-root difference to the participant. It is important that a unique control is used for each participant, to achieve the most accurate evaluation. This preserves the independence of the matched pairs for later statistical analysis. Therefore, once matched, the selected control is removed from the database to ensure that it will not be used for a second participant. This means that participants are not matched with the best possible control but with the best possible control from those that are still available.

The VBA script calculates a parameter for each participant and control selected as the best possible match. This parameter is the squared sum of differences between the demands in each month for the participant and control, and reflects the quality of the match. The matching is done through the Least Squares Method, given by the square-root difference between monthly consumption between the control and participant. The equation is as follows:

$$\sqrt{\left(C_{Jan04} - P_{Jan04}\right)^2 + \left(C_{Feb04} - P_{Feb04}\right)^2 + \ldots + \left(C_{Dec04} - P_{Dec04}\right)^2}$$

Where P = Monthly demand of participant, C = Monthly demand of associated control

We needed to ensure that the water consumption for each property selected to form a “match” was at a level appropriate for the analysis. As we were confident that matching on demand over a 12-month period was appropriate for the majority of matched households, we only wanted to investigate further those pairs of properties for whom the match was not as good. For example, we suspected that for high water users it was likely to be harder to make a good match with a control household. As high water users are a reality in any population, we did not want to discriminate against them and we therefore developed a filtering process that treated all customers equally.

3.6 Filtering of matched Pairs

This section outlines the rules for filtering matches, based on:

- Meter read errors;
- Quadrant analysis;
- Correlation;
- Variance ratio.

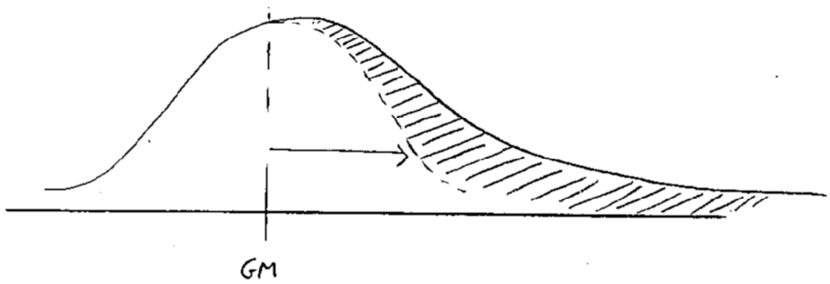
As explained in the previous section, the matching process was applied over a 12-month period. To ensure that we did not have erroneous high readings due to meter reads or human error all through the historical readings, we removed households showing one or more monthly demand 12 times greater than the monthly average.

The following set of rules was applied to identify the properties which would be further investigated as part of the matching process.

Rule 1 Mirror Test
The distribution of the data for all participant zones is skewed to the right. To partly correct for this, we used a geometrical mean. The side of the distribution not skewed was mirrored at the geometrical mean (GM) point. Properties with demand falling outside the profile represented by this mirror distribution were investigated further.

The shaded section of Figure 3 represents the properties that had to be investigated further.

Figure 3 Geometric mean of a probability distribution.



Rule 2: Correlation Test

The correlation is a figure between -1 and +1 that indicates the closeness of the match between the participant and control profile. A value of +1 indicates perfect correlation. A negative value indicates negative correlation, i.e. participant consumption goes up in months when control consumption goes down, or vice versa. A higher positive correlation indicates greater confidence in the match.

Using a threshold value of 0.96, pairs which had a correlation of less than 0.96 underwent further testing. This is to account for the possibility that the participant and control had near-constant consumption over the matching period (i.e. low variance), which would give a low positive correlation even though the match was of an acceptable quality. For this reason we needed to look at the variance ratio as well.

Rule 3. Variance ratio test

A high variance ratio can also indicate a poor match, particularly when combined with low correlation. If the variance of the participant's consumption is much larger than the variance of the control's consumption, or vice versa, then the consumption ranges will be different and the match may be unacceptable. We set the variance ratio between 0.5 and 2 for cases where the correlation was smaller than 0.96.

3.7 Net savings calculation and Paired t-test

This section describes the method used to estimate average monthly savings and to assess whether the estimated monthly average is valid.

Net savings calculation

Savings calculations begin with the calculation of the difference between the consumption of each participant and the consumption of its corresponding control (Table 3). The average monthly savings calculation is based on households which have already had program 'intervention', so the savings is an average across only households which had took up the water efficiency program.

Table 3 Calculation of net monthly average per-household savings.

Pair ID	Monthly consumption (kL/hh/mo)					Month 1	Month 2
	Before Period		…	After Period (savings)			
	Jan-05	Feb-05		Jan-06	Feb-06		
1	Δ(P1,C1)	Δ(P1,C1)	…	Δ(P1,C1)	Δ(P1,C1)	ΔΔ (P1,C1)	ΔΔ (P1,C1)
2	Δ(P2,C2)	Δ(P2,C2)	…	Δ(P2,C2)	Δ(P2,C2)	ΔΔ (P2,C2)	ΔΔ (P2,C2)
…	…	…	…	…	…	…	…
n	Δ(Pn,Cn)	Δ(Pn,Cn)	…	Δ(Pn,Cn)	Δ(Pn,Cn)	ΔΔ (Pn,Cn)	ΔΔ (Pn,Cn)
						Average Net Saving	Average Net Saving

Next, a period for the mean comparison is selected. The 'before' period corresponds entirely to the matching period. Ideally, the 'after' period selected is a full 12-month period of readings after the programs commenced (earliest being August 2003). The most recent data reading is for May 2007, which suggests there are sufficient data points to obtain a savings figure. The statistical evaluation is conducted based on the average net savings figure across participants in each month.

Statistical analysis

As a result of the various exclusions from the full set of program participants - due to both data cleaning and matched-pair cleaning - varying proportions of the total participant population are used to calculate net monthly average savings across households. This implies that the pairs available for a given month represent a *statistical sample* of the participant population for that month. The participant population varies over time depending on the uptake of the program.

To determine if the net savings estimated for a given month can be used in calculating the average savings of the particular program, monthly results were evaluated with a paired, two-tailed t-test.

A t-test evaluates the *null hypothesis* (H_0) that the *expected values* (means) of two groups are equal. In our case, *each month* provides two groups of observations (Table 3):

- the *differences* in water consumption between (actual) controls and (future) participants **before** program implementation (Δ_{BEFORE}); and
- the *differences* in water consumption between (extrapolated) controls and (actual) participants (Δ_{AFTER}).

The alternative hypothesis (H_A) is that the opposite is true, i.e., that the groups are **not** equal. With a confidence of 95% the null hypothesis can be rejected if the result from the t-test (the so-called p-value) is below 0.05.

The null hypothesis (H_0) for our case can be formulated as follows:

> the *mean* difference in water consumption between (actual) controls and (future) participants before program implementation and the *mean* difference in water consumption between (extrapolated) controls and (actual) participants are equal.

If the null hypothesis can be rejected, the difference between the groups is statistically significant at the 95%-confidence level. This means that the two means (their difference being the expected *net* savings for the month) are valid and can be used in the calculation of the average *monthly* savings of the particular program.

Weighted analysis of variance

The statistical test described above was used to calculate net monthly savings across households. In order to obtain a *global annual* savings and confidence interval, a weighted analysis of variance was necessary on account of changing variance over the period of analysis. The changing variance is due to the different number of observations in each month as the participant population increases.

First, the global weighted average *monthly* savings (global monthly mean) was calculated. This was done by taking the sum of all monthly savings observations and dividing by the total number of monthly observations. The number of monthly observations for each participant varies depending on its length of participation, so the global monthly mean is weighted according to households' length of participation. Multiplying the global monthly mean by 12 gives the global weighted *annual* mean (global annual mean). The following formula was used:

$$GlobalMonthlyMean = \frac{\sum_{i=1}^{N}\left(MonthlyAve_i \cdot MonthsParticipation_i\right)}{\sum_{i=1}^{N} MonthsParticipation_i}$$

Next, the global weighted monthly standard deviation (global monthly s.d.) was calculated by taking the square root sum of monthly variances for all participants across all months of participation. The formula used is given as:

$$GlobalMonthlyS.D. = \sqrt{\frac{\sum_{i=1}^{N}\left[\left(MonthlyAve_i - GlobalMonthlyMean\right)^2 \cdot \left(MonthsParticipation_i\right)\right]}{\sum_{i=1}^{N}\left(MonthsParticipation_i\right) - 1}}$$

N is the total number of participants.

The denominator $\sum_{i=1}^{N}\left(MonthsParticipation_i\right) - 1$ is the degrees of freedom.

The global monthly s.d. is used only to calculate the global monthly standard error (global monthly s.e.), which is given as the global s.d. divided by square root number of observations, *N* (total number of participant households):

$$GlobalMonthlyS.E. = \frac{S.D.}{\sqrt{N}}$$

The global monthly s.e. is multiplied by 12 to get the global *annual* s.e.

The global monthly and annual savings, t-stat, and confidence interval can then be calculated using the global mean and global s.e.

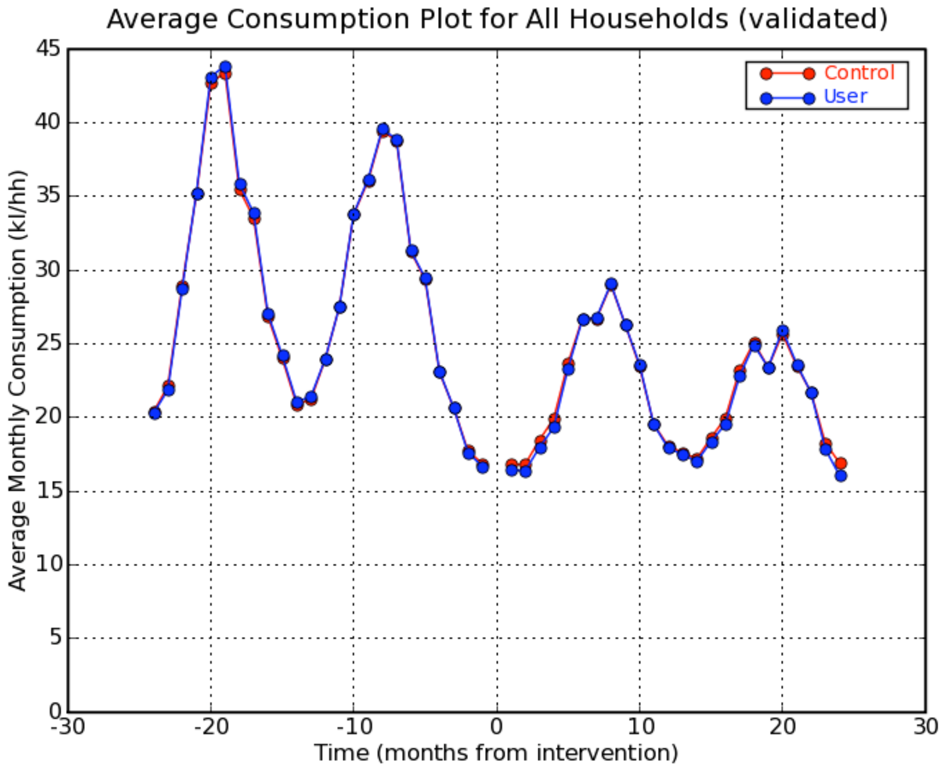
These statistics are reported in the results sections below.

4 RESULTS

In the first trial of pair-matching, it was decided that all participating households would be aggregated into one 'participant' group in order to obtain the combined impact of all water efficiency programs on water consumption. The 'intervention date' was set to the earliest of the program participation dates if the household had participated in more than one program. Matching was done for the period August 2002 to July 2003, because the earliest program uptake date was in August 2003 (rainwater tank rebate). The 'after period' was set to August 2003 onwards.

Results based on the first trial of pair-matching showed negligible savings, possibly because all programs were amalgamated into one single group in the analysis. The impacts of more effective water savings programs may have been be nullified by programs that have produced fewer savings.

Figure 4 Water savings plot of Trial 1, where all participants in all programs were matched in the one lot.



Furthermore, the programs were introduced at different times. *Rainwater Tank* rebates have been in place for the longest of the four programs. In the database, the first participation was a year prior to other *Think Water, Act Water* programs. Since many participants had not taken up the water efficiency measures in the first year of analysis, averaging savings from the rainwater tank participants over all program participants therefore biases savings downwards.

For this reason, it was decided, in consultation with TAMS, to segregate the program participants into cohorts according to program participation and rematch according to the earliest program participation date ("intervention date") for each program.

It came to light that the rules of *Rainwater Tank* rebates had changed in August 2005 so only households which made an *internal* connection to their rainwater tank (e.g. to the toilet cistern or washing machine) could receive the rebate.

The *Rainwater Tank* participants were therefore separated into those with internal connections and those with only outdoor connections. This allows the effectiveness of the rainwater tank with internal connections to be isolated. Effectively, five sub-programs were evaluated if rainwater tank rebates were regarded as two separate programs (i.e., before and after rule changes). Program participants were therefore separated into the respective program groups as follows:

- *Dual Flush*
- *GardenSmart*
- *WaterSmart Homes*
- *Rainwater Tank* (Indoor connection)
- *Rainwater Tank* (Outdoor connection)

These five cohorts of participants were then matched to the controls in separate lots, ensuring that the same control is not used more than once. The matching period for Rainwater Tank participants was set to January 2003 to December 2003, and other program participants were matched over January 2004 to December 2004.

4.1 Aggregated Results

The evaluation was carried out over two years, counting from the start of each program. With the exception of rainwater tank rebates, the water savings were estimated for 2005 (year 1) and 2006 (year 2). For rainwater tanks, the water savings are estimated for 2004 (year 1) and 2005 (year 2) due to an earlier program start date.

Note that the *Dual Flush* program is a conjoined program with *WaterSmart Homes*. Participants in *WaterSmart Homes* have the option of participating in *Dual Flush* as an extra service (rebate for switching to a 6/3litre cistern). The savings figure for *Dual Flush* is therefore a combined saving from the *WaterSmart Homes* and *Dual Flush* programs.

***Think Water, Act Water* sub-program savings**

The estimated water savings for the *Think Water Act Water* sub-programs is shown in Table 4. These figures were derived using the global weighted mean and standard error formulas presented in Section 3.7.

Figures in italics indicate that the net savings are statistically insignificant. That is, the sample size is not sufficient to determine the level of savings associated with these programs (specifically Rainwater Tanks or the Garden Smart Program).

Table 4 Estimated net water savings for the *Think Water, Act Water* sub-programs.

Estimated annual savings (kl/hh/a)	Dual Flush	Garden Smart	Water Smart Homes	Raintank (Indoor)	Raintank (Outdoor)
Measured savings for 2005 and 2006 combined	29.2±17	*-13.4±15*	20.4±5.9	*13.8±40*	*8.3±9.1*
Measured savings for 2005*	46.4±16	*-7.2±22*	25.0±7.7	*26.0±37*	*-4.7±14*
Measured savings for 2006*	20.2±20.2	*-15.8±17*	18.2±6.8	*11.4±45*	12.1±9.8
Estimates used in progress reports	37	29	22	n/a	86

* Except for rainwater tank programs, which are for 2004 and 2005.

The net annual household savings measured for the *Dual Flush* program were 46.4±16 kL for 2005 and 20.2±20.2 kL for 2006. Over the 24 month period from January 2005 to December 2006 the overall average savings was 29.2±17 kL per household per year (kL/hh/yr).

The annual household savings measured for the *WaterSmart Homes* program were 25.0±7.7 kL for 2005 and 18.2±6.8 kL in 2006, for an overall average over the 24-month period January 2005 to December 2006 of 20.4±5.9 kL/hh/yr.

For the *Rainwater Tank* program (outdoor only), considering the savings by year of program participation, the average annual household savings for 2005 (year 2 of program participation) were measured at 12.1±9.8 kL. This is despite the savings measured across the 24 months just outside of being statistically significant.

The indoor *Rainwater Tank* program produced no statistically significant savings on account of the low number of available observations. This is similarly the case for the *GardenSmart* program, although its 24-month average savings is borderline insignificant.

The estimates used so far by TAMS in their progress reports are also provided as a comparison, noting that these were in part derived from previous ISF studies (Turner *et al*., 2003). The estimates for all programs but the indoor *Rainwater Tank* program are greater than the measured savings found in this study. The most dramatic differences are observed for the *GardenSmart* program and *Rainwater Tank* (outdoors), which shows either opposing signs or an estimated savings several times greater than what was measured.

Aggregated results, over 24 months of program participation and by year, are presented graphically in Figure 5 and Figure 6 below. The savings are undiscernible from zero where the confidence intervals bound zero (crosses the x-axis).

Figure 5 Annual savings based on 24 months data.

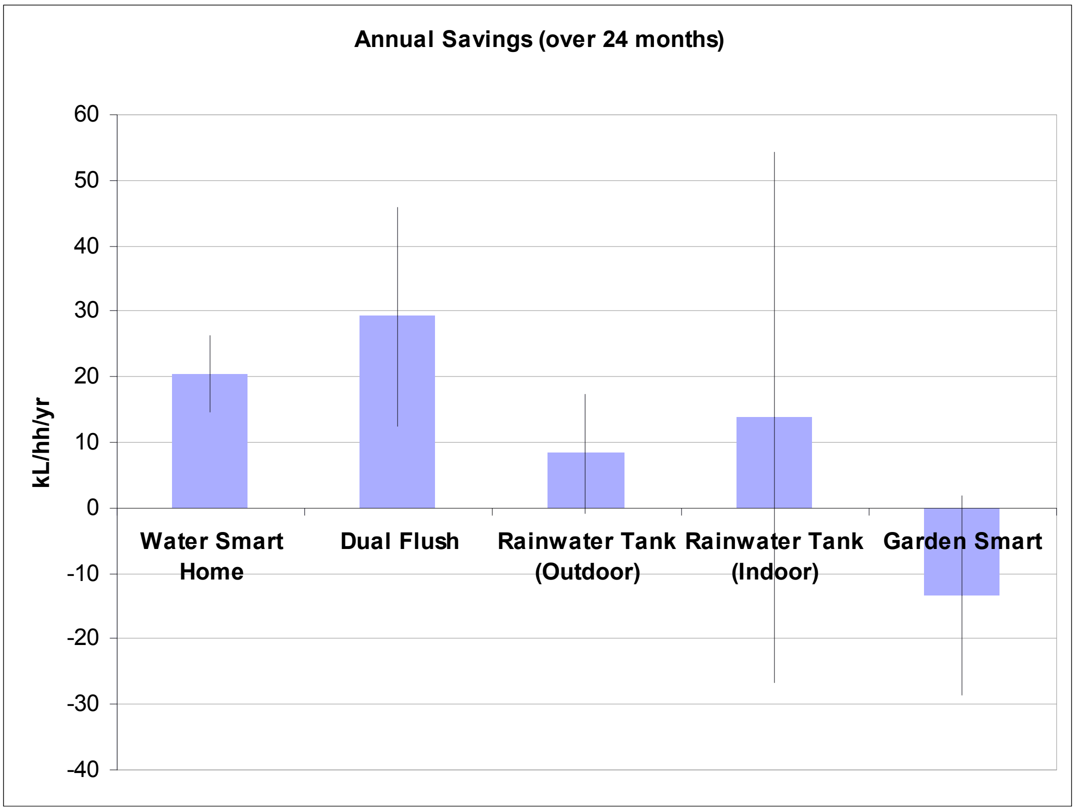
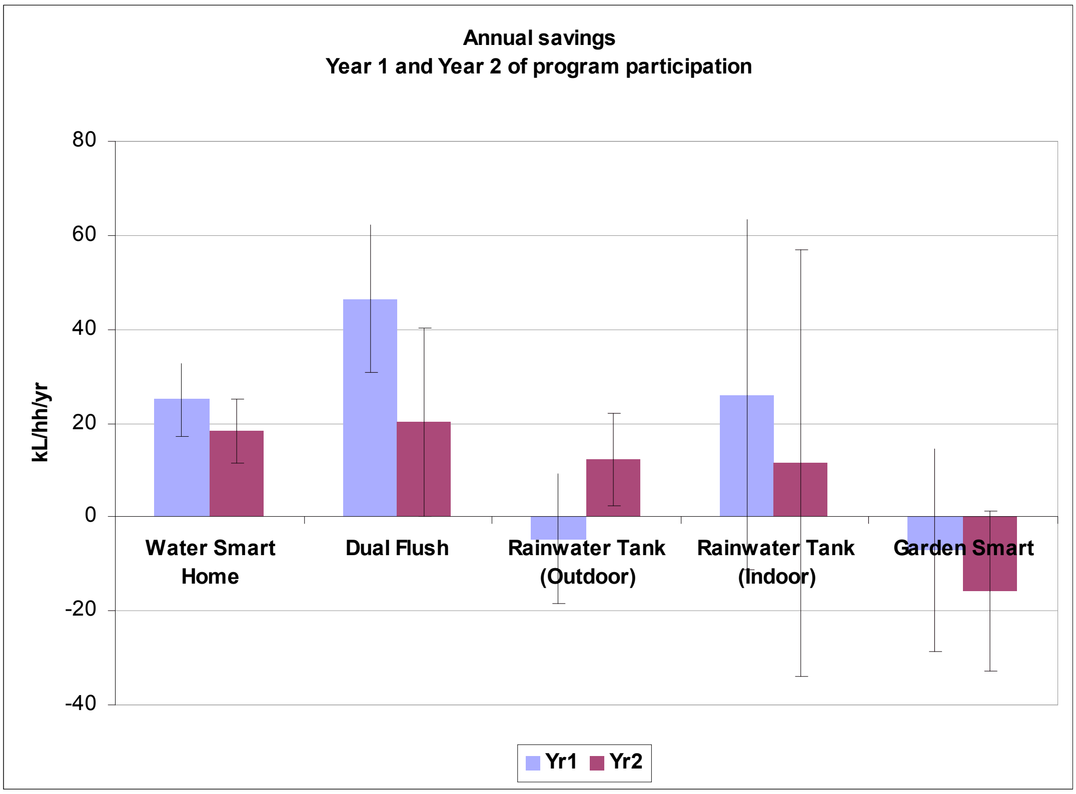


Figure 6 Annual savings by year of program participation.



The maximum number of observations by year and over 24 months are presented in the table below. The number of observations is always lower than the population of participants because some households took up the program outside of the analysis period. For extrapolation of the results to the total population of Canberra's residential population, the number of observations should ideally be greater than 300. It may be useful to repeat the analysis at a later stage when there are more participants.

Table 5 The maximum number of observations by year and over 24 months.

Number of observations	Year 1	Year 2	24 months
WaterSmart Home	985	1,453	1,453
WaterSmart Home with Dual Flush	117	158	158
Rainwater Tank (Outdoor)	280	571	571
Rainwater Tank (Indoor)	17	33	33
Garden Smart	157	317	317

Comparison with other studies

Other ISF studies of similar residential water efficiency programs in other jurisdictions are presented in Figure 6. Figures underlined indicate a higher measured savings relative to the *Think Water, Act Water* programs. Although the magnitude of savings varies considerably, the measured savings for *Think Water, Act Water* reflect the findings from similar studies of water efficiency measures. Figures in italics indicate that savings cannot be measured at a statistically significant level (95% confidence).

Table 6 Comparison of net savings estimates with results from other studies.

[kL/hh/yr]	Dual Flush	Garden Smart	WaterSmart Homes	Raintank (Indoor)	Raintank (Outdoor)
ACT	29.2±17	*-13.4±15.2*	20.4±5.9	*13.8±40.5*	*8.3±9.1*
Other ISF studies					
Kalgoorlie-Boulder	<u>54.8±51.1</u>[4]	-37.2 ±31.8	<u>28.5±21.</u>[2]		
Sydney			<u>20.9±2.5</u>[5]		
Gold Coast	*17.5±20.6*	<u>*-1.37±8.37*</u>			<u>20.4±17.6</u>[6]

Note: Numbers in italics are not significant at the 95%-confidence level.

[4] Sarac & White (2002). This estimate refers to 'tap and toilet' however much of the savings was thought to be due to retrofitting toilets to 6/3L cisterns.
[5] Turner *et al*. (2005). This result is for the WaterFix program which performs retrofits, installs flush arrestors and fixes leaks in homes (as an overall savings of all participants). This is comparable with the *WaterSmart Homes* program.
[6] Snelling *et al*. (2006). The raintank estimate is a combined savings for various tank sizes. Very few if any households in this analysis were connected indoors.

Note that the equivalents of the *Dual Flush* program in other comparison studies are typically stand-alone programs, whereas the *Think Water, Act Water* Dual Flush program represents a combined savings figure with *WaterSmart Homes*. The relative difference between the *Dual Flush* and *WaterSmart* Homes program will provide an indication of the savings attributed to *Dual Flush* alone – approximately 9 kL/hh/yr – although this will be an underestimation because *WaterSmart Homes* also involves placing cistern weights in toilets, so that the savings estimates for *WaterSmart Homes* would include savings from improving toilets flush *efficiency* as well as dual flush capacity.

The outdoor program, *GardenSmart*, did not show statistically significant savings for either 2005 or 2006, or for the 24-month period. There is some indication that this program did not save water, or even increased water use amongst participants. While this result, that is, an *increase* in water demand, has been seen in one example in the past, in Kalgoorlie-Boulder, this was with a very differently designed program (Sarac and White, 2003). The Sydney Water outdoor water efficiency program has greater similarity to the design of the ACT's *GardenSmart* program and was rolled out based on the results of an evaluation of a pilot program, in which water savings were measured (Andre Boerema, pers. comm. 2 April 2008).

It is highly likely that the restrictions being in place at the time of the program have confounded these results. Some garden water around the time of the program visit is likely to have occurred, relative to the control group. This does not mean that efficiency levels will be increased relative to the control once restrictions are lifted. It is recommended that a long term time series analysis be undertaken after restrictions have been lifted for over 12 months.

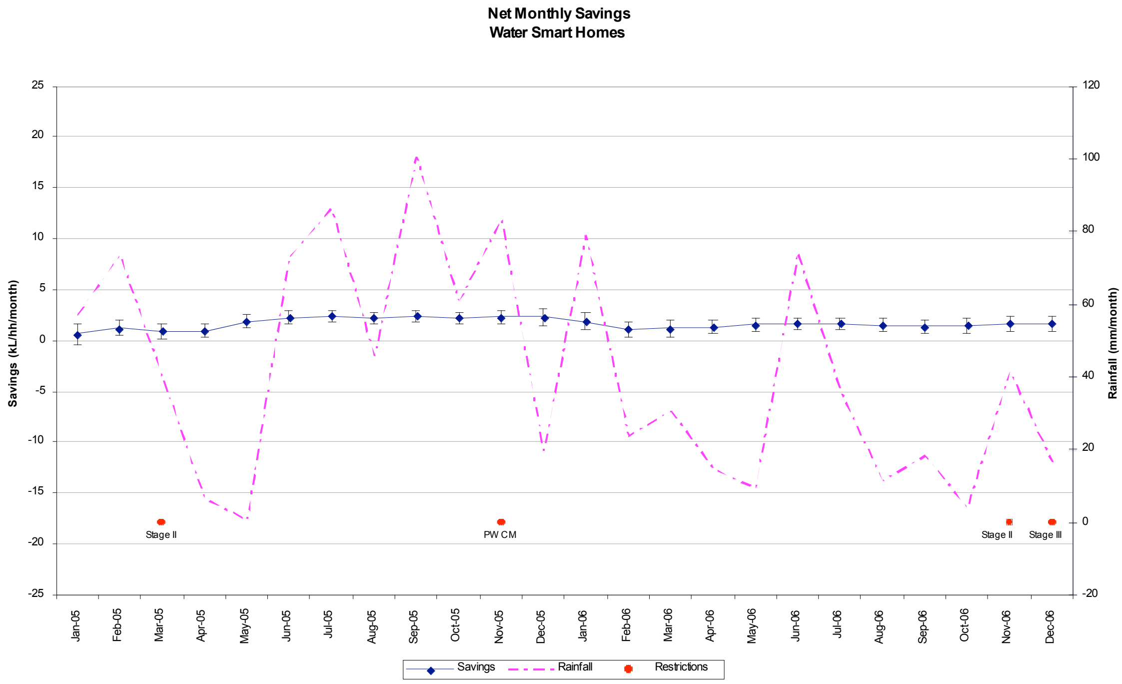
Turner and White (2003) reported that savings from the ACT's indoor tune-up program (now *WaterSmart Homes*) would be 21 kL/hh/yr (expected savings were provided by the ACT). Compared to the empirical results from the current study, which shows overall savings of 20.4±5.9 kL/hh/yr, the assumption that indoor tune-ups (*WaterSmart Homes*) would achieve 21 kL/hh/yr was very accurate.

4.2 *Monthly Savings for Each Program*

Results for *WaterSmart Homes*

Figure 7 below shows the results of the water savings evaluation for *WaterSmart Homes*. In the figure, the estimated water savings and confidence intervals are shown by the marked lines. The average rainfall and water restrictions are also included for information.

Figure 7 Monthly savings for the *WaterSmart Homes* program.

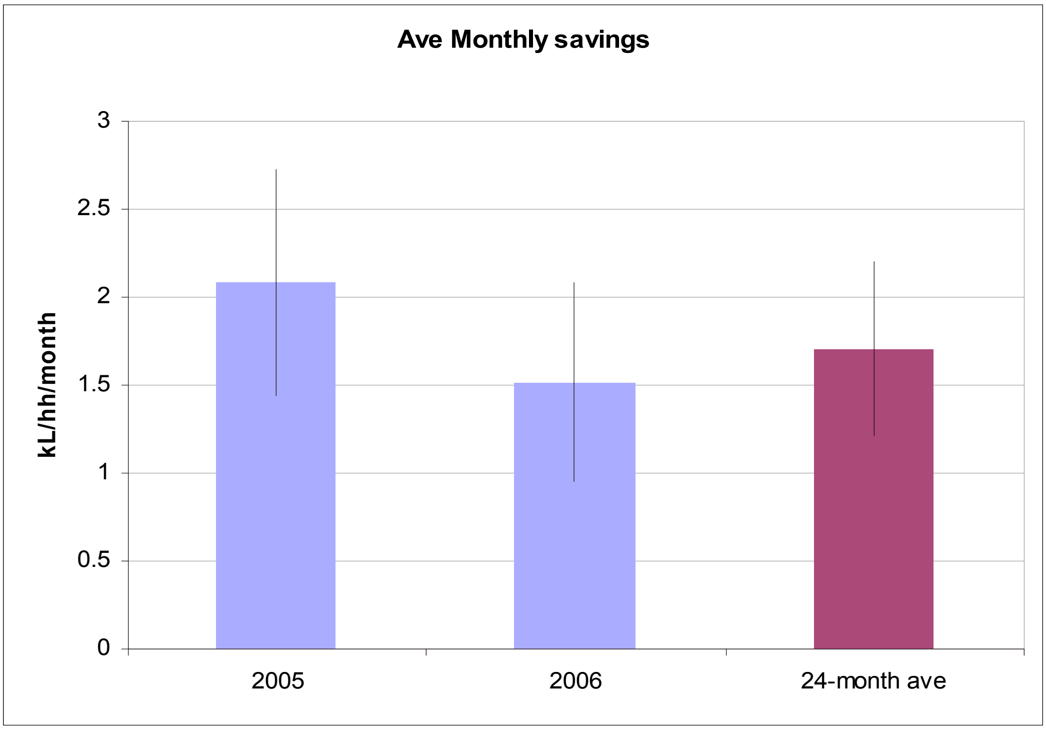


The 24-month average monthly savings is 1.7±0.5 kL per household. In 2005, the average monthly savings was 2.1±0.6 kL per household, but dropped to 1.5±0.6 kL per household in 2006. This indicates a gradual reduction in water savings over time.

Table 7 - Average monthly savings for the *WaterSmart Homes* program.

Period	Average Monthly savings (kL/hh/month)
2005	2.1±0.6
2006	1.5±0.6
24 months	1.7±0.5

Figure 8 Average monthly savings for the *WaterSmart Homes* program.



Results for *Rainwater Tank* rebate – Internally connected tanks.

In the database initially provided by TAMS, there was no indication of whether the households had internal connections or not. For this reason, the client provided new Excel files separating these households with corresponding participation dates.

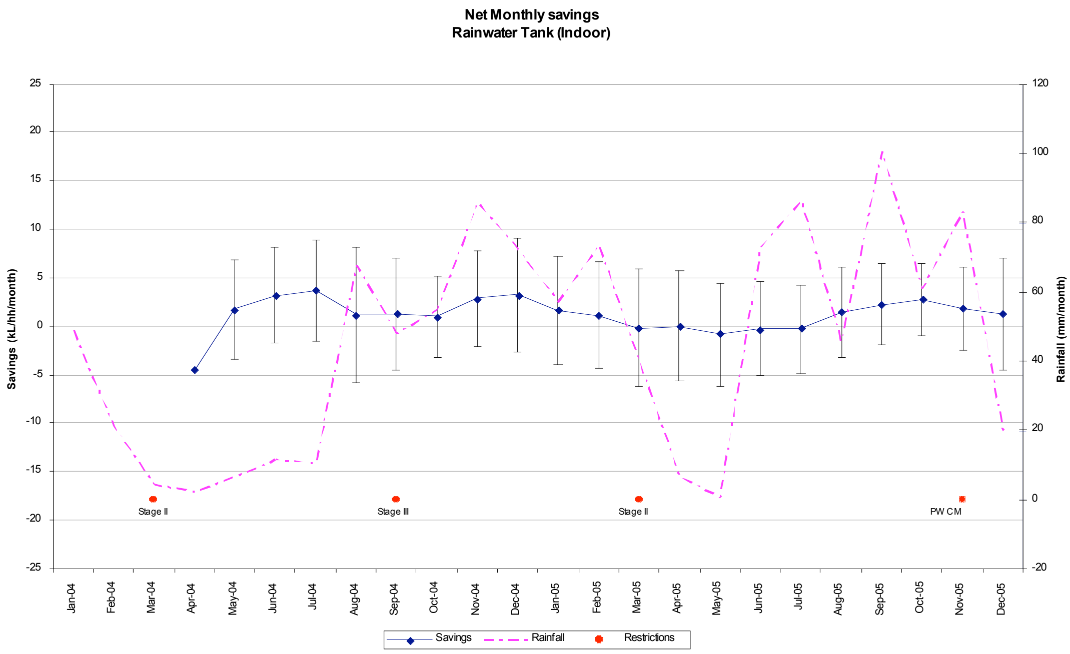
There were duplicate entries and common households between internally connected and outdoor-only households. After correcting for these anomalies, the number of households common with the original database is 1,285 (as opposed to 1,286 in the database).

Table 8 Participants in the different Rainwater Tank programs.

Total Rainwater Tank Participants	1,285
Internally connected	143
Outdoor connection only	1,142

Figure 9 shows the results of the water savings evaluation for the *Rainwater Tank* rebate (with *indoor* connections). There were no participants in the first few months of 2004, hence savings were zero for the start of 2004. The net monthly savings calculated based on following months, however, were also not statistically distinguishable from zero due to the low number of observations.

Figure 9 Monthly savings for the *Rainwater Tank* (Indoor) rebate program.

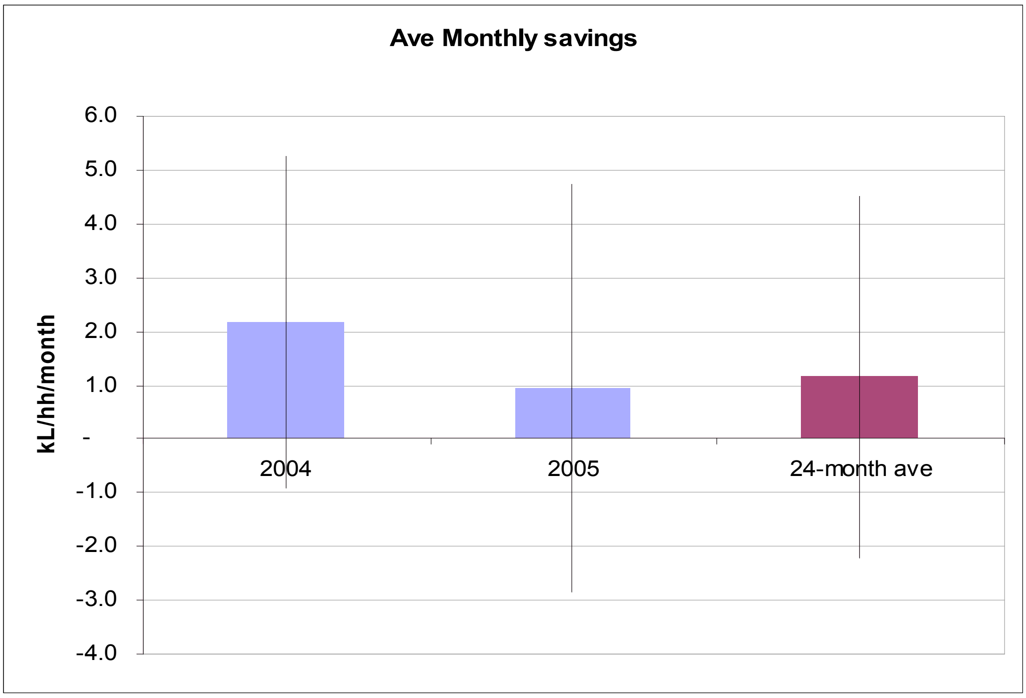


The 24-month average monthly savings is 1.2±3.4 kL per household. In 2004, the average monthly savings is 2.2±3.1 kL per household, which drops to 1.0±3.8 kL per household in 2005. While these savings figures are not statistically significant, they indicate a drop in monthly savings.

Table 9 Average monthly savings for the *Rainwater Tank* (Indoor) rebate program.

Year	Average Monthly savings (kL/hh/month)
2004	2.2±3.1
2005	1.0±3.8
24 months	1.2±3.4

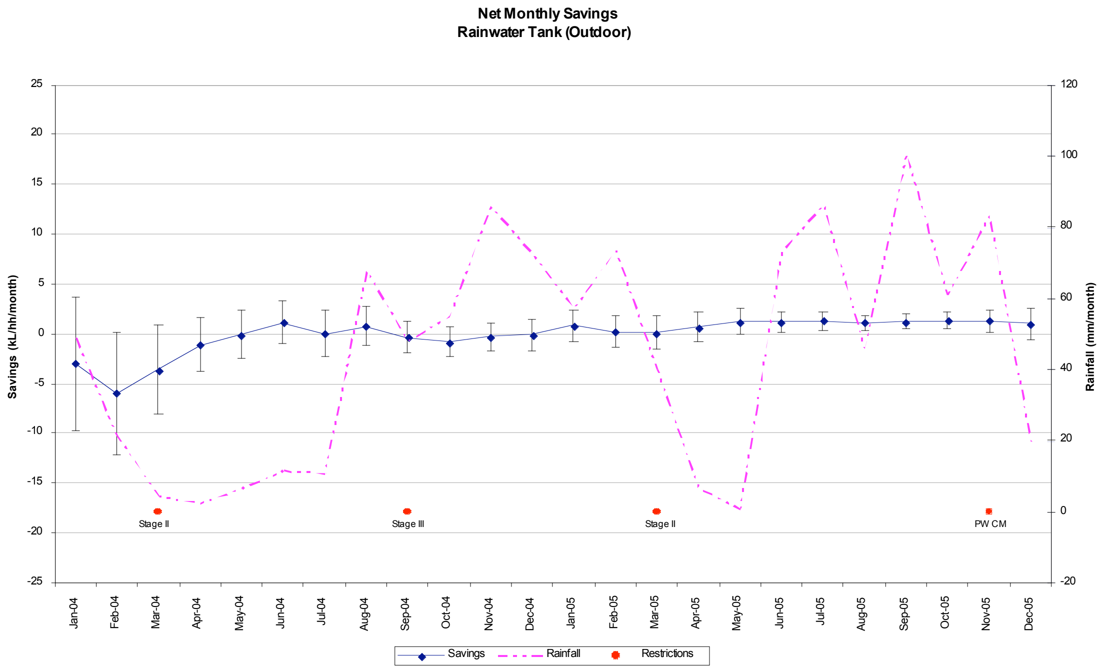
Figure 10 Average monthly savings for the *Rainwater Tank* (Indoor) rebate program.



Results for the *Rainwater Tank* Program – Outdoor connected tanks

The monthly savings estimated for *Rainwater Tank* participants (with *outdoor* connection only) are shown below. There were statistically insignificant savings in the first year (2004) and positive savings in the second year (2005). This is a significant change in the magnitude of savings from 2004-05, however less emphasis should be placed on 2004 estimates as the savings obtained are not statistically distinguishable from zero.

Figure 11 Monthly savings for the *Rainwater Tank* (outdoor) rebate program.

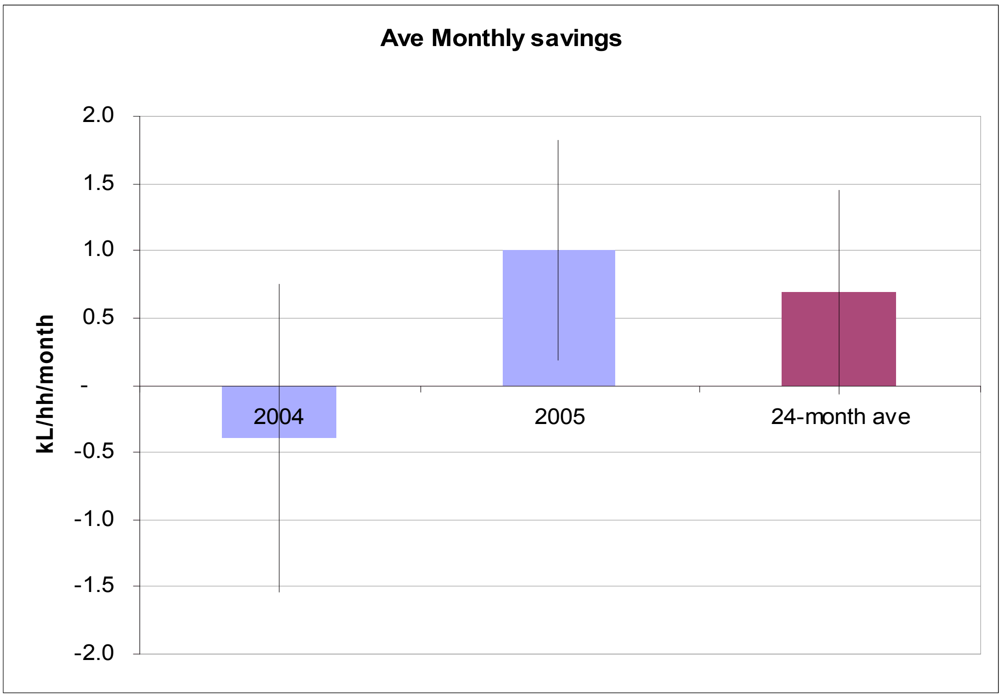


The 24-month average monthly savings is 0.7±0.8 kL per household, which is statistically insignificant at the margin. The monthly savings obtained for 2004 is -0.4±1.1 kL per household, which is statistically insignificant at the 95% confidence. The savings achieved in 2005 of 1.0±0.8 kL per household is statistically significant from zero, and provides a good indication of the savings achieved via outdoor connected rainwater tanks.

Table 10 Average monthly savings for the *Rainwater Tank* (outdoor) rebate program.

Year	Average Monthly savings (kL/hh/month)
2004	-0.4±1.1
2005	1.0±0.8
24 months	0.7±0.8

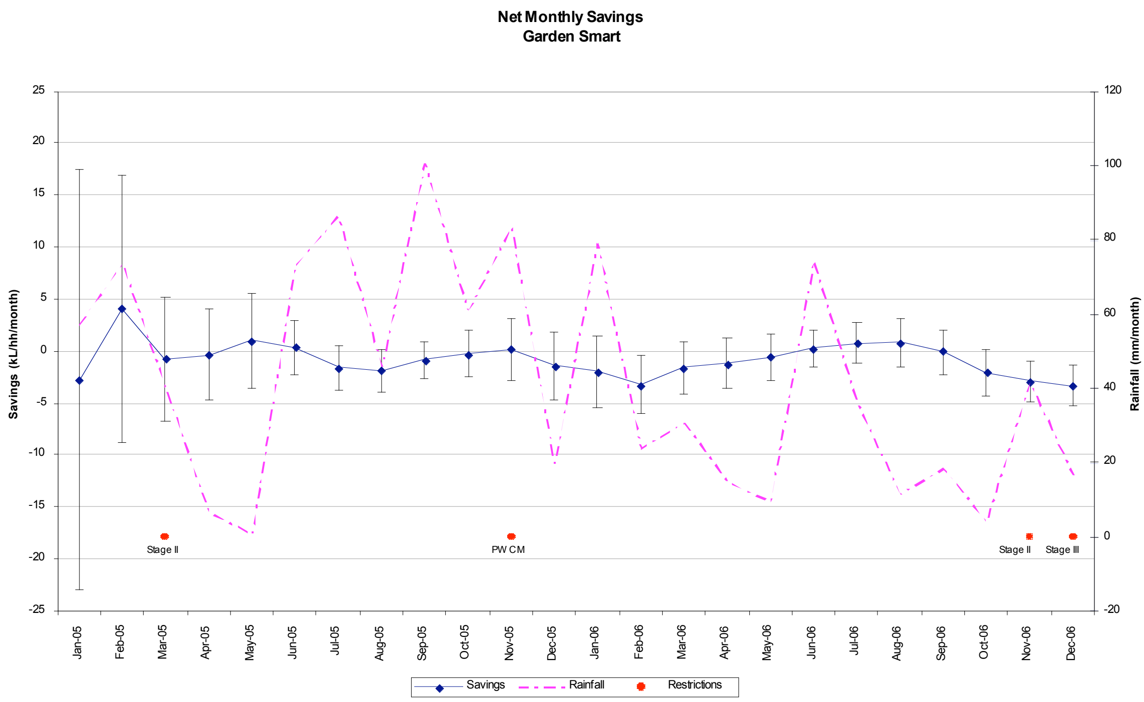
Figure 12 Average monthly savings for the *Rainwater Tank* (outdoor) rebate program.



Results for the *GardenSmart* Program

The *GardenSmart* program consistently achieved negative savings over 2005-06. While the monthly savings estimates are statistically insignificant, almost every monthly average is below zero. This implies *GardenSmart* participants have shown an increase in water use after taking up the program.

Figure 13 Monthly savings for the GardenSmart program.



The 24-month average savings is -1.1±1.3 kL per household, which is borderline insignificant and indicates that household water use increases post intervention. In 2005, the savings are -0.6±1.8 kL per household, which is statistically insignificant. However, the 2006 savings figure of -1.3±1.4 kL per household provides a relatively more reliable figure (although borderline statistically insignificant at the 95% confidence level) and indicates an increase in participant water use relative to its control household after intervention.

This result, that is, an *increase* in water demand, has been seen in one example in the past, in Kalgoorlie-Boulder, but this was with a very differently designed program (Sarac and White, 2002). The Sydney Water outdoor water efficiency program has greater similarity to the design of the ACT's *GardenSmart* program and was rolled out based on the results of an evaluation of a pilot program, in which water savings were measured (Andre Boerema, pers. comm. 2 April 2008).

It is highly likely that the restrictions in place at the time of the program have confounded these results. Some garden water around the time of the program visit is likely to have occurred, relative to the control group. This does not mean that efficiency levels will be increased relative to the control once restrictions are lifted. It is recommended that a long term time series analysis be undertaken after restrictions have been lifted for over 12 months.

Table 11 Average monthly savings of the *GardenSmart* program.

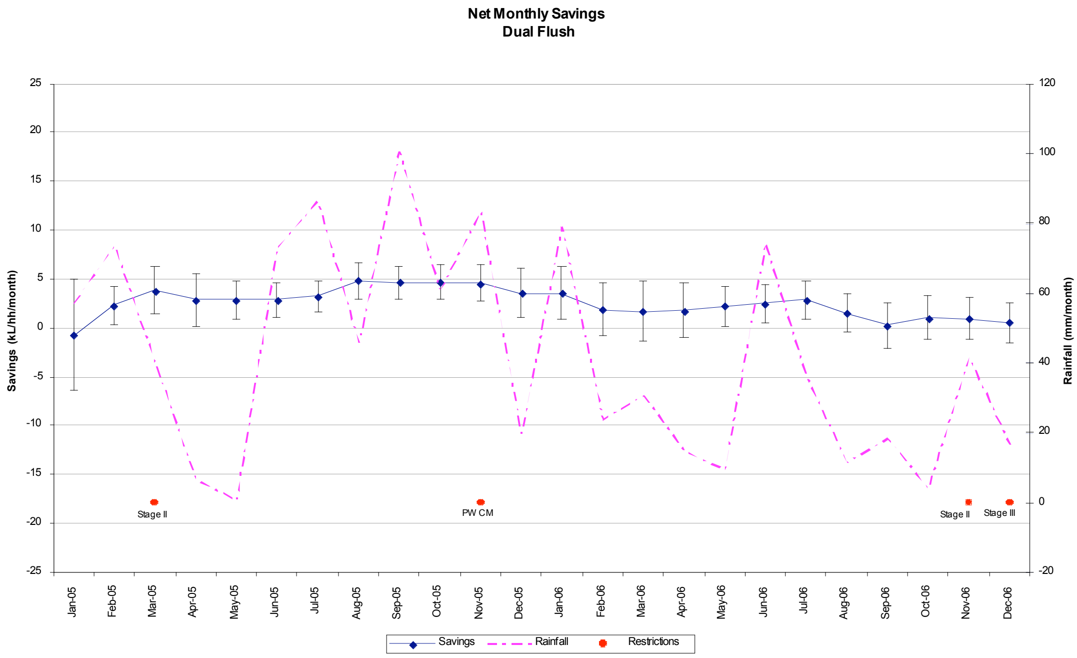
Year	Average Monthly savings (kL/hh/month)
2005	-0.6±1.8
2006	-1.3±1.4
24 months	-1.1±1.3

Figure 14 Average monthly savings of the *GardenSmart* program.

Results for the *Dual Flush* Program

The figure below shows the estimated monthly savings for the *Dual Flush* program. Note that *Dual Flush* participants must also participate in *WaterSmart Homes* to qualify for the rebate. The monthly savings are therefore indicative of the *combined* savings from *Dual Flush* and *WaterSmart Homes*.

Figure 15 Monthly savings from the *Dual Flush* program.



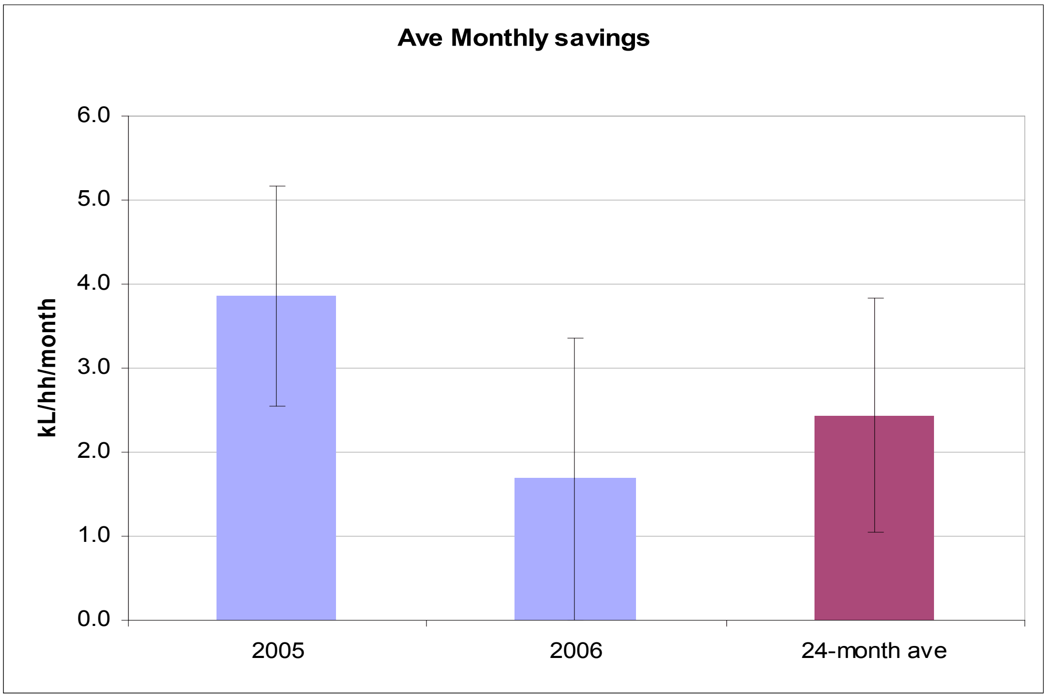
The 24-month average savings is 2.4±1.4 kL per household for participants in the joint *Dual Flush* and *WaterSmart Homes* program. In 2005, the monthly savings achieved was 3.9±1.3 kL per household, which falls to 1.7±1.7 kL per household in 2006. This indicates a drop in monthly savings over time.

It should be noted the savings from the *Dual Flush* program alone would be at least the difference in savings from the combined *Dual Flush* and *WaterSmart Homes* (DF&WSH), and savings from WSH-only. This is because the WSH program includes a toilet component, which involves putting a weight in the toilet cistern for single-flush toilets. So the savings derived from increasing toilet flush efficiency will be slightly more than the difference in savings for DF&WSH participants, and WSH-only participants.

Table 12 Average monthly savings from the *Dual Flush* program.

Year	Average Monthly savings (kL/hh/month)
2005	3.9±1.3
2006	1.7±1.7
24 months	2.4±1.4

Figure 16 Average monthly savings from the *Dual Flush* program.



5 CONCLUSIONS AND RECOMMENDATIONS

The *Think Water, Act Water* sub-program that achieved the greatest water savings was the *Dual Flush* program, which reduced residential household water use by 29.2±16.7 kL per year on average over 24 months. *WaterSmart Homes* produced the second largest savings of 20.4±5.9 kL per household per year over 24 months.

Taking the difference in savings between *Dual Flush* (participants in both *WaterSmart Homes* and *Dual Flush)* and *WaterSmart Homes* alone, the savings achieved by *Dual Flush* alone were estimated to be at least 8.8 kL per household per year. This may represent a slight underestimate of the impact of increasing toilet flush efficiency because *WaterSmart Homes* also includes a toilet component.

An evaluation of Sydney Water's retrofit programs, based on participants who had a shower retrofitted and leaks repaired, indicated savings of 20.9±2.5 kL/hh/yr (Turner et al., 2005:4). This compares favourably with the results for ACT's indoor tune-up program.

Due to small sample sizes, it was not possible to discern statistically significant water savings for the other programs under *Think Water, Act Water*. However, *Rainwater Tank (Outdoor)* participants did show significant savings in the second year of participation of 12.1±9.8 kL per household in 2005.

The outdoor program, *GardenSmart*, did not show statistically significant savings for either 2005 or 2006, or for the 24-month period. There is some indication that this program did not save water, or even increased water use amongst participants. While this result, that is, an increase in water demand, has been seen in one example in the past, in Kalgoorlie-Boulder, this was with a very differently designed program (Sarac & White, 2002). The Sydney Water outdoor water efficiency program has greater similarity to the design of the ACT's *GardenSmart* program and was rolled out based on the results of an evaluation of a pilot program, in which water savings were measured (Andre Boerema, pers. comm. 2 April 2008).

The restrictions in place at the time of the program may have confounded these results. Some garden watering by participants around the time of the program implementation is likely to have occurred, relative to the control group due to the intervention itself. This does not mean that the underlying efficiency levels will not be higher relative to the control once restrictions are lifted. It is recommended that a long-term time series analysis be undertaken after restrictions have been lifted for over 12 months.

References

ACT Government (Territory and Municipal Services) 2006, *Think Water Act Water Strategy for Sustainable Water Resource Management in the ACT*. Progress Report 2004-2005 (online).

ACT Government (Territory and Municipal Services) 2007, *Think Water Act Water Strategy for Sustainable Water Resource Management in the ACT*. Progress Report 2005-2006 (confidential).

Sarac, K. and White, S. 2002, *The Kalgoorlie-Boulder Water Efficiency Program: Evaluation and Next Steps*, *Final Report 2002*, [prepared for Water Corporation WA] Institute for Sustainable Futures, UTS, Sydney.

Snelling, C., Simard, S., White, S., and Turner, A. 2006, *Gold Coast Water Evaluation of the Water Demand Management Program, Final Report*, [prepared for Gold Coast Water] Institute for Sustainable Futures, UTS, Sydney.

Turner, A. and White, S. 2003, *ACT Water Strategy, Preliminary Demand Management and Least Cost Planning Assessment. Final Report* [prepared for ACTEW Corporation Ltd] Institute for Sustainable Futures, UTS, Sydney.

Turner, A., White, S., Beatty, K., & Gregory, A. 2005, 'Results of the largest residential demand management program in Australia', *Water Science and Technology: Water Supply*, vol. 5, pp. 249 -256.