University of Southern Queensland
Faculty of Engineering & Surveying

Investigation of Domestic Water End Use

A dissertation submitted by

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towards the degree of

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Abstract

This project explores domestic water end use and investigates water consumption in ten households in Toowoomba to determine a methodology for a possible future expansion of study, incorporating a larger number of residential houses. Water restrictions, rebate programs and WaterWise education form the essential elements of water demand management in Toowoomba but little is known about the effectiveness of these programs and the actual impact they have on per capita water use – particularly on individual end uses over time. Reliable measurements of water savings are essential to determine the impacts of conservation projects on urban water demands. Other factors that affect water consumption, demand patterns and peaking factors are also investigated. The information can be used to educate the community and promote their participation in water conservation activities and behaviours.

The basic methodology of the project was as follows: A sample of 10 households was selected to be fitted with high resolution water meters and data loggers. The data on water use in these households were collected every 10 seconds for a continuous period of 138 days. This data was then analysed and disaggregated into relevant end use categories using Trace Wizard software.

The average water consumption for the ten households under study was found to be 112 litres/capita/day, which is well under the Level 5 water restrictions target of 140 L. It was found that the implementation of water restrictions had changed the peaking factors for Toowoomba significantly and these need to be taken into account for planning purposes. Showers contribute to the largest end water use amounting to 43.5% with washing machines using the second largest amount at 22.7%. Volume used by showers (and other flow based devices) was governed by the flow rate from the showerhead (Low Flow, Ultra Low Flow or Normal), the duration spent in the shower (7.2 minutes on average) and the number of events/capita/day, which was inversely related to the number of children present in the household. The total volume used by washing machines (and other volume based devices) was governed by the volume used per cycle and the number of cycles/capita/day. It was found that front load washers used less than half the amount of water as top loading washers.

Water restrictions have significantly decreased the average demand of water. This is evident through the lack of a seasonal pattern due to residential water being used solely for indoor purposes. The provision of rebates for water efficient devices by both the State Government and Toowoomba Regional Council are currently targeted to the areas where they are likely to save the most water. The uptake of these water efficient devices from the ten households under study was good with 60% of households having the most water efficient devices installed. WaterWise education was highlighted as a significant and essential part of demand management programs with changes in consumer's behaviours likely to save the most water when compared to retrofitting of water efficient devices.

The information from this study will be used to educate the community and promote their participation in water conservation activities and behaviours. This project supports the sustainable use of the region's scarcest resource and will have major implications for demand management programs in Toowoomba and across Australia.

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Contents

List of Figures

List of Tables

Chapter 1 Introduction

Toowoomba's specific location and current water shortage provides a unique opportunity to conduct an end water use study. This report seeks to evaluate several similar studies and determines that specific conditions experienced in Toowoomba are likely to provide new and significant data pertaining to demand management.

A small pilot study which addresses this opportunity is described. Conceptual and physical parameters of the study, scope and limitations are identified and framed by a simple methodology appropriate to an undertaking by a local water authority.

1.1 Background

The city of Toowoomba in Queensland, Australia is supplied by three dams; Cooby, Cressbrook and Peserverance and a growing number of bores. Toowoomba Regional Council (TRC) provides water service to more than 90,000 people. Prior to the 1940's, the city's bulk water was sourced from the underlying basalt aquifer. As the city grew the bulk water source was supplemented with the construction of three dams; in the 1940's Cooby, 1960's Perseverance and 1980's Cressbrook Dam.

Over time the city expanded and more bores were installed to augment a dwindling surface supply. This has culminated in today's complex reticulation network consisting of over 700km of main and tens of thousands of residential and industrial connection points.

Currently, the city's potable water supply utilises approximately thirty percent groundwater supplied from 22 bores. The remainder of the supply comes from surface storage supplies. The water network uses 16 reservoirs to feed 11 pressure zones.

Due to Toowoomba's undulating terrain, a wide variety of static water pressures are encountered throughout Toowoomba. This results in excessive pressures experienced in some areas and higher than anticipated consumption. This also leads to an increase in mains bursts in high pressure areas.

Air temperatures in Toowoomba vary considerably between summer and winter months. This fluctuation traditionally is positively correlated to water consumption. Following the introduction of water restrictions however, consumption throughout the year has normalised to an annual demand pattern with negligible variation. See Figure 1-1.

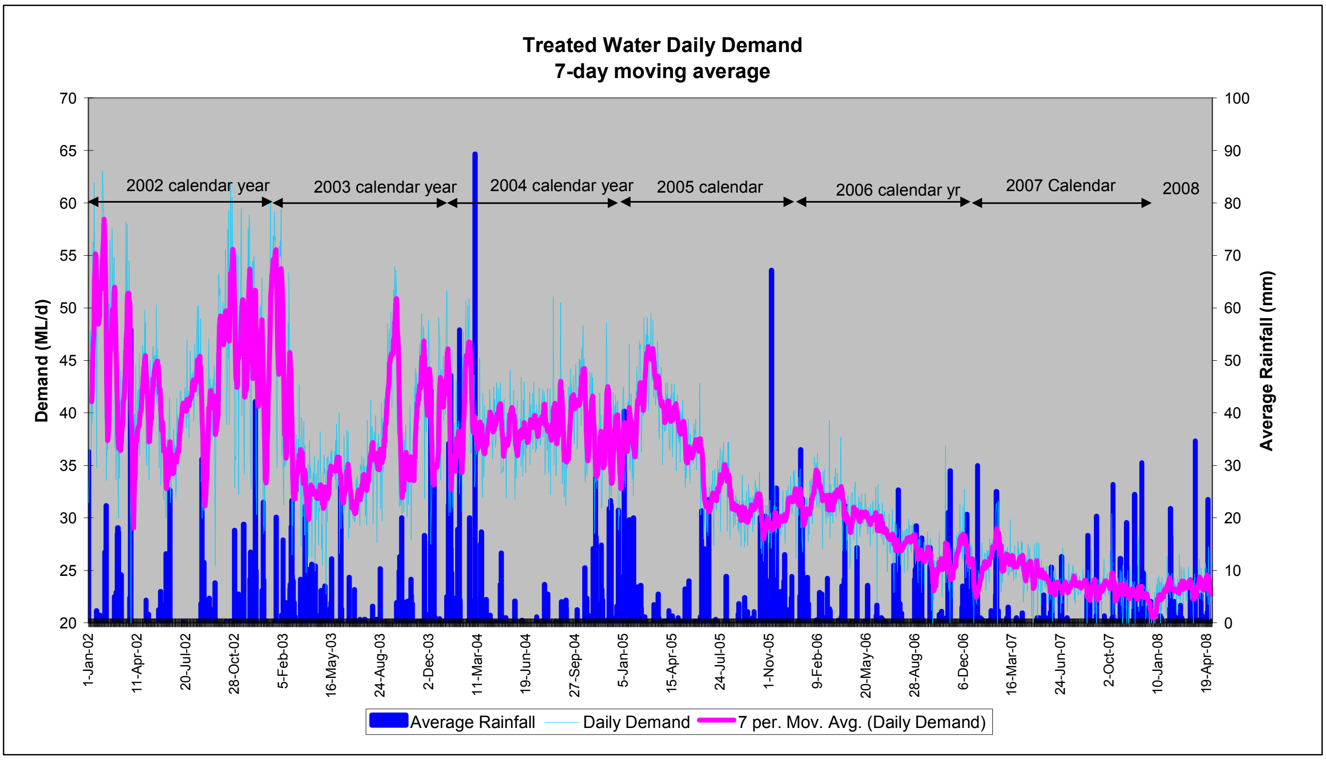


Figure 1-1 Toowoomba's Daily Demand

To ensure that water exigency does not exceed available supply the urban water supply industry must employ a variety of demand management strategies (Coombes et al. 2000). One of Toowoomba Regional Council's (TRC) most important priorities is to conserve water thus both long and short term approaches are being undertaken to ensure sustainable supply. Demand management methods such as community education and specific water conservation strategies have been articulated.

TRC has set a per capita consumption target of 140L/person/day. Recommended demand reduction measures include; the introduction of regulation for AAA shower roses, AAAA washing machines, incentives for rainwater tanks and/or recycling at individual properties. Level 5 water restrictions were introduced on 26 September 2005 and still apply today. This level prohibits all outside use of town water; including washing of cars and filling of pools.

1.2 Justification

The Australian Water Association (2001) found that in the last 15 years water use has increased but that there is a lack of detailed knowledge about end use. The 'end use' of water is the breakdown of the total household water usage in a single dwelling to outlets such as toilets, showers, washing machines, taps etc.

Accurately measuring and modeling the residential end uses of water and the effectiveness of conservation efforts has been one of the major problems of urban water planning for many years (American Water Works Association 1999). To date, strategies to directly measure residential end use have been limited by expense and sample size. Planners have instead relied on mechanical estimates of water savings based on the manufacturers' specifications. This approach, according to Chestnut and McSpadden (1991) is subject to systematic errors.

Currently, a rating scheme is used to evaluate the efficiency of water using devices. Consumers are increasingly familiar with AAA shower roses and AAAA Washing Machines. These efficiency ratings are based on strict laboratory experiments under controlled conditions. Concerns with this strategy include questions surrounding the relevance of experimental conditions to those encountered in the field. For example: varied pressure experienced in the field may alter performance.

People's attitudes to water use and their behavior as consumers are also a source of variation. This variation is difficult to estimate and cannot be determined from mechanical trials. High usage behaviours such as longer showers and flushing the toilet twice, will increase the volume of water used but cannot be predicted from either appliance or demographic analysis.

An end use analysis, even in a micro-scale, provides this valuable information relating to actual use.

Understanding where water is used by the consumers is critical information for water authorities and planners. It is essential to identify and quantify usage strategies and water consumption influences in order to evaluate and implement effective demand management.

End use studies provide quantified evidence of the impact of specific conservation measures. Furthermore such evidence can be used to improve the design of conservation programs and provide justification for continued support of conservation measures.

Given the current water shortage, an investigation into Toowoomba's water demand is deemed highly beneficial if not essential. Demand patterns are expected to differ from the classic demand curve. Water use patterns and trends are likely to be unique to the Toowoomba area due to the distinctive climate of the region, high water pressure and strict demand management regulations.

Therefore, an end use analysis in a micro-scale will give valuable information relating to actual use. Understanding where water is used by the consumers is critical information for water authorities and planners. Evidence of the effectiveness of specific conservation measures can be used to improve the design of conservation programs and can provide justification for continued support of conservation measures.

The application of the results expected from this investigation are wide ranging. The design of water supply schemes (especially when bore water is used for augmentation of existing supplies), Average Demand (AD), Mean Day Maximum Month (MDMM) and Peak Demand (PD) values are generally taken from the QUDM planning guidelines for water supply and sewage. Are these values still applicable/relevant when Toowoomba is currently under Level 5 water restrictions? How do the peaking factors change depending on local conditions? This study will investigate the answers to these concerns.

The study will allow demand management programs to be targeted to where they will be most successful. Additionally the effectiveness of current demand management programs and water restrictions can be evaluated.

1.3 Aim & Objectives

This project seeks to establish a methodology to investigate end water use in residential properties in Toowoomba. It will define the major factors that affect domestic water consumption within the city. Collected data will then be used to establish a demand pattern & identify peaking factors for Toowoomba. Guidelines for the successful expansion of the study will also be provided.

The objectives of this research are to:

- Identify daily urban water use patterns on an hourly basis for total household usage and for major components of indoor use (e.g. toilets, showers, washing machines etc.).
- Identify variations in water usage for each water-using appliance according to influencing factors such as season, temperature, rainfall and household size.
- Establish diurnal demand patterns & peaking factors based on the data collected.
- Examine the effectiveness of the currently implemented demand management programs.
- Provide guidelines for extension of the study to a larger, more representative sample of households.

1.4 Scope

The scope of this research is to establish the methodology to collect water end use data and use this preliminary data to establish diurnal demand patterns, investigate specific end use factors and provide feedback on existing demand management initiatives.

The limitations of this research are:

- Only water use from single residential properties is considered in the end use analysis. Other types of housing such as townhouses and multi-occupant residences are not investigated.
- Only residential water use is analysed, other uses such as commercial or industrial consumption is not considered.
- Only a small sample of 10 households will be used to establish the methodology.

1.5 Overview of Dissertation

Chapter 2 presents a literature review which discusses the development of end use data collection and investigates results from similar studies. This chapter also outlines demand patterns and demand management programs.

Chapter 3 gives an overview of the methodology used to collect and analyse end water use. This includes details on participant selection, the meters & loggers used, the software used for the disaggregation of water use ‘race Wizard’ and a brief overview of the database that was collated.

Chapter 4 presents results relating to the total water consumption. This includes per capita use and the relative distribution of water throughout the household. An investigation into planning parameters and peaking factors from the resulting data is also presented. Diurnal demand patterns for the ten households are also included.

Chapter 5 details the water use by volume based appliances and fixtures. These include washing machines, toilets, dishwashers and baths. Chapter six investigates flow based fixtures such as showers and faucets.

The effectiveness of Toowoomba’s demand management programs based on the data collected is presented in Chapter 7. This covers water restrictions, rebates and waterwise education. Finally, the conclusions and recommendations from this study are presented in Chapter 8.

Chapter 2 Literature Review

This literature review will cover two main topics. Firstly the development of water end use measurement, including results from studies in both the US and Australia. Secondly the methodology behind calculating demand patterns and establishing demand models will be investigated.

2.1 End Water Use

In 1984 Brown and Caldwell noted that in the June 1984 Department of Housing and Urban Development (HUD) report, Residential Water Conservation Projects continued to represent the standard reference on water use rates. This American report documents end uses of water in the single-family residential sector for selected appliances and fixtures. The HUD study was able to quantify the water savings from low-flow plumbing fixtures and devices from data that was collected from more than 200 single-family homes in California, Colorado, Washington DC, Virginia, Georgia and New Jersey. The study investigated water saved by low volume toilets, low flow shower heads, retrofit programs, advanced water saving fixtures, water pressure reductions, water regulation, and water meters. The study broke down water use into 'non-conserving' and 'conserving' homes on a per capita basis, established measurements of water savings due to conserving fixtures and devices, gave water savings from retrofit programs and metering and furthermore analysed the effect of reducing pressure on water use.

Although useful, this information is outdated (Mayer et al. 1999) and lacks precise information on individual residential water uses and data from a larger sample of single-family homes. It was also not designed to address outdoor residential irrigation demand. The techniques to monitor water use implemented in the study were described as intrusive and cumbersome. Although they were considered to be the best available at the time participants were always aware that they were being monitored (Mayer et al. 1999).

Subsequent studies have collected specific data on residential water use rate using technology not available in 1984 (Mayer et. al 1999). The East Bay Municipal District (EBMUD) is perhaps the most well known of these studies. Conducted in California six years after the HUD study was completed, it examined water use in 25 homes in the Oakland area (Aher et al. 1991). The study collected water use data using micro-meters on a small number of important fixtures, wired to an on-site computer, enabling data collection and transfer. The total cost of the study was substantial at US$10,000 per home. Significantly the EBMUD report did not break down water use into end use components beyond toilets and showers as the focus was on indoor use.

A Tampa, Florida study used the same system to examine indoor use in 25 single-family homes before and after a retrofit of ultra-low-flow toilets and low-flow showerheads. This study, although focused on toilet and shower use attempted to quantify outdoor water use as well. The cost of this study was high, with the data collection being intrusive and not sufficiently structured to permit end use disaggregation (Mayer et. al 1999).

Later, several studies including Buchberger and Wells (1996) used electronic data collection techniques on a small sample of single-family homes to determine instantaneous flows, peak flows, hourly consumption and seasonal patterns. This data again did not provide sufficient resolution to segregate flows into individual end uses (Mayer et. al 1999).

In 1994-1996 the Heatherwood Studies used a concept instigated by Dziegielewski et al. (1993) to collect instantaneous flow data from a customer's water meter (Mayer 1995). In these studies, sponsored by the City of Boulder, Colorado and conducted by Aquacraft Inc, data loggers were used to collect flow trace data at 10 second intervals from the standard magnetic water meters in residential houses. These flow traces were precise enough to permit disaggregation. Significant variations in water use patterns were revealed by these traces that would not have been found in previous examinations of billing data. The Heatherwood study was also cost effective, at US$30,000 to estimate water use in 16 houses (Mayer et. al 1999).

This technique was further used to measure the impacts of a conservation retrofit program in Boulder Colorado (DeOreo et. al 1996). Aquacraft developed the first version of Trace Wizard software to automatically segregate the recorded flow traces into specific end water uses. This greatly increased the speed and accuracy of the analysis. This study showed that it was feasible to inexpensively collect and analyse end use data which provided unprecedented detail about water consumption habits.

In 1997 the American Water Works Association (AWWA) Research Foundation sponsored the Residential End Use Water Study (REWS) which was conducted in 14 American cities. The REWS study was able to identify the different ways households use water and describe variations in water use between different households. Differences in water use at the end use level were attributed to causal factors that related to price and socio-economic characteristics (Mayer et. al. 1999).

The REWS methodology has now been adopted by the Water Corporation in Western Australia, and by Yarra Valley Water (YVW, 2001) in Melbourne. Being an American study, REWS provides a basis for further study but cannot be considered definitive in the Australian context because of clear differences apparent in water consumption patterns between the two nations. A summary of the findings of the REWS are given below to allow comparison with Australian Studies:

- The average annual water use was 553kL/household/yr, proportioned as 42% indoor and 58% outdoor usage. These were strongly influenced by annual weather patterns.
- The average daily water use per capita was 262L including leakage.
    - Toilet 70Lpcd (Lpcd)
    - Clothes Washer 57Lpcd,
    - Shower 44Lpcd,

- Tap 37.85Lpcd,
- Leaks 36Lpcd,
- Bath 4.5Lpcd,
- Dishwasher 3.8 Lpcd and
- Other 6.1 Lpcd.

- The average daily leakage was 82.89L, but only a small number of homes were responsible for the majority of leakage.
- The average number of loads of laundry/day was 0.96 with a volume of 56.78Lpcd. The average volume per load was 154.8L
- Study participants flushed the toilet an average of 5.05 times/person/day and took 0.75 showers/person/day.
- The pattern of residential water use followed the classic diurnal pattern, lowest at night, highest in morning, moderate throughout the day with a second peak in the evening.

The Water Corporation of Perth and YVW in Victoria are the only Austalian water utilities that have completed studies of residential end use data. However, Gosford City Council and Gold Coast Water are currently collecting residential end use data using the same method.

The Domestic Water Use Study (DWUS) undertaken by the Western Australian Water Corporation follows the methodology adopted in the REWS conducted in the US. It provides a more current understanding of domestic water use patterns and trends in Australia (Coghlan and Higgs 2000, Loh and Coghlan 2003). The objectives of the DWUS study were to collect data on household water usage, identify water use patterns and develop a demand forecasting model and a water use efficiency program. Data was collected from 720 single residential households and 297 multi-residential households across Perth. The data was downloaded to data loggers every 6 weeks and processed using Trace Wizard. The main findings of the DWUS include:

- The average total usage per household was 1259 Lphd with 56% for outdoor and 42% indoor with 2% leakage.
- Bath and Shower 171 Lphd, washing machine 139 Lphd, toilets – 112 Lphd, taps – 83 Lphd and other – 18 Lphd.
- Toilet use decreased from 32% to 21% due to increased ownership of dual flush toilets.

YVW conducted a similar study in 2001 surveying 25 of its staff who were single residential household owners with gardens across Greater Melbourne. As part of its High Water Using Appliances Study (Gato et. al 2004) this research aimed to determine by demographic profile total water usage resulting from engagement of a variety of indoor and outdoor water using appliances. Data loggers were installed in these households to monitor and record water usage at one-minute intervals over 3 weeks. Householders were also asked to keep a diary to record when they used their toilets, showers, washing machines etc. during the first week of logging. Garden usage was recorded in the diaries for the whole 3 week period. This data was combined and reported with the following study.

Additionally, YVW conducted a second study which surveyed and logged 93 households for two weeks over two periods in 2004 (February and August). The data was disaggregated into major end uses of water using Trace Wizard software. Results from this study are detailed below:

- Average Daily Indoor Use is 523 Lphd or 169 Lpcd.
- Shower – 49.1 Lpcd, Clothes washer – 40.4Lpcd, Toilet -30.4 Lpcd, tap -27 Lpcd, Leak -15.9 Lpcd, Bath – 3.2Lpcd and Dishwasher -2.7 Lpcd

Although these studies give an indication of water use in Australia, the results differ significantly between the two regions. This could be a due to a number of reasons but is likely to include climate, water restrictions, differing attitudes and water pressures.

Toowoomba's end water use results are expected to differ again from these studies due to its unique geographical area and the impact the severe water shortage will have on total consumption and consumption patterns.

2.2 Demand Patterns

The consumption or use of water, also known as *water demand*, is the driving force behind the hydraulic dynamics occurring in water distribution systems.

There are three types of basic demand types:

Customer demand – is the metered portion of the total water consumption required to meet the non-emergency needs of users in the system,

Unaccounted-for water – is the portion lost due to leakages in the system and

Fire flow demand – is a computed system capacity requirement for ensuring adequate protection is provided during fire emergencies (Haestad et al*.* 2003).

Water demand varies continuously over time but generally trends in accordance with several time scales (hourly, daily, weekly, or seasonally). The demand may also vary due to changing factors such as climate, population, and pressure.

The temporal variations in water usage for a municipal water system typically follow a 24-hour cycle called a *diurnal* demand pattern. Figure 2-1 illustrates a typical diurnal curve for a residential area. There is relatively low usage at night when most people sleep, increased usage during the early morning hours as people wake up and prepare for the day, decreased usage during the middle of the day, and finally, increased usage in the early evening as people return home.

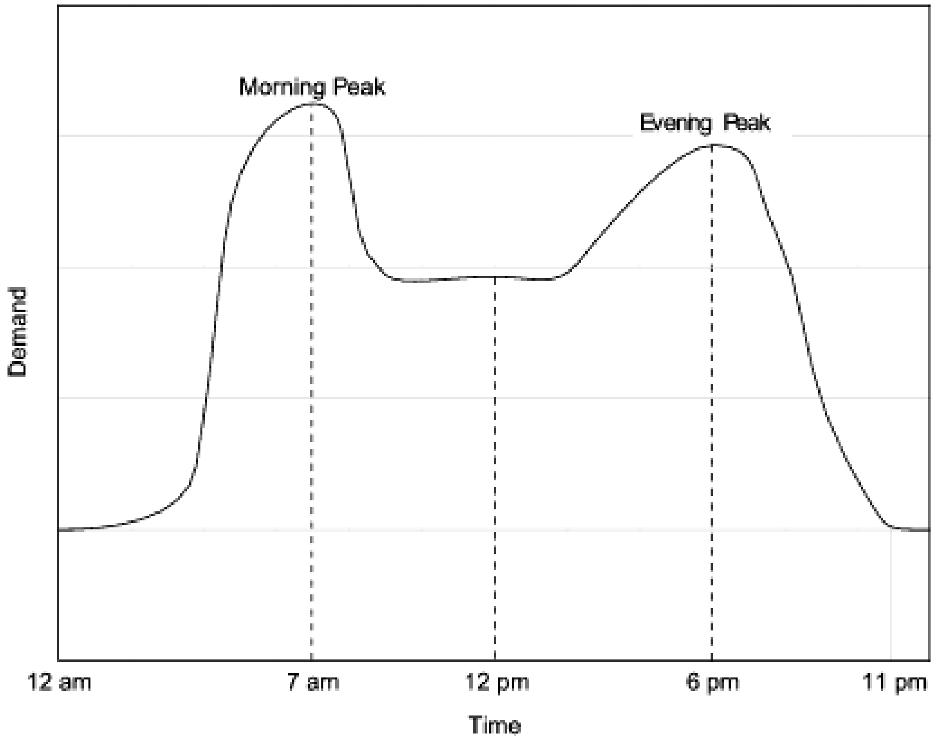


Figure 2-1 A typical diurnal curve (Source: Haestad et al. 2003)

Toowoomba planners currently assume demand patterns that have been sourced from other areas such as the Department of Natural Resource and Water, and other regional areas. Some research has been carried out on fully residential areas such as Harlaxton and Prince Henry Heights by placing water meters on trunk mains leading to these areas. Good diurnal patterns were achieved from this and have been used for computer modeling purposes.

2.3 Water Demand Management

Water demand management is an important part of managing public water systems under stressed conditions. Public water systems have two options when levels of water use approach the physical limits of water supply sources or the limits of water infrastructure capacity. They may either increase water supply or decrease water demand (Griffin 2006). Temporary restrictions are used to balance short to mid-term supply and demand, while permanent water conservation measures are implemented for long-term demand management. Educating the public about the need to conserve water resources is a common approach to demand management during times of water stress. Renzetti (2002), Timmins (2003), and Kenney et al. (2008), all point out that water conservation education can lead to reductions in water demand, but that these programs are most effective when used in conjunction with pricing strategies or technical measures for demand reduction. There is also some indication that long-term water conservation may be subject to a declining effectiveness over longer time periods (Howe 2007).

Water restrictions are in place in cities and towns across the country. Many commentators and consumers have questioned the value of long-term water restrictions, asking why governments have not taken steps to alleviate the squeeze on supply (National Water Commission 2006). While governments have announced major investments to boost urban water supplies, the ongoing use of restrictions in major centres across Australia has prompted public debate on the role, effectiveness and costs of restrictions (NWC 2006). The project was designed to address issues and concerns that have been raised, some of which are given below:

- Poor understanding in the community about how restrictions are set and why
- A lack of confidence and awareness as to whether restrictions achieve meaningful outcomes relative to their real and perceived impacts
- Confusion over the different roles and effectiveness of temporary restrictions versus water conservation measures
- Economic costs related to water restrictions are borne disproportionately by certain industries and sections of the community
- A lack of rigorous monitoring and evaluation of water restrictions that results in a general lack of understanding about the economic, environmental and social impacts of water restrictions

2.4 Chapter Summary

This chapter has reviewed the literature relevant to end use technologies and explored the basics of water usage demand patterns. End use studies from the USA, Melbourne and Perth were investigated and their values compared. These studies had significantly different results and justified the need for local data on end use. Demand patterns are assessed as important for planning water distribution systems; from reservoirs and trunk mains to reticulation pipes. Water demand management is made up of complex interactions between water restrictions, rebates on water efficient devices, waterwise education and water pricing.

Chapter 3 Methodology

The end water use study consists of a number of steps:

1. Selection of study participants
2. Selection and installation of monitoring equipment
3. Audit and data collection
4. Analysis of results and report writing

This chapter provides an overview of the selection methodology, the monitoring equipment and other data collection.

3.1 Selection of Study Participants

3.1.1 Sample Size

As this is a pilot study, a statistically relevant sample was not required. Cost relative to the value of results provided was the main determining factor in sample size selection. It was therefore decided to sample 10 households and to target Toowoomba Regional Council employees.

3.1.2 Sample Selection

High use customers are responsible for a higher proportion of peak demand use, outdoor use and possibly other less well understood end uses such as evaporative air conditioners, spas and swimming pools. It is therefore important to allocate resources in proportion to total use of customers; hence the actions of high use customers are more important than those of low use customers.

An invitation package was sent out to all Toowoomba City Council employees containing a covering letter, a description of the study and brief questionnaire. These can be viewed in Appendix B.

3.1.3 Distribution

Figure 3-1 shows the location of the ten volunteer households. A total of six responses were received, two of these could not be included since they were either not a single residential household or their water meter had been recently replaced and it was not feasible to replace it again. Family and friends of the author made up the remaining six participating households. No incentives were offered to participate in this study, accounting for the low response rate.

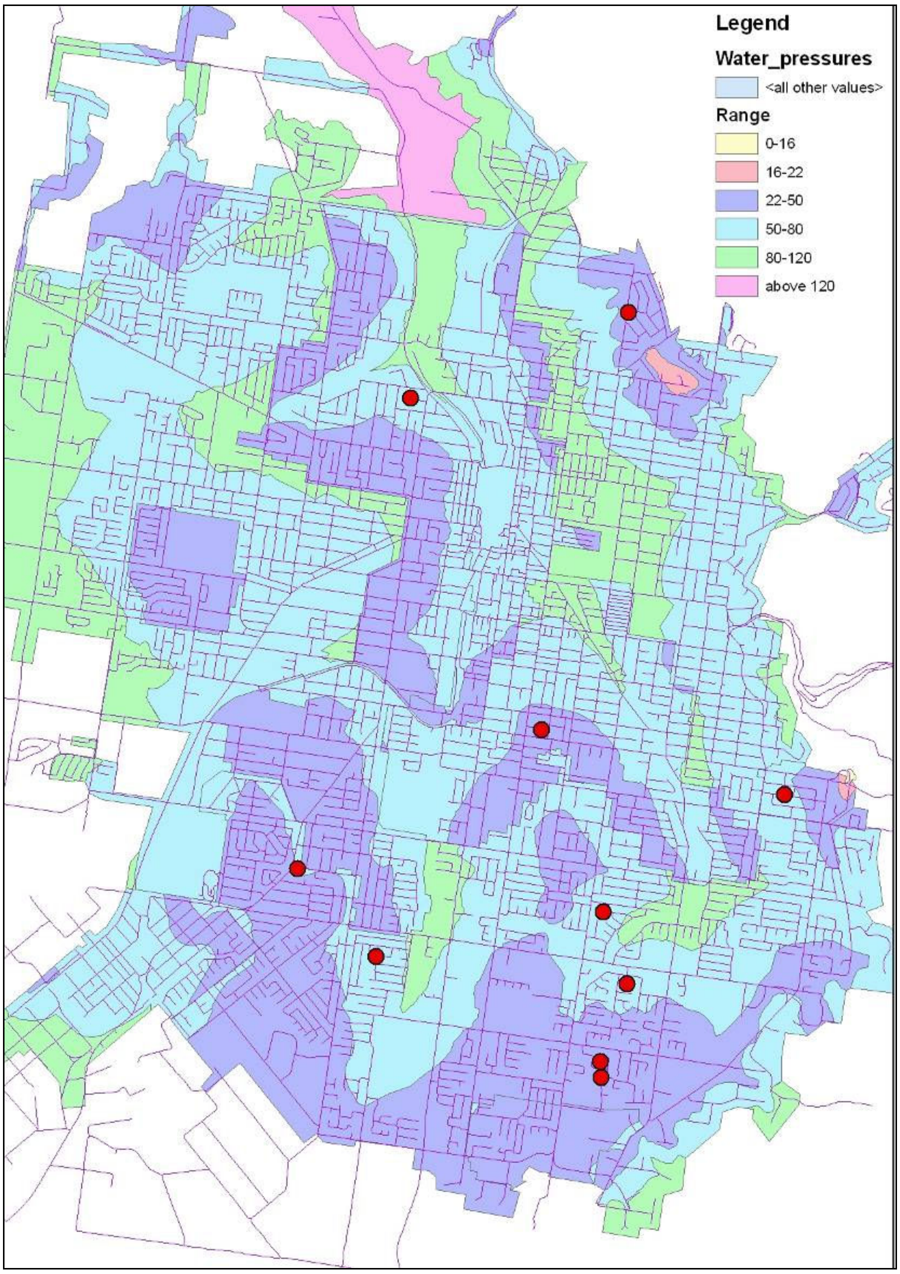


Figure 3-1 Location of Study Households

Sample selection in this study did not allow for the emphasis on high use customers due to the low response rate. However, the ten participating households do have a higher water use than the average Toowoomba single-residential household. Figure 3-2 shows the study group vs. Toowoomba average use over the last four years.

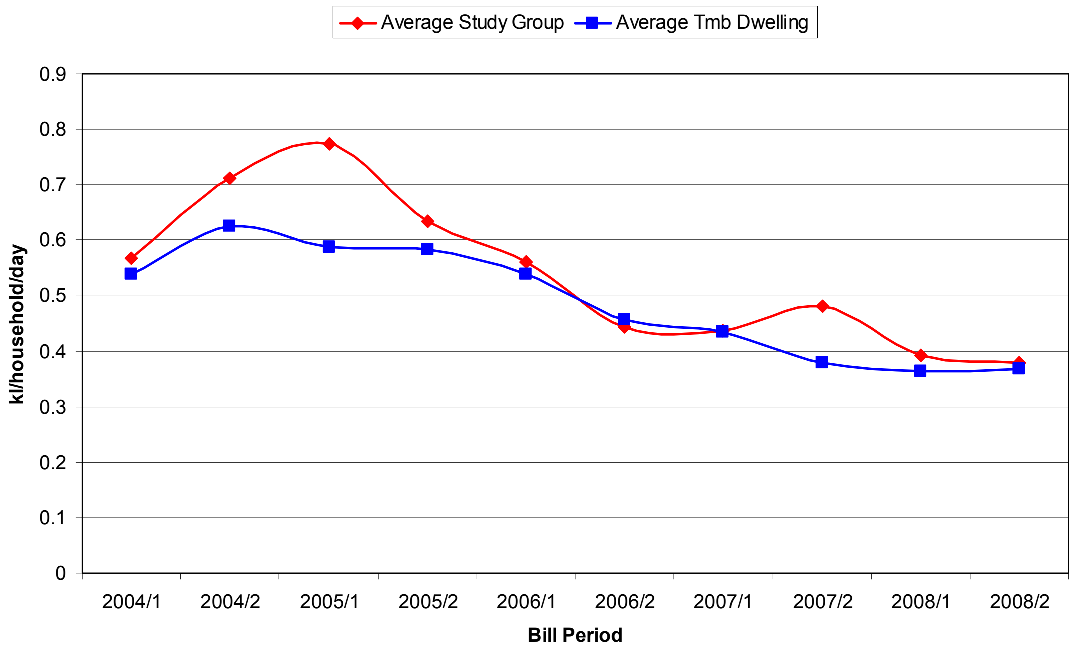


Figure 3-2 Average Usage vs. Study Group Usage

3.2 Monitoring Equipment

The approach used to collect end use measurement is similar to other end use water studies and used similar equipment to the YVW and the pilot Gold Coast Water study. A high resolution record of water use was collected which could then be disaggregated into individual water use events using the Trace Wizard water use analysis tool.

3.2.1 Meters

A key consideration of flow trace analysis is the high level of resolution required for accurate analysis. Residential fixture analysis requires >10 pulses per litre (Mayer et al. 1999). US residential studies use meters that provide 25-30 pulses per litre, while some New Zealand studies have used Neptune MES25 meters which pulse 34.2 times per litre. In this study Actaris TD8 meters were used which were modified from their normal 2 pulse per litre to operate at 72 pulses per litre. These meters are then called CT5-S meters and have a unit cost of $250. The meters are capable of reading volumes as small as 14 ml. The meters are fitted with a high resolution reed switch contact closure output; and are shown in Figure 3-3. The specifications of the modified meters are given in Appendix C- Measuring Equipment.

Figure 3-3 CT5-S meter(left) and installed(right)

The meters were installed over a two week period by qualified Toowoomba City Council plumbers.

3.2.2 Loggers

The water measurement information from the meter is captured by Monatec Data Monita R Series data loggers. The Monita Series, as shown in Figure 3-4, were necessary because they were one of the few data loggers on the market that had the ability to collect pulses up to 100Hz (72.5 ppL x 83.3 L/min). These loggers are the remote series and have not been previously used in any large scale studies. Gosford City Council has tested this unit and found the benefits of auto-reporting to outweigh the GPRS and data communication costs significantly (Thornton N. 2008, pers. Comm., 14th January). The remote loggers cost $750 each, while the D Series cost $450. The loggers have a storage capacity of 2 million records, which is equivalent to 33 weeks storage at ten second intervals. In the event that the 33 week time period is met, the oldest data will be overwritten. The loggers are self-powered with a battery life of ten years or 2000 calls and are IP68 compatible, resulting in weatherproof and waterproof abilities. They are SMS and email enabled and can be setup to auto report. The loggers in this study have been set to record at an interval of ten seconds and to report weekly via email. The logs are sent to two email addresses to facilitate a backup of data. Each email is approximately 250kB in size and the loggers use a rolling log so no information that will be sent on multiple occasions. The programming of loggers cannot be completed remotely as programming is carried out via an infra-red connection.

The emails of traces from the loggers need to be processed from their raw form into their log form to enable them to be entered into the Trace Wizard software. This is done using the Monita Command software which is also used to program the loggers.

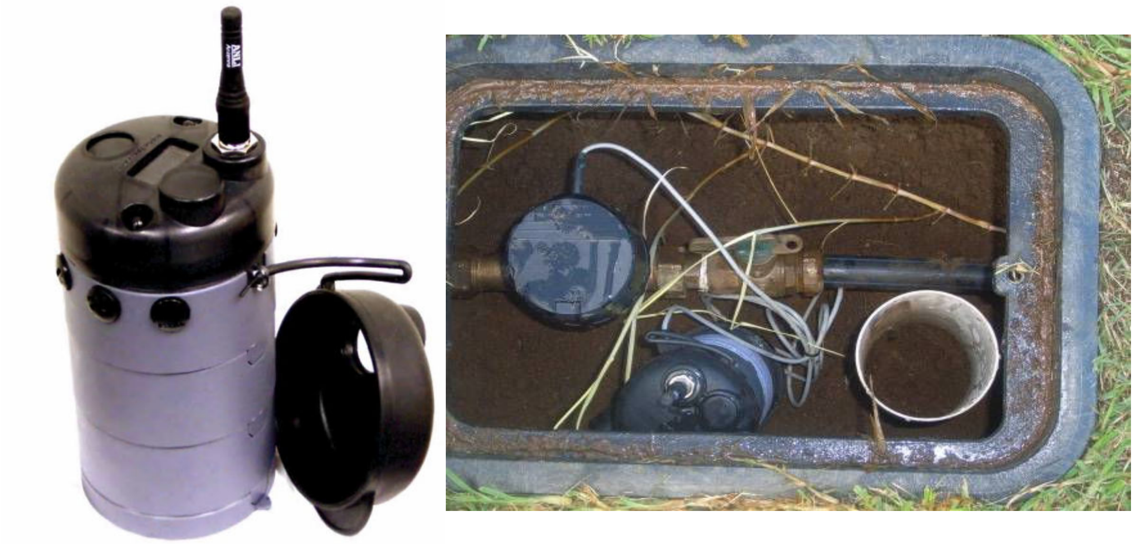


Figure 3-4 Monita R Series (left) and installed(right)

The loggers were installed during the last week of March 2008. The logging period ran for 138 days (31st March – 4th August). Each logger had been synchronized with the PC time to ensure all time recordings were the same. Once the loggers were in place, collection of information from the home could take place.

3.3 Household Data Collection

An audit questionnaire was developed to allow collection of data regarding the size, composition, year of construction, existing water fixtures, water use habits and attitudes of the home and its users. The questionnaire is included in Appendix D – Audit Questionnaire. The questionnaire was administrated by a TRC representative and involved personal consultation with a member of the household where questions about the home were reviewed. During this visit, a walkthrough of the home was also conducted and each fixture in the home was operated and the time of each operation noted. This was intended to provide a signature trace of each fixture to be captured by the logger. Considerations were given to ensure that operations were for a long enough time to be captured by the data logger i.e. longer than ten seconds. Time was left between operations to allow for discreet events to be recognized.

The flow of the fixtures was also recorded during the site visit using a calibrated jug and stop watch, the results of which were then converted into L/min. Flow rates above 8L/min could not be measured accurately due to the small volume of the jug. The collection of this data was necessary due to the inexperience of the analyst in identifying the various fixtures in the house. The participants were also asked to record all water use events in the house over three days on a series of log pages that were provided. The purpose of the log pages was to capture information related to washing machine and dishwasher cycles.

A calendar was also left with the householder so that they could record time periods whee the house was left unattended for extended periods i.e. overnight/weekends away. The initial site visit took between thirty and forty minutes to complete per household. The data from each household was entered into a database and checked to ensure the accuracy and quality of the database.

3.3.1 Participant Agreement

During the home visit, the participation agreement was explained to the householder and their signature obtained. The key terms included agreement to:

- keep a log of water use during the first three days
- provide information on household characteristics pertaining to the study
- allow information from the study to be used for statistical purposes

A copy of the participation agreement is included in Appendix E – Participation Agreement.

3.4 Weather Data

All weather data is sourced from the Australian Bureau of Meteorology website. Maximum and minimum air temperatures and quanitites of rainfall are recorded for each day throughout the trial.

3.5 Pressure Data

Actual pressure at the households was measured using an hydraulic pressure logger connected to a nearby hydrant with a fitting commonly known as a hydrant cap, as shown in Figure 3-5. Hydrants closest to the properties were chosen and logged over a few days to ensure any significant fluctuations were recorded.

Figure 3-5 Pressure logging. Flushing (left), hydrant cap and logger in place(top right) and reading the logger (bottom right)

3.6 Accuracy and Quality of Data

A range of quality assurance and control measures were undertaken during the collection process to ensure the quality and accuracy of the data obtained in the study. These measurements included:

- data logger calibration
- water meter calibration
- field verification of data logger operation
- fixture signature traces
- participant log sheets
- checks of analyzed flow traces

These are described below:

Data logger preparation – Each data logger's serial number was recorded against the participant address, time synchronised to local time and numbered externally to ensure the correct traces were attributed to the correct addresses. An installation report was generated from each of the loggers to verify correct SIM card installation and signal strength. Verification between logs sent via email and logs stored on logger were undertaken , with both producing identical results.

Water meter calibration – The new water meters that were to be installed were tested by the manufacturer for accuracy.

Field verification of data logger operation – Once the logger was connected to the water meter, verification that the logger was picking up the pulses from the meter was required. This was done by running 5 litres through an outside tap on the property and reading the meter and logger output to verify the 5 litre output. Later in the study, accuracy checks were also undertaken by comparing the mechanical register against the logger’s calculation of consumption. Slight inaccuracies were found however these can be attributed to the 0.5 pulses per litre that are lost since programmable entry into the logger permits only whole numbers. Hence for every litre of water consumed, 7 ml is not recorded, giving a consistent inaccuracy of 0.7 %.

Fixture Signature Traces – As described in 3.4 Household Data Collection, signature traces were obtained during the audit to improve identification in Trace Wizard.

Participant log sheets – Log sheets were left with the participants in order to ascertain the timing, duration and description of recorded flow events. This process assisted with the recognition of appliances such as washing machines and dishwashers. Calendars were also filled in by participants to indicate which days the house was left unattended. These procedures greatly assisted with calculating per capita consumption.

Checks of analysed flow traces – Flow trace analysis in Trace Wizard is sometimes a subjective process. To ensure accuracy other studies have had two analysts analysing the traces and if any significant discrepancies exist, the traces are re-examined and finalised in consultation with both analysts. In this study, traces were compared from one week to the next and any large discrepancies in percentage contribution were investigated.

3.7 Trace Wizard

Trace Wizard is a software package developed by Aquacraft specifically for the purpose of analysing water flow trace data (Mayer et. al 1999). As at October 2008, Trace Wizard software costs US$1000. Trace Wizard provides the analyst with powerful processing tools and a library of flow trace patterns for recognizing a variety of residential fixtures. Any consistent flow pattern can be isolated, quantified, and categorised using Trace Wizard. Trace Wizard 4.0 has been modified to accept flow traces from the Monita series of loggers. Analysis in Trace Wizard is an iterative process. Trace Wizard takes the flow data from the flow trace and disaggregates the data into individual water use events. Trace Wizard then calculates a specific set of data about each water event during the process. These are: start time, stop time, duration, volume, peak flow rate, mode flow rate, and mode flow frequency. All of this data is recorded in the final database of water events.

Once all the water events have been quantified using the pre-defined elements, Trace Wizard uses a defined set of parameters to categorise the water use events and assign a specific fixture to each event. The parameters are developed for each individual study residence. These parameters can include the volume, duration, peak flow, rate and mode flow rate of each specific fixture. For example, a toilet may be defined as using 9 Litres/flush. Similar parameters are established for each of the fixtures found in the household. The parameters are fine-tuned to fit the fixtures in each house and the program is re-run until the analyst is satisfied with results.

The analyst uses the survey response data and signature trace data to detail the specific water-using appliances and fixtures in the house. Such data is incorporated into a parameters file which assigns fixtures to water use events. The graphical display also allows the analyst to inspect water use events and build the parameter file so that it can correctly identify as many of the events as possible. Once an accurate parameter file has been created for that specific household, the analysis time can be significantly reduced.

Trace Wizard has the ability to recognize simultaneous events. For example if someone is taking a shower while someone else uses the toilet, Trace Wizard is able to separate these distinct events. Figure 3-6 below shows a sample trace output depicting a toilet flush and simultaneous hand wash followed by a shower.

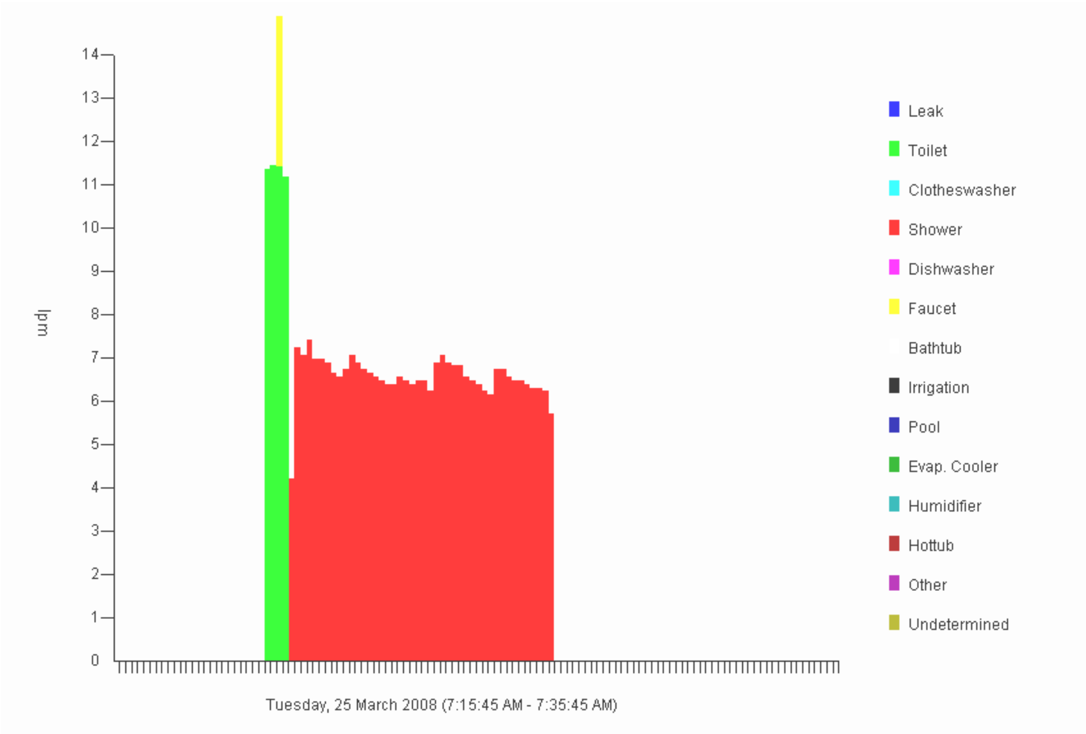
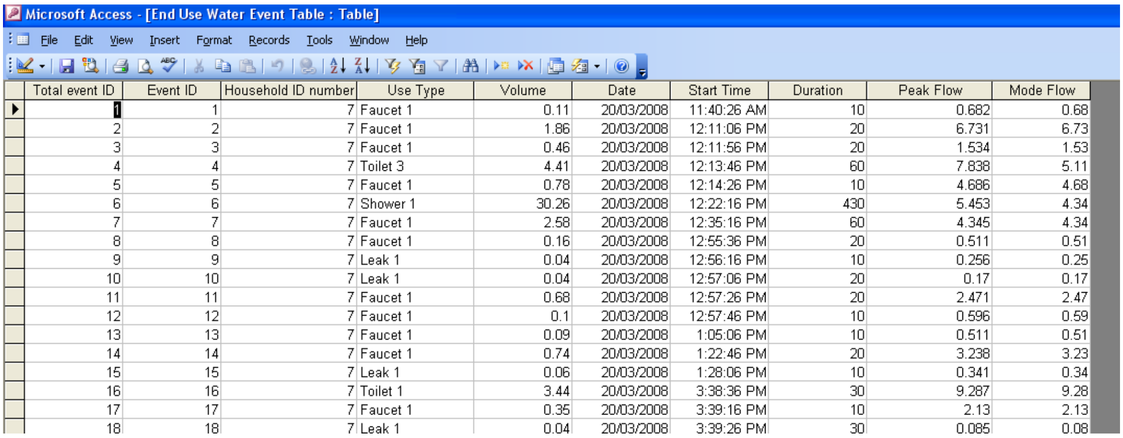


Figure 3-6 Sample Trace Output

Once the analysis has taken place, the final product is a database of water use events which have a fixture ID associated with them. This database is in Microsoft Access format. Each household's completed trace is imported into the main database for further investigation.

3.8 Database Structure

A database of all events was constructed by importing each week's trace from each of the participating households into a central database. This database contained several important tables and queries, such as household demographics, weather data and daily water use queries. This allowed the extraction of data needed to meet specific criteria for the selection and analysis process. A sample of the End Use Water Event Table is shown in Figure 3-7. The database contained 150,153 records in this table. Each event details the household's number, use type, volume, date, start time, duration, peak flow and mode flow attributed to it.


Microsoft Access - [End Use Water Event Table : Table]

Total event ID	Event ID	Household ID number	Use Type	Volume	Date	Start Time	Duration	Peak Flow	Mode Flow
1	1	7	Faucet 1	0.11	20/03/2008	11:40:26 AM	10	0.682	0.68
2	2	7	Faucet 1	1.86	20/03/2008	12:11:06 PM	20	6.731	6.73
3	3	7	Faucet 1	0.46	20/03/2008	12:11:56 PM	20	1.534	1.53
4	4	7	Toilet 3	4.41	20/03/2008	12:13:46 PM	60	7.838	5.11
5	5	7	Faucet 1	0.78	20/03/2008	12:14:26 PM	10	4.686	4.68
6	6	7	Shower 1	30.26	20/03/2008	12:22:16 PM	430	5.453	4.34
7	7	7	Faucet 1	2.58	20/03/2008	12:35:16 PM	60	4.345	4.34
8	8	7	Faucet 1	0.16	20/03/2008	12:55:36 PM	20	0.511	0.51
9	9	7	Leak 1	0.04	20/03/2008	12:56:16 PM	10	0.256	0.25
10	10	7	Leak 1	0.04	20/03/2008	12:57:06 PM	20	0.17	0.17
11	11	7	Faucet 1	0.68	20/03/2008	12:57:26 PM	20	2.471	2.47
12	12	7	Faucet 1	0.1	20/03/2008	12:57:46 PM	10	0.596	0.59
13	13	7	Faucet 1	0.09	20/03/2008	1:05:06 PM	10	0.511	0.51
14	14	7	Faucet 1	0.74	20/03/2008	1:22:46 PM	20	3.238	3.23
15	15	7	Leak 1	0.06	20/03/2008	1:28:06 PM	10	0.341	0.34
16	16	7	Toilet 1	3.44	20/03/2008	3:38:36 PM	30	9.287	9.28
17	17	7	Faucet 1	0.35	20/03/2008	3:39:16 PM	10	2.13	2.13
18	18	7	Leak 1	0.04	20/03/2008	3:39:26 PM	30	0.085	0.08

Figure 3-7 End Use Water Event Table

Crosstab queries were used frequently to sum total volumes according to household numbers, use type, date etc. Figure 3-8 shows a sample crosstab query for calculating the total volume of water used by each use type in each of the households.

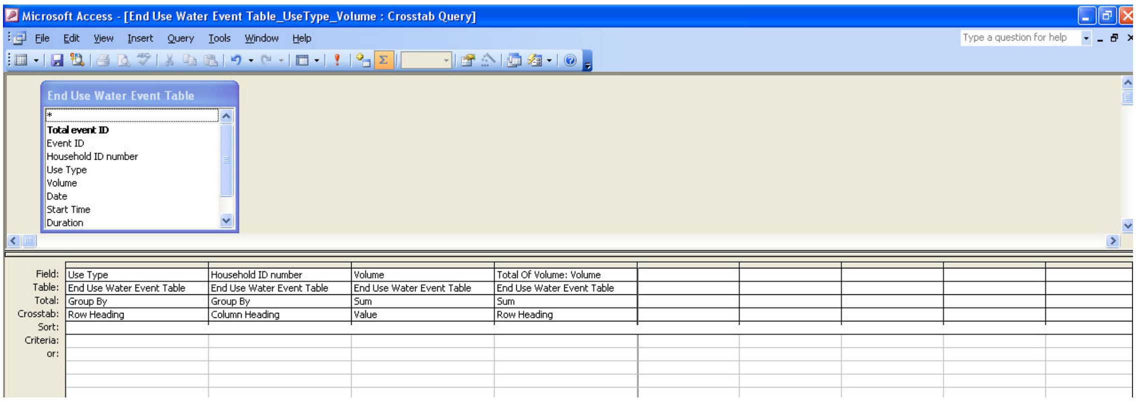


Figure 3-8 Volume/Use type/Household sample Crosstab Query

3.9 Chapter Summary

This chapter has discussed the selection of participants for this study, their distribution and water use characteristics. An overview of the monitoring equipment that was installed at each of the participating households was also given. High pulse count meters (72.5 pulses/litre) were needed to ensure that all water use (down to 14ml), including small events such as filling a glass of water and leaks were detected. The data loggers that were used were unique in that they could auto-report through a GPRS/GSM telephony network so manual downloads were not necessary. The software used to disaggregate flow patterns (Trace Wizard) was explained as well as some of the limitations in its use. The setup of the database that was used to collate and analyse the data was explained and a sample query shown.

Chapter 4 Total Water Use

This chapter describes the total water used by the 10 households (31 people) that were involved in this study. The total water use in this study only encompassed indoor water use, since Toowoomba was on Level 5 water restrictions. All outdoor water use, such as the watering of plants and washing of cars was prohibited on this level of water restrictions.

4.1 Volume Comparison

4.1.1 Daily per Capita Water Use

The daily per capita water used by the study households was obtained for the 138 days of monitoring. These values were used to develop a histogram relating to frequency distribution as shown in Figure 4-1. The distribution is almost symmetrical but with a large peak at 110-120 Lpcd (Lpcd). This symmetrical pattern is expected, since all water use is indoor due to water restrictions, which reduces variability. The mean and median water use are 112 Lpcd and 113 Lpcd, respectively. The standard deviation of daily water use is 22.7 Lpcd or 20%, which suggests a high variability in daily water consumption. 50% of water use was below 113 Lpcd with 90% below 144 Lpcd as can be seen in the cumulative frequency in Figure 4-1. The majority of days come well below the 140 Lpcd target that Toowoomba Regional Council has set. The 95% confidence interval for total daily water use was found to be 3.79 L.

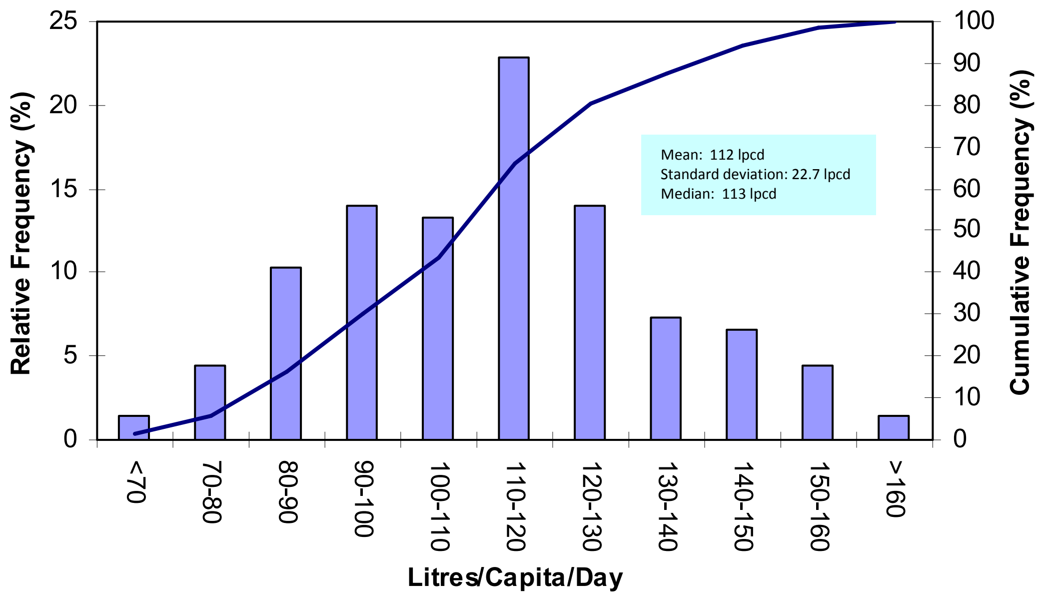


Figure 4-1 Frequency distribution of daily per capita water use

4.1.2 Indoor Water Use

This has been calculated through the summation of all water used by each fixture and appliance in all 10 households and calculating the percentage that each fixture contributed to total water use. The pie chart shown in Figure 4-2 below shows the proportion of water used for each fixture or appliance. Shower use contributed the largest component of total water use at 43.5 %. Washing machines used the second largest amount at 22.7 %, followed by faucets at 15.5 % and toilets at 12.76 %. Leaks were minimal when compared to other studies (29.8% EBMUD, 2% Perth) at 0.36 %, most of these leaks were not constant. It appears that dripping faucets were turned off properly after a short period of time. The leakage in these households is small probably due to the newer age of the houses in this study or the awareness of the shortage of water which motivates people to locate and fix any leaks that they may have. Not all households had dishwashers or used the bathtub so these values are relatively small due to this. The outdoor use detailed here was found in only two households.

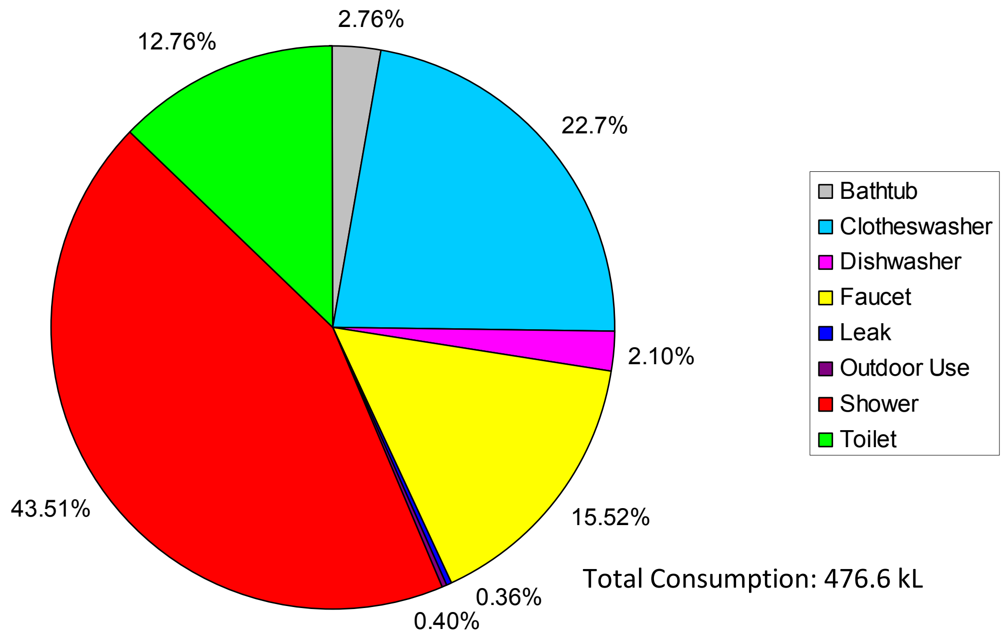


Figure 4-2 Percentage Volume of fixtures and appliances

The prevalence of leaks and the use of dishwashers, baths and outdoor use are better shown in Figure 4-3 which shows water consumption per appliance for each individual house. This once again shows the higher proportion of water that is used in the shower and washing machine, but also the range of values that are possible for faucet and toilet use which would depend on the type of device fitted in the home. Household 6 has a very small faucet use; this household consists of a single person who uses the dishwasher for everything (including pots/pans) and does not pre-rinse dishes which might explain this lower value. From this figure, it can be seen that leaks are concentrated in a small number of homes. The outdoor use seen here was found to be the watering of pot plants in household 7 and the use of water to clean and refill ponds and dog kennels in household 6.

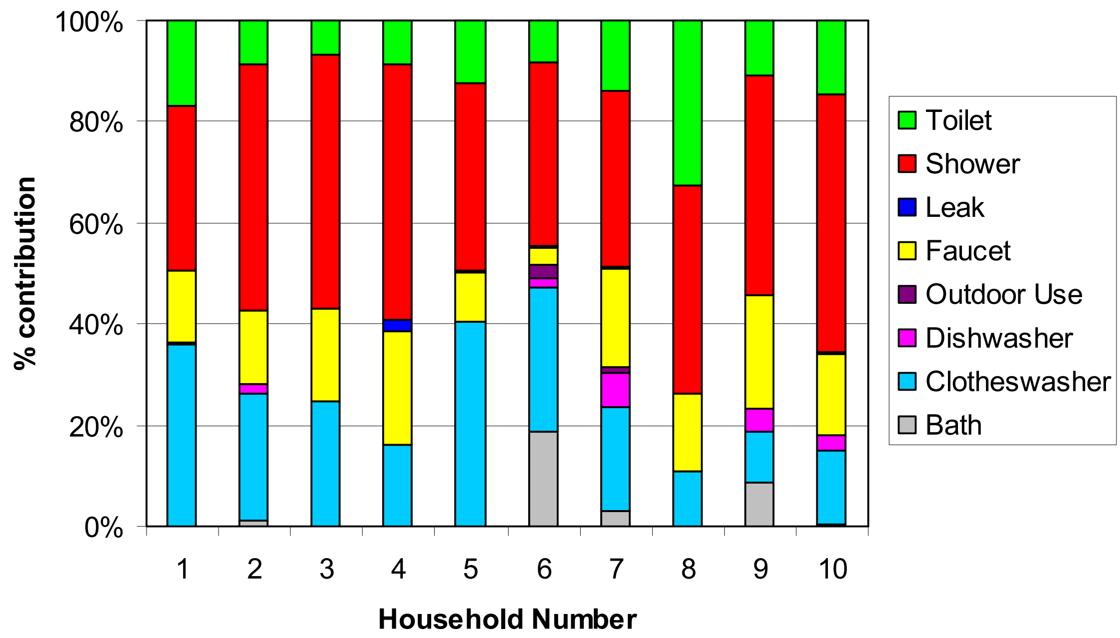


Figure 4-3 Water Consumption per appliance in individual households

From this analysis, it is clear that Toowoomba Regional Council needs to place additional emphasis on shower use which is consistently high and also washing machine and toilets whose importance vary depending on each household's characteristics. These characteristics could include the number of people residing in each home, the type of washing machine or toilet in use and the attitudes and habits that affect their use. TRC currently has a free shower rose exchange program, and has offered rebates on washing machines and the retrofitting of single flush toilets. These initiatives align well with the results from Figure 4-2 and Figure 4-3 and are discussed further in Chapter 7 – Effectiveness of Demand Management Initiatives.

4.1.3 Effect of Temperature on Total Consumption

An attempt was made to check if there was any correlation between the maximum daily temperature and the water used by all the houses. The general hypothesis that higher temperatures lead to higher water consumption was not verified. Figure 4-4 shows a poor correlation (5%) between the two parameters with a decrease in consumption as temperatures get higher. This could be due to random variation. It is shown that indoor water consumption is independent of the temperature during the study period. The temperatures recorded during this time rarely went above 30°C, where it is expected that showers and the use of washing machines may have contributed to higher volumes, however this was not verified here. Any anticipated increase in outdoor consumption, due to increased temperature may not have been apparent in this study given TRC's current ban on external watering.

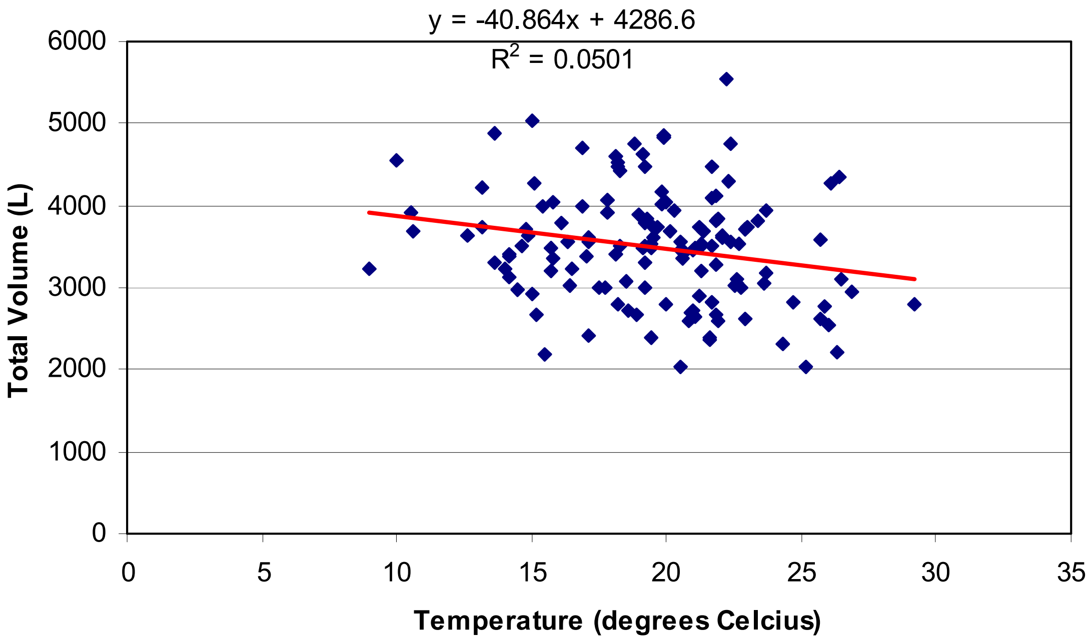


Figure 4-4 Temperature vs. Total Volume used

4.1.4 Effect of Capita/Household on Total Consumption

Another hypothesis that was tested was that water consumption per capita would decrease with increasing household size. Figure 4-5 shows a general decrease in consumption but with a relatively low fit (31%). The most variation was seen with single households whose consumption was as low as 88 Lpcd and up to 280 Lpcd. This suggests that the attitudes of householders have as much to do with consumption as the size of the household.

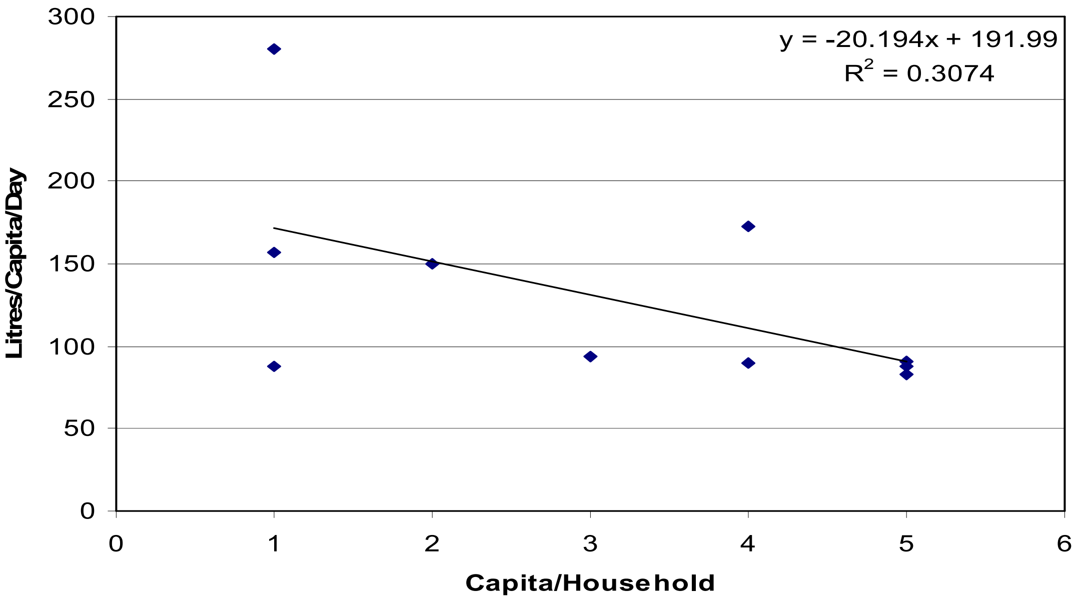


Figure 4-5 Effect of household size on Total Consumption

4.2 Planning Parameters and Key Peaking Factors

A fundamental consideration for the sizing of water systems, or its parts, is an estimate of the amount of water expected to be used by customers using the system (Water System Design Manual 2001). Although there are guidelines given for Queensland, there is no accurate data related to the residential demand under different levels of water restrictions. The design of water systems requires estimates of water demands applicable to the sizing of system pumping equipment, transmission and distribution lines, and storage facilities. Water restrictions would decrease the sizing requirements but will have a big impact on detention times and the age of the water. This will have an impact on the residual chlorine levels, so it is still important to be able to estimate the average demand and peaking factors to ensure that the water supply system is operating within acceptable limits.

Figure 4-6 shows the variation of demand across the study period, the average of this is the Average "Annual" Demand (112.6 Lpcd). The monthly demand was summed and divided by the number of days and the number of people, to give an average monthly demand per capita. The standard deviation shows the weekly variation in average demand. As this study only ran for four months this value may vary from a true 'annual' demand.

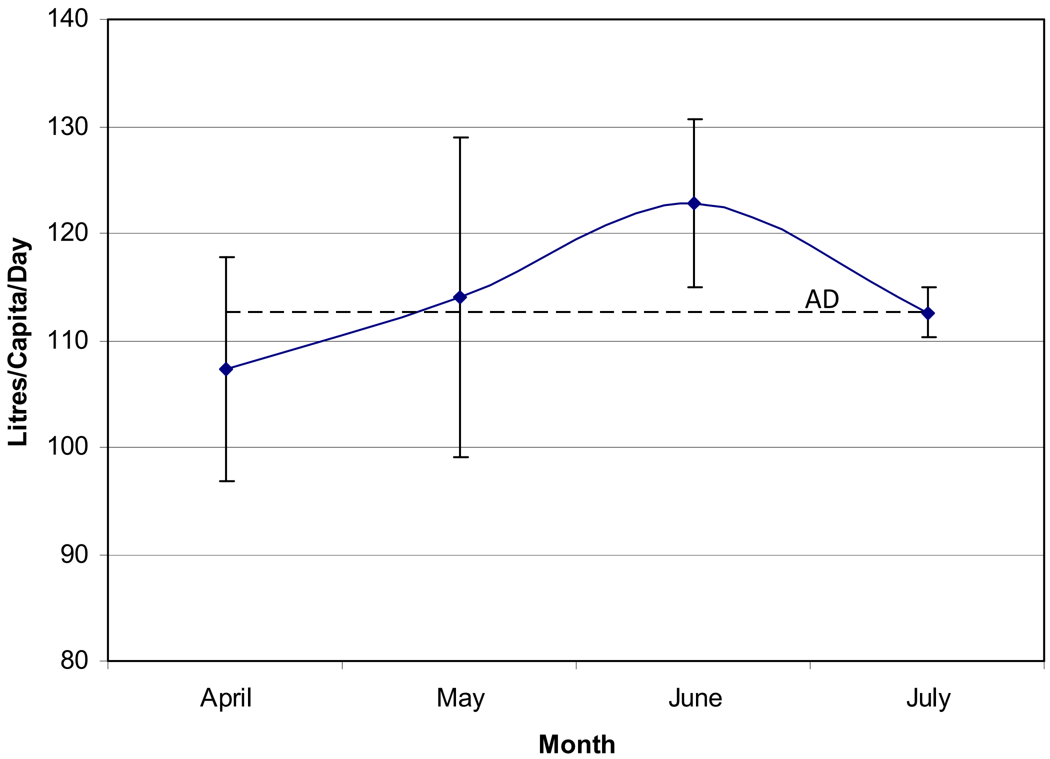


Figure 4-6 Flow Variation - Monthly

The month containing maximum usage is hence June. Figure 4-7 shows the variation of flows across June on a weekly basis, the average of this becomes the Maximum Monthly Demand (MMD) (120.65 Lpcd). This is higher than the Average Day Demand. The standard variation shows the difference in daily consumption values.

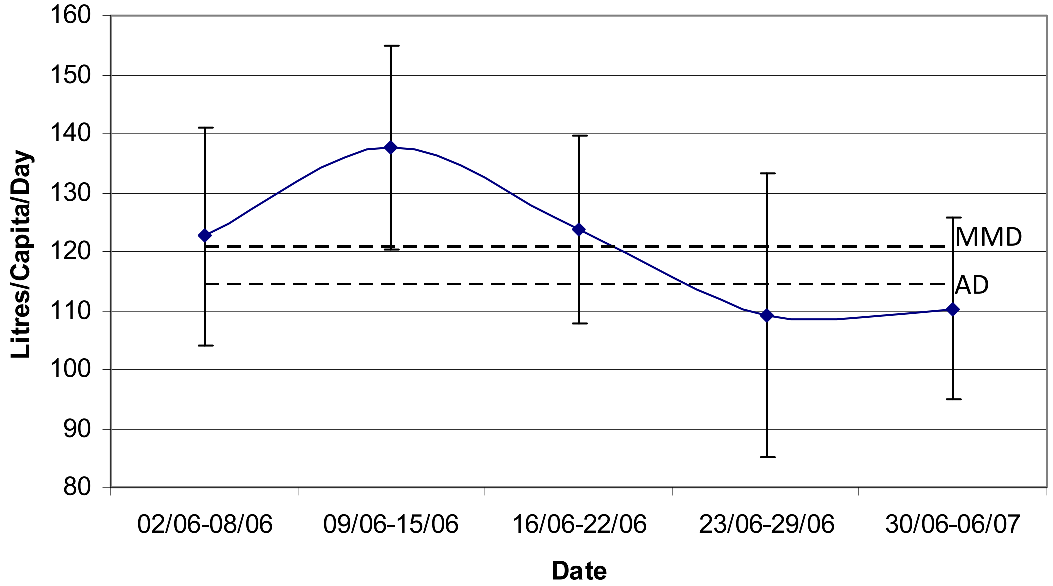


Figure 4-7 Flow Variation - June (Maximum Month)

The maximum week is therefore Week 24 (09/06 – 15/06). Week 24 is shown in Figure 4-8 split into daily flows. The average of these values gives the Maximum Weekly Demand (MWD) (138.3 Lpcd).

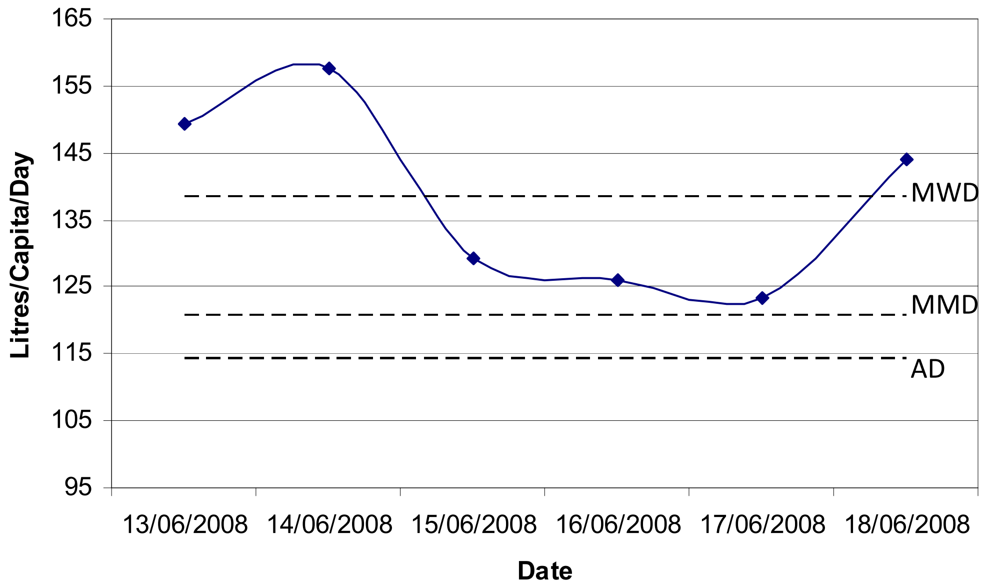


Figure 4-8 Flow Variation Week 24

The maximum day is therefore the 14 June. The diurnal demand on this day is shown in Figure 4-9. The average of the diurnal pattern gives the Maximum Daily Demand (MDD) (156.8 Lpcd).

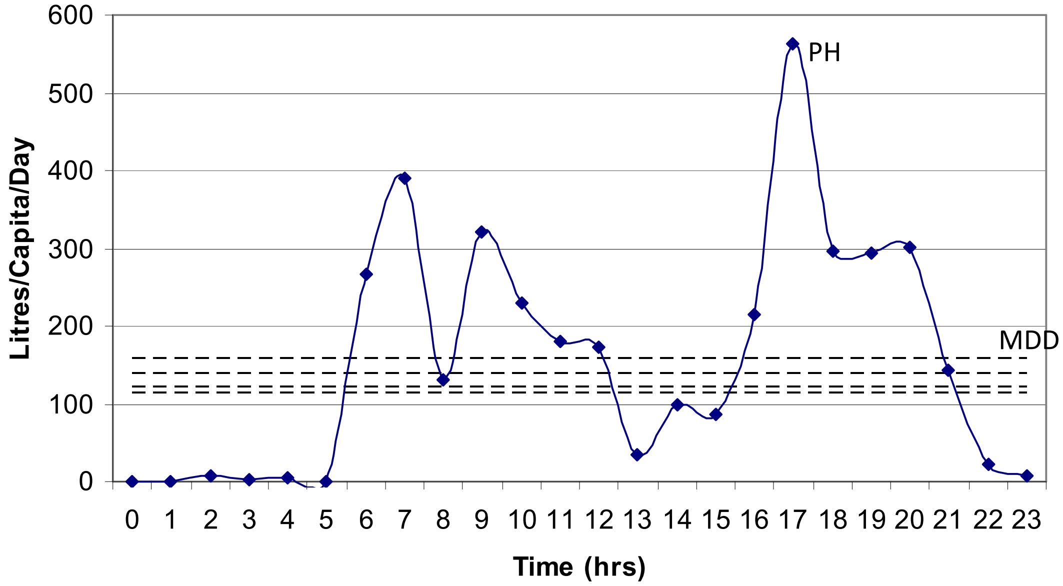


Figure 4-9 Flow Variation 14 June

The instantaneous peak demand occurs at 6pm on 14th June with a peak hour demand (PH) of 562.5 Lpcd. The 14th of June was a Saturday, which accounts for the higher use.

The calculation of Mean Day Maximum Month is slightly different because it uses a 30 day moving average. This meant that only 107 days of the data that was collected could be used to calculate the MDMM value. Figure 4-10 shows the graph produced by calculating the 30 day moving average.

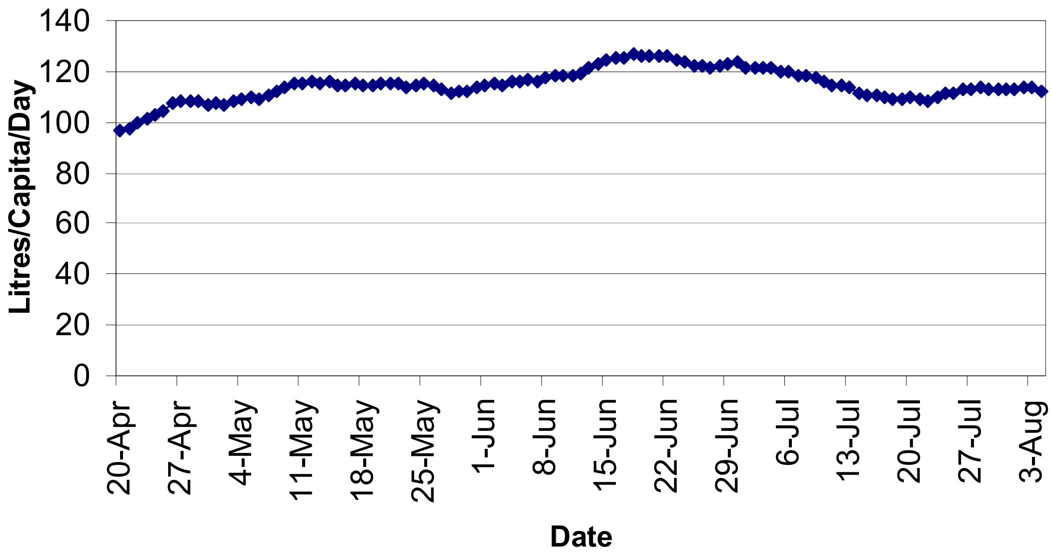


Figure 4-10- Mean Day Maximum Month Values

The highest daily water demand using the 30 day moving average was 126.9 Lpcd. The results from this analysis are summarized in Table 4-1.

Table 4-1 Water Supply Planning Parameters

Parameter	Abbreviation	Comments	Value
Average Day Demand	AD	Total Demand during study period divided by number days of study period	112.6 L/Capita/Day
Mean Day Maximum Month	MDMM	The highest 30 day moving average daily water demand during the study period	126.9 L/Capita/day
Peak Day Demand	PD	Water Use on the maximum usage day	156.7 L/Capita/Day
Peak Hour	PH	Water use during the maximum hour of usage equivalent to the peak instantaneous demand	562.5 L/Capita/Day

Peaking factors (ratio of peak: average flows) are used to evaluate the water demand flow, generally used in the design of transmission pipes, service reservoirs and reticulation systems. These values are generally taken from the Queensland Planning guidelines, which gives ranges of overall peaking factors. These guidelines were created when there were no water restrictions (therefore residential water use also included outdoor water consumption) and without consideration of drought conditions or other aspects that may affect the peaking factors. The peaking factors for the 31 people in this study were calculated and are shown in Table 4-2.

Table 4-2 Peaking Factors

Factors	Queensland Planning guidelines (<5000 people)	Study Value (31 people)
MDMM:AD	1.4 - 1.5	1.13
Peak Day Factor PD:AD	1.5 - 2.0	1.39
Peak Hour Factor PH:AD	3.0 - 4.0	5.00

The MDMM:AD value calculated for this study is much lower than the predicted range, which means that the Average Demand does not differ greatly from the average day during the maximum month. This is due to the reduction in the variability between seasons because of the introduction of water restrictions (no irrigation during hot days etc.). The Peak Day Factor calculated is slightly lower than the predicted value. Once again this shows the impact that water restrictions have on the variability of demand. The peak hour factor is much higher than the Queensland Planning Guidelines. The reason behind this is related to the nature of peak hour demand which is generally caused by people having showers and not by outdoor use such as irrigation. As the average demand has dropped significantly due to water restrictions and the peak hour demand has not, the peak hour factor is much larger than the estimated value.

4.3 Demand Patterns

Establishing water demand curves is very complicated when accurate end use data is not available. It is usually done in Toowoomba by analyzing reservoir levels and using the decrease in level as an indicator of water demand. This method is plausible, but with Toowoomba’s supply significantly supplemented by bores, it is not possible to integrate this volume of water supplied with the reservoir levels. Consideration also needs to go to the variation in demand that occurs over weekends or during hot weather (if irrigation occurs). Demand patterns determined from reservoirs only provide a snapshot of the demand and cannot reveal these differing trends.

4.3.1 Hourly and Half Hourly Residential Demand

The total residential demand was calculated by summing the total volume required hourly (or half hourly) by all houses and dividing this by the number of days of logging and the number of households. This gives a demand value of Litres/household/hour (or half hour). Figure 4-11 and 4-12 below shows the demand pattern for the 10 households studied on a half hourly basis and hourly basis respectively.

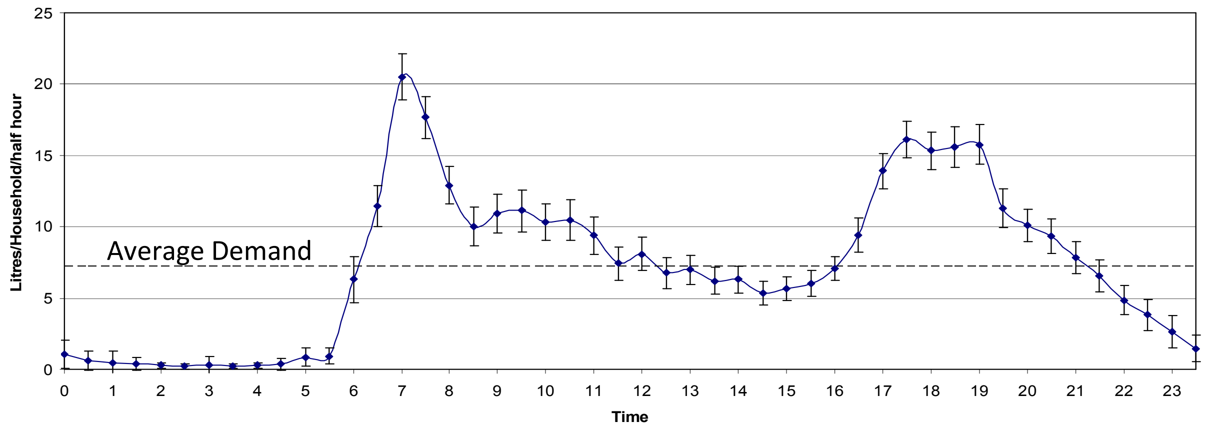


Figure 4-11 Diurnal Demand Pattern – Half Hourly

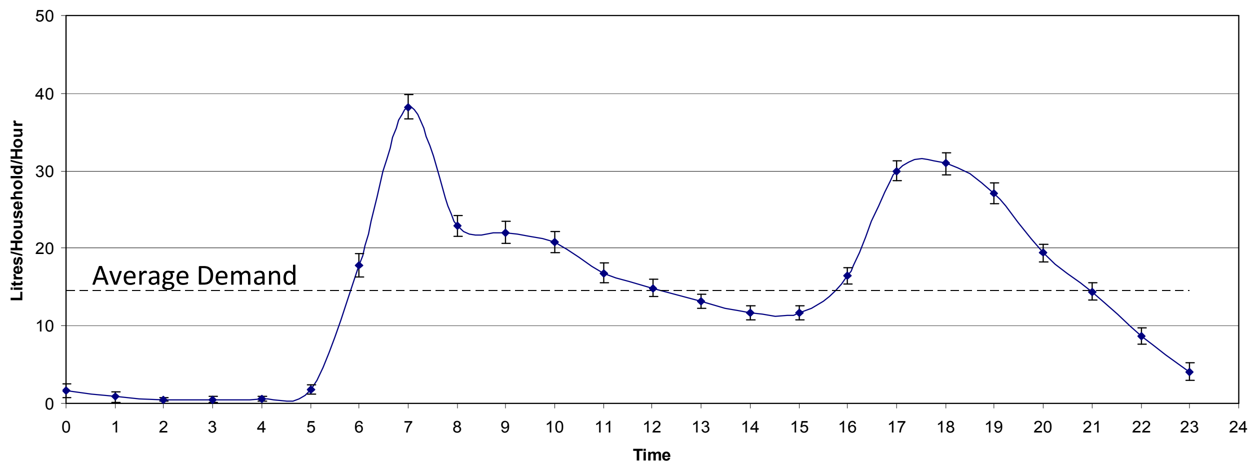


Figure 4-12 Diurnal Demand Pattern - Hourly

From the figures above, the demand pattern in Toowoomba represents the typical demand pattern. Very low flow is recorded during the early morning, with the highest peak between 6am and 8am before people go to work and school. Demand decreases during the day with another peak in the evenings that relates to people coming home and using water for showering, dinner preparation and clean up. There is not much difference between the hourly and half hourly patterns so only hourly diurnal patterns have been used in the next sections.

Further to this analysis, a diurnal demand pattern was constructed that showed what kind of appliance or fixture was in use during each hour of the day. Figure 4-13 below shows the relative usage of each appliance throughout the day according to the ten households studied. Showers account for the most fluctuation in the demand pattern, with a high morning and afternoon peak. Clothes washers are used mainly in the mornings, contributing to a higher mid morning point. Baths mainly occur in the early evening, with the use of dishwasher peaking later on in the night between 7pm and 8pm. As expected toilet and faucet use is lowest during the middle of the day when the least people are home and higher in the mornings and evenings.

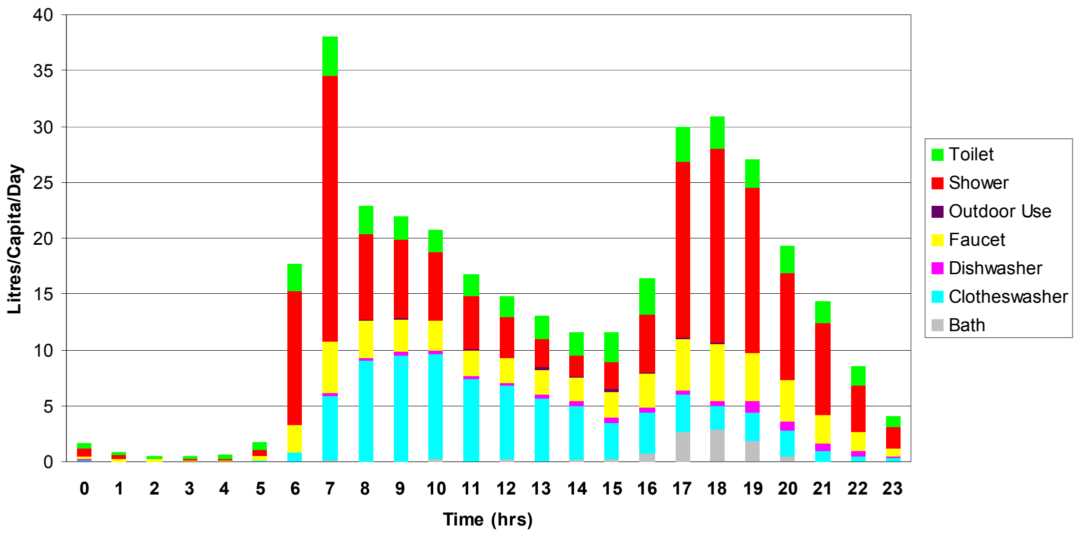


Figure 4-13 Diurnal Demand Pattern for Appliances and Fixtures

4.3.2 Weekday and Weekend Demand Pattern

The demand pattern fluctuates from the week to weekends because the majority of people spend a greater portion of time at home throughout the weekend. Figure 4-14 below shows the effect that this has on the diurnal demand pattern. The standard deviation has been calculated by looking at the difference between the days rather than each day, for example Mondays and Tuesdays rather than 16/06/08 and 17/06/08.

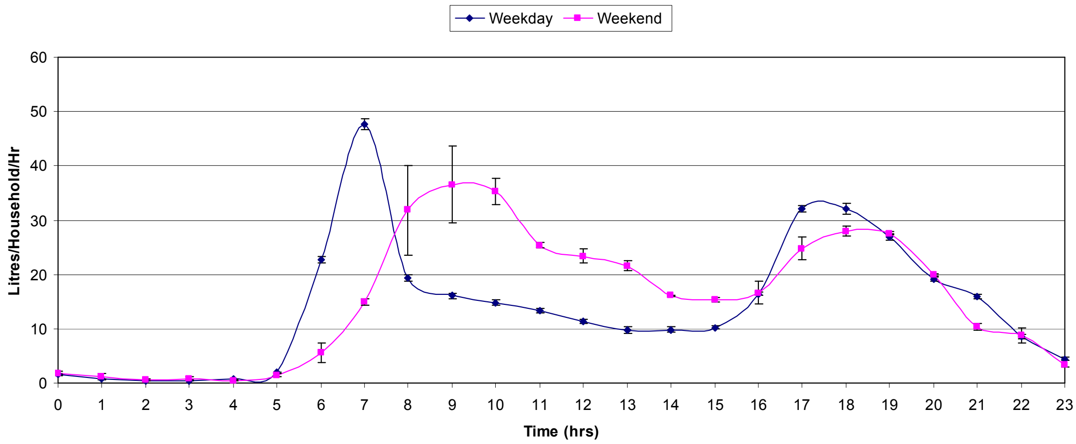


Figure 4-14 Weekend and Weekday Diurnal Patterns

The weekday and weekend pattern from the 10 households that were being studied varies as expected. The weekday diurnal pattern has a higher peak earlier in the morning and a much lower day use than the weekend; while the peak in the evenings is slightly higher and the whole pattern has a very small variability. The weekend diurnal pattern has a lower but more extended morning peak that is highly variable form Saturdays to Sundays. Water use continues at a higher rate throughout the day with a gentler peak in the evenings. The weekend use is different due to the propensity of people to get up later, use more water during the day as they are generally home, and doing a greater proportion of clothes washing.

Due to the significant fluctuation that was found when comparing weekend to weekday used, more information was needed as to which appliances contributed the most to this phenomenon. Figure 4-15 below shows the relative volumes of water used in the different fixtures relative to the day of the week. This clearly shows the increase in volume of water used in washing machines on a Saturday as well as an increase in toilet and faucet volumes, closely associated with a greater number of people being at home.

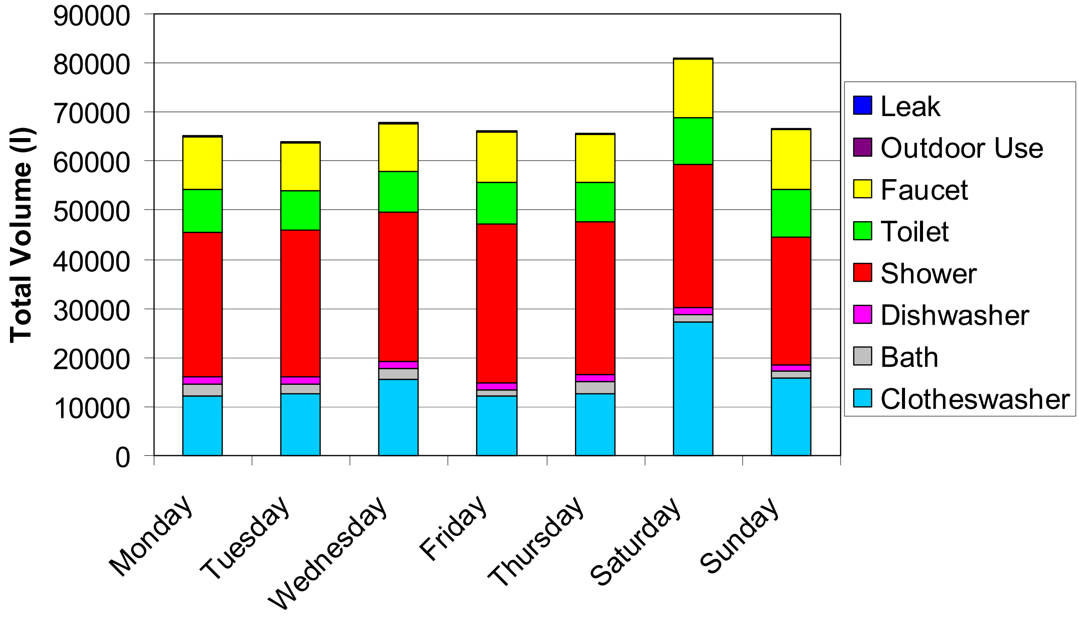


Figure 4-15 Daily Volume used by Appliances and Fixtures

4.3.3 Seasonal Differences

There is expected to be a seasonal difference in diurnal demand patterns due to the temperature change and the length of day change that occurs from summer to winter. Figure 4-16 shows the diurnal pattern that occurs when comparing the 3 hottest weeks (March –April 08) and the three coldest weeks (July 08). The standard deviation was calculated by comparing the weekly volume/hour within the three weeks.

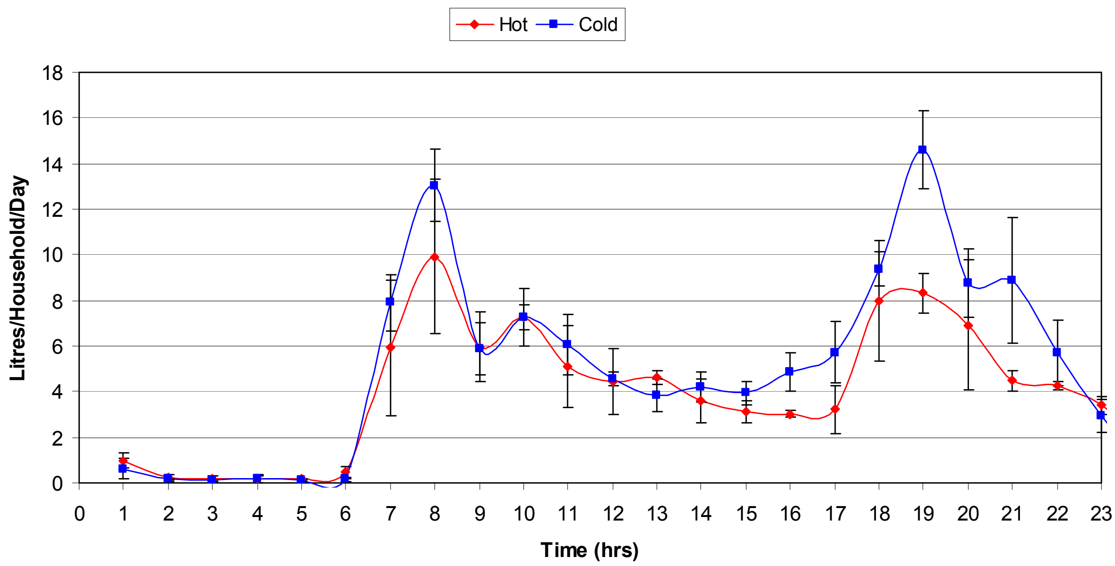


Figure 4-16 Hot and Cold Weather Demand Pattern

The variability in these values is significant but is probably due to the very few weeks of data that was used to calculate these values. From the graph it can be seen that water use peaks much higher during the colder weeks of the time studied. This could be due to householders taking longer showers due to the colder weather. Another possible reason is that the warmer weeks were also the first weeks that residents were being monitored so they were very aware of their water use behaviour.

4.4 Chapter Summary

The average water consumed by the ten households under study was found to be 112 Lpcd. No seasonal trend was observed due to the introduction of water restrictions which reflects the non-seasonal nature of indoor use. Most of the indoor water use was attributed to showers (43.51%) and washing machine use (22.7%); these proportions vary depending on different households. Shower use varies from 35% up to 50% of consumption and washing machine use varies from 10% up to 40%. As expected, no trend was apparent in relation to total water use and maximum temperature. There was a decrease in total volume consumed in larger households due to the economies of scale that arise from the use of washing machines, and the presence of small children in the larger households which reduces water consumption.

Water restrictions have affected the peaking factors due to the lower average demand. The demand curve established for the ten households represents a typical pattern with the highest peak in the morning and a lower peak during the evening. Most of this peak was found to be due to shower use and the use of washing machines in the morning. A significant difference was found between the weekday and weekend diurnal pattern, with weekends tending to have a lower, later and longer peak during the mornings and continued use throughout the day. After examining the weekly pattern in its different use types, it was found that this was mainly due to the increase in water use by washing machines on Saturdays, as well as the increase in the use of toilets & faucets.

Chapter 5 Water consumption by Volume Based Appliances/Fixtures

This chapter discusses the water used by appliances such as washing machines, dishwashers and toilets where a fixed volume of water is needed for the water events. The parameters affecting the volume of water used by each of these appliances is critically analysed based on the data collected during the study period. This chapter also includes a model that simulates the total amount of water used and water savings that can be achieved by switching to water efficient appliances.

5.1 Washing Machines

There are many different brands, models and sizes of washing machines available on the market. These have been categorized into the two main types of washing machines; the front loader and the top loader. Front loading washing machines are considered to be more water efficient than top loaders. There is no survey data available regarding the type of water appliances used in Toowoomba households. TRC has been encouraging residents to switch to front loading washing machines because they can save a large amount of water that would otherwise be wasted. This research explores this assertion and determines whether this is justified. The different types of washing machines that were encountered in this study are summarized in Table 5-1.

Table 5-1 Washing Machine Brands, Models, Size and Type

Brand	Model	Size (kg)	Type
Miele	Novotonic	5	Front
Kleenmaid		8	Top
Fisher and Paykal		5.5	Top
Ariston		7	Front
Maytag	Performa	8	Top
Fisher and Paykal		Lge	Front
Samsung	Triflo	7	Top
Simpson	Esprit450	4.5	Top
Whirlpool		7.5	Front
Electrolux		8	Top

Figure 5-1 shows an example of a washing machine cycle, showing a wash and two rinse cycles. This is typical of a top load washing machine, which has few cycles but uses a large volume.

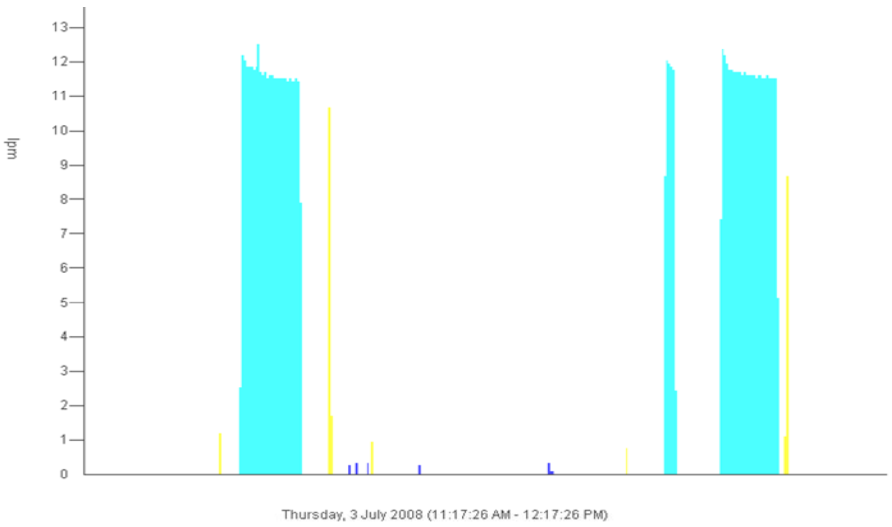


Figure 5-1 Washing Machine Trace

The parameters that affect the total volume of water were identified as:

- Volume/Cycle
- No. cycles/capita/day
- Persons/household

The volume per cycle depends on the type of washing machines in the home. There are two main types of washing machines; the front loader and the top loader. There were 402 front load cycles recorded and 581 top load cycles recorded during the study. Figure 5-2 shows the difference in volume/cycle of each of the washing machine types.

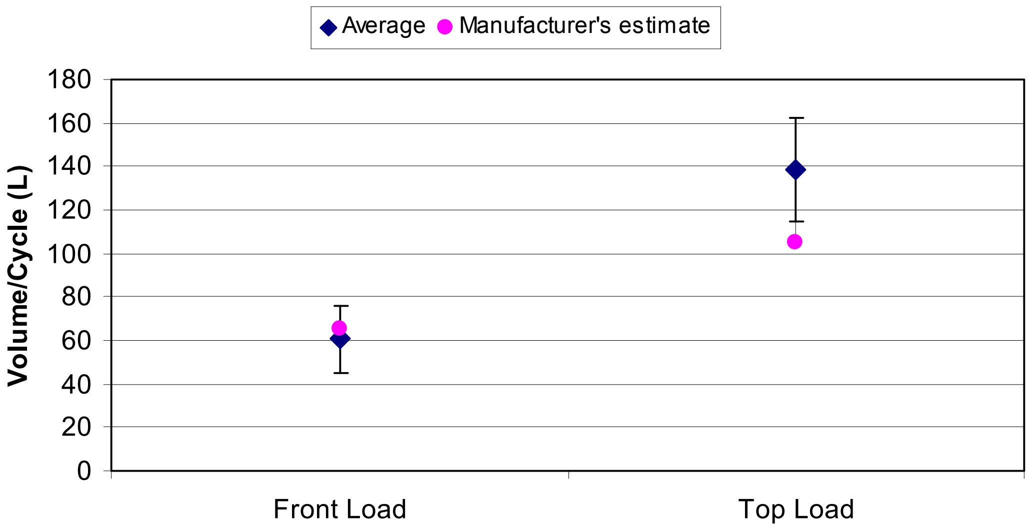


Figure 5-2 Washing Machine Volume/Cycle

Front load washing machines use an average of 60.6 ± 15.7 L per cycle, whereas top load washing machines use 138.9 ± 23.9 L per cycle. Manufacturer's estimate that front load washing machines use 65 L/cycle and top loaders use 105 L/cycle. Top load washing machines use more than double the amount of water as front loaders. The standard deviation of volume/cycle is 26% and 17% of the mean for front and top loaders respectively. This could be due to the different models, makes and sizes of the machines as well as different types of cycles used or the differing size of the loads. The 95% confidence intervals for top load and front load washers were found to be very wide at 12.6 L/cycle and 23.422 L/cycle respectively. The differences in volume/cycle could be due the size of the washer or the type of cycle used.

Manufacturer's estimates on front load washing machines vary between 56 L and 70 L with an average of 65L/cycle as shown in the graph (Good Guys catalogue). Values from this study vary between 48 L and 82 L. The size of the wash would affect the volume/cycle. The average volume used by a front load washing machine is 60 L which falls well within the manufacturer's estimate. Manufacturer's estimates of water used by top load washing machines vary greatly from as low as 62 L/cycle up to 161 L/cycle with an average of 105 L/cycle as shown in Figure 5-2 (Good Guys catalogue). These estimates have come from new washing machines that are subject to the new water rating scheme, so these estimates are likely to be lower than the estimates are for the washing machines that are in the houses being studied. Top load washing machines use 139 L/cycle on average, the minimum being 100 L/cycle up to 163 L/cycle. These values fall on the higher end of the manufacturer's estimates but this could be due to the age of the top load washing machines in the study group. From this data, switching from a top load to a front load can potentially save 79 Litres per wash.

The second parameter of interest is the number of cycles/capita/week, which varies due to a number of reasons. The effects of seasonality, economies of scale and types of washing machine have been looked into here.

The difference in the number of cycles/capita/week as affected by seasonality is shown in Figure 5-3. The mean and standard deviation were calculated by summing the number of cycles in each week of the month and dividing this by the number of people under study.

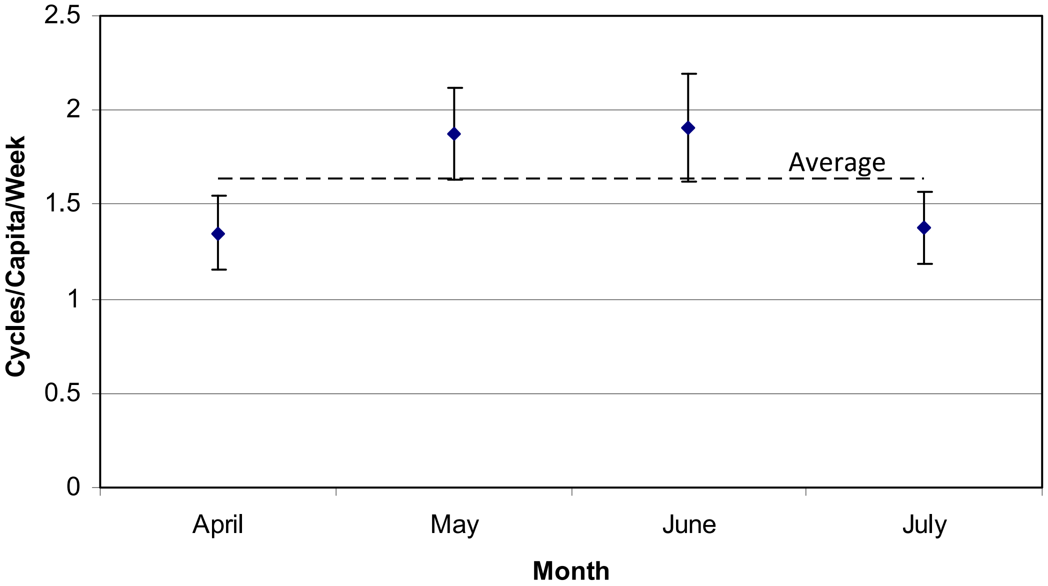


Figure 5-3 Washing Machines Seasonal Variability

Based on the data collected from the 10 households, the average cycles/person/week was found to be 1.63. This value was compared to the use of washing machines in the Tampa, Florida study which estimated washing machine usage as 2.94 cycles/capita/week. This shows a large difference which could be due to the better awareness of Toowoomba residents about water savings, one of which is to do large loads of washing. There is very little difference between the number of cycles per week over the study period, which suggests that the capacity of the washing machines has nothing to do with the increase/decrease of loads. As only four months of data was collected, there was no seasonal variation observed but a seasonal trend may still occur so a whole year's data would be needed to determine if there was a significant seasonal effect on the number of cycles/week.

As expected the number of people living in a house dramatically affects the number of cycles/capita/week as economies of scale come into effect. For example, a single person may do three loads of washing/week; one for whites, one for colors and one for delicates. These loads would generally be very small as there is only the one person's washing to do. A large household on the other hand may do six loads of washing, but the loads will always be full. The number of washing machines cycles was known for each household, the size of the household was also known from the initial survey. From this information, the number of cycles/capita/week could be calculated for the each of the different sized households. Figure 5-4 below shows the effect household size has on the number of cycles/capita/week.

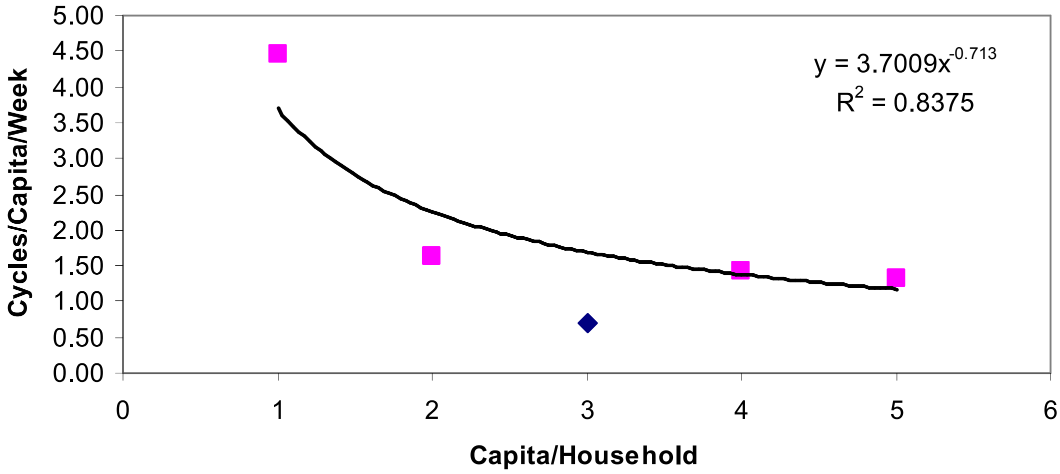


Figure 5-4 The Effect of Household size on Cycles/Capita/Week

The trendline shown does not take into account the household with 3 occupants as this household is made up of university students who rely on their parents to do some washing. Based on this graph, the lower the number of occupants, the higher the cycles/capita/week value which results in a higher volume of water needed. The trend can be modeled as $y=3.7009x^{-0.713}$. However, this investigation only takes into account ten households with a total of 31 people. The proposed model would need to be validated with at least 100 households with varying numbers of occupants.

The last factor that could affect the number of cycles/capita/week is the type of washing machine. Figure 5-5 shows the average number of cycles/capita/week for each of the different types of washing machines. This was calculated by averaging cycles/capita/day for the households with the different types of washers. Those households that have front load washers, wash on average 3.01 times/capita/week but have a high variation of 2.2 times/week. Those households that use top load washers wash only 1.37 times/capita/week with a smaller variation of 0.61 times/capita/week. Although this finding seems significant the effect of the number of capita/household will have an effect on these results because most of the households with top load washers were in fact the larger households in the study, this is reflected in the standard deviation of the values. This phenomenon will need to be further investigated in a larger study.

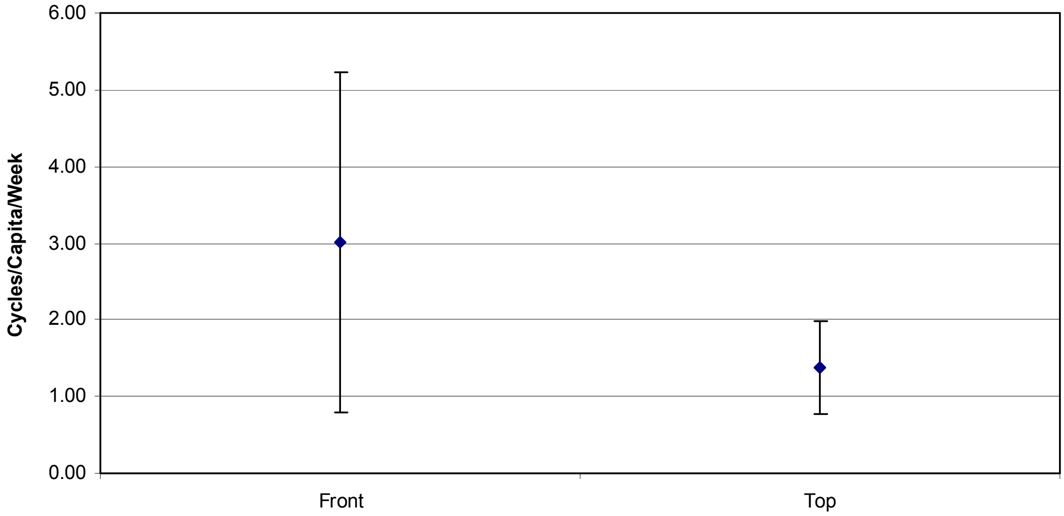


Figure 5-5 Effect of type of washing machine

Based on the investigation of the data collected, the following model is proposed to express the total volume consumed by different washing machines. The volume/cycle depends on the type of washing machine present. The number of cycles/day depends on the number of persons in the household as defined above.

$$\text{Volume}_{\text{Total}} = \frac{\text{volume}}{\text{cycle}}\sum(\text{front load, top load})\times(\sum\frac{\text{No.cycles}}{\text{capita}\times\text{day}}\times\frac{\text{person}}{\text{household}}\times\text{No.households})\times\text{No.Days}$$

This formula has been used in Table 5.2 below to calculate the total volume used by washing machines in the study. A simulation of the total volume of water used by Toowoomba residents has also been undertaken along with a comparison that shows how much water can potentially be saved if all households switch to front loading washing machines.

Table 5-2 Washing Machine Simulation

Simulation Details	Type	Ratio	Volume/Wash	Cycles/capita/day	Capita/household	No. households	No.days	Total Volume (ML/year)	Actual
Study Group	Front	0.4	60	0.236	3.1	10	138	0.108	0.108
	Top	0.6	138	0.236	3.1	10	138		
Toowoomba	Front	0.26	60	0.283	2.4	40100	365	1171.163	
	Top	0.74	138	0.283	2.4	40100	365		
Toowoomba (all front load)	Front	1	60	0.283	2.4	40100	365	596.923	
							Simulated Savings	574.24	

The simulation results show that the formula is useful for estimating total volume. The actual result for the study group was 0.108028 and the simulated volume is 0.107815, very close to the actual results. Using this formula and data from the Australian Bureau of Statistics an estimate of volume used by washing machines in Toowoomba was calculated as 1171 ML/year. The ratio of front to top load washers was found in 1999 by a survey undertaken in the US that found the percentage of front loading washers was only 13.3%. This value has been doubled for use in this study due to the water shortage and the impact that rebates that would have increased the prevalence of front load washing machines. A comprehensive survey will need to be done for Toowoomba to determine the actual ratio. A rough estimate of savings was also done and it was found that up to 574.24 ML/year could be saved if all households converted to front load washing machines.

5.2 Dishwashers

Dishwashers were used in 50% of the households, all of whom were using 3 star or better appliances which are considered water efficient. TRC does not currently offer rebates on water efficient dishwashers. The effect that dishwasher ownership has on faucet use is described in 6.2 – Faucets. Table 5.3 below details the different makes, models and cycle used of the dishwashers that were found in this study.

Table 5-3 Dishwasher Brands, Models and cycles used

Brand	Model	Cycle Used
Smeg		Regular
Miele		Universal
Westinghouse		Normal
Dishlex	Ecosafe	Normal
Westinghouse	921	Normal

Figure 5-6 shows a typical dishwasher cycle, the volume of the dishwasher cycles are very specific and typically quite small so Trace Wizard can pick up dishwasher cycles very easily because the parameters can be set very strictly. The small volume events that occur before and after the main cycles are rinse events.

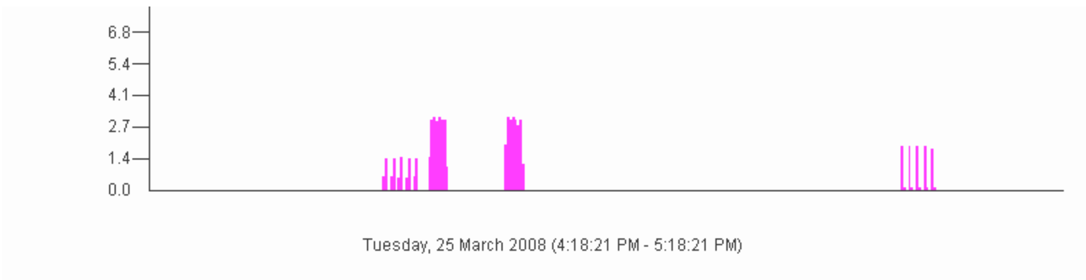


Figure 5-6 Dishwasher Trace

The parameters that affect the total volume of water were identified as:

- Volume/Cycle
- No. cycles/capita/day
- Persons/household

Figure 5-7 shows the range of volumes that were recorded by each of the 5 different dishwashers. The average volume/cycle was found to be 17.69 ± 2.37 L. There were 580 dishwasher cycles recorded in total. The differences between volume/cycle were relatively low, suggesting not much difference between the models. The 95% confidence interval for dishwashers was found to be quite wide at 2.08 L/cycle

Manufacturers estimate that dishwashers use 15 L per cycle. The average volume found is higher than this, but these volumes have been taken from newer models which would be more efficient and waterwise.

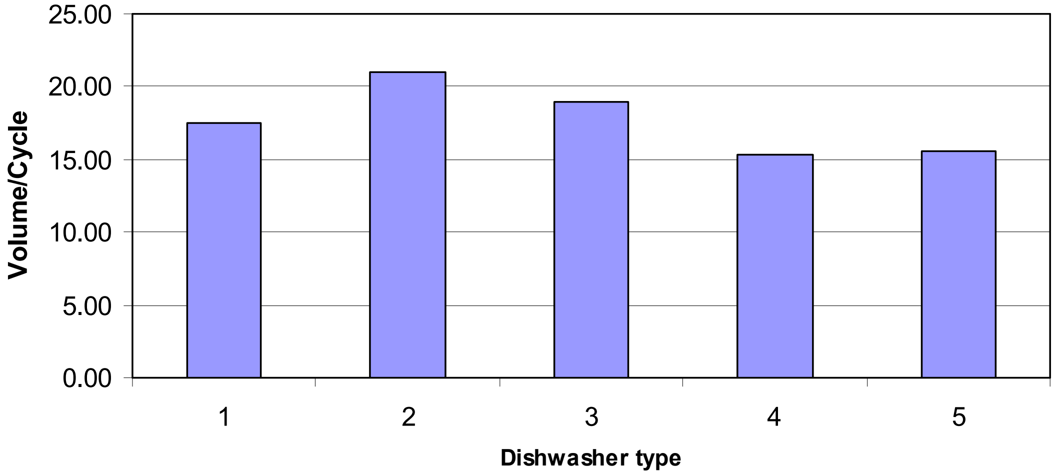


Figure 5-7 Dishwasher Volume

The number of cycles/capita/week will depend on the number of people living in the house. Figure 5-8 shows the effect that household size has on the number of cycles/day. The number of cycles/capita/day is very variable, with no clear trend. After consulting the survey data it was found that the households that used the dishwasher the most were those households that indicated that they placed all pots and pans in the dishwasher and hardly ever hand washed items. The lower values were from households that did not put pots and pans in the dishwasher and hand washed about once a day. This factor cannot be estimated as it relates to people's habits and attitudes rather than their demographics, hence a single value for cycle/capita/day has been used. The average number of cycles per day was found to be 0.95 cycles/capita/week.

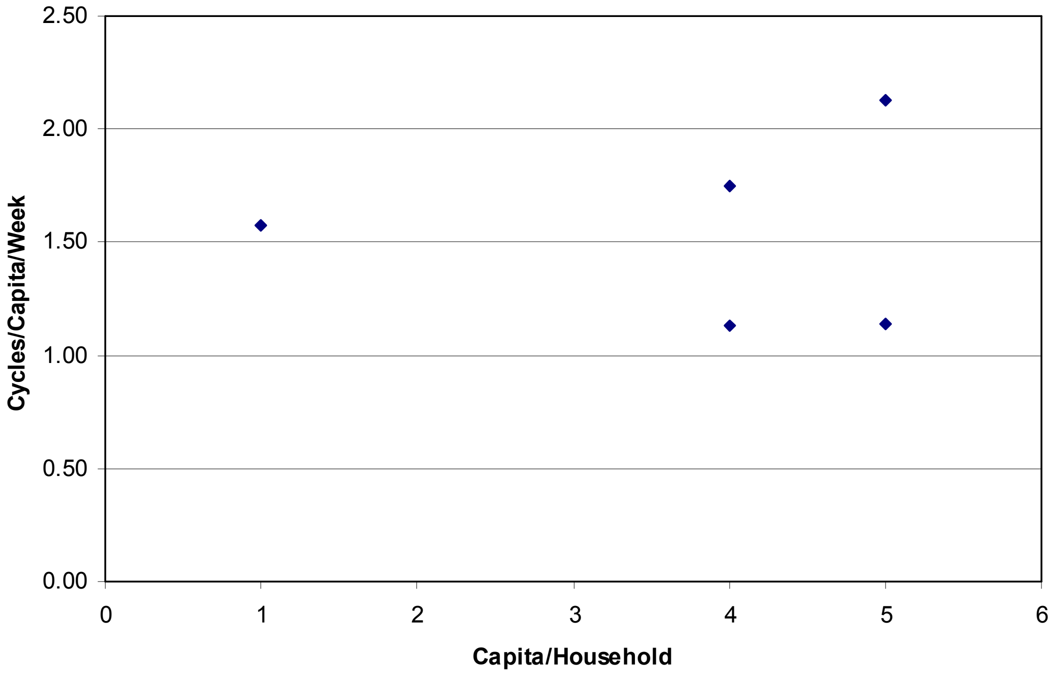


Figure 5-8 Effect of household size on Cycles/Capita/Week

Similar to washing machines, the volume of water used by dishwashers can be expressed as:

$$\text{Volume}_{\text{Total}} = \frac{\text{volume}}{\text{cycle}} \times \sum\left(\frac{\text{No.cycles}}{\text{capita} \times \text{day}} \times \frac{\text{person}}{\text{household}} \times \text{No.households}\right) \times \text{No.Days}$$

Where the number of households with dishwashers has been taken as 50%, these being larger households with 1.23 time as many people as the average house. The number of cycles/capita/day was taken as 0.136 (0.95/7) with the total volume/day being multiplied by the total number of days to give the Total Volume.

Table 5-4 Dishwasher Simulation

Simulation Details	Volume/Cycle	Cycles/capita/day	Capita/household	No. households	No.days	Total Volume (ML)	Actual
Study Group	17.69	0.136	3.8	5	138	0.0063	0.010063
Toowoomba	17.69	0.136	2.94	20050	365	51.76	

This simulation shows that the derived formula and values are not very useful in calculating total volume, with a percentage error of -37%. This is due to the high variability in the number of cycles/capita/week due to the habits of the consumers. From these statistics and values, it is roughly estimated that Toowoomba uses 51.76 ML/year in dishwasher use.

5.3 Toilets

There were a variety of toilets present in each of the households, table below summarises the makes/ model and types of toilet present in the households.

Table 5-5 Toilet Brands, Models & Types

Brand	Model	Type
Fowler	Slimline	Dual Flush
Caroma	Uniset	Dual Flush
Caroma		Hold
Vista		Dual Flush
Caroma		Dual Flush
Hindware		Dual Flush
Caroma		Dual Flush
Caroma		Single Flush
Kelvinware	Deluxe	Single Flush
Verona		Dual Flush

Figure 5-9 shows a typical toilet flush. It has a high flow rate initially which tapers down as the cistern fills up. This toilet has a particularly long tail, which is generally not evident in other toilet traces.

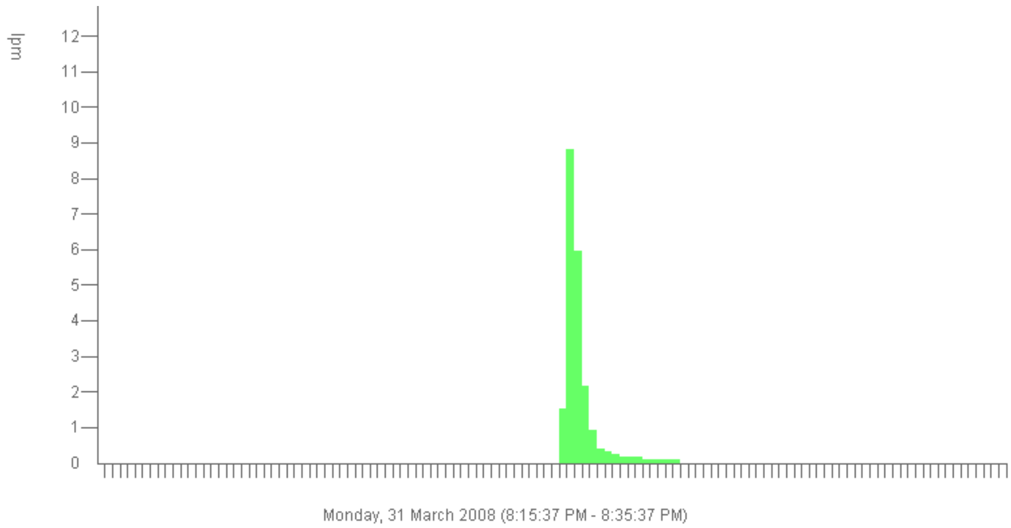


Figure 5-9 Toilet Trace

There were three different types of toilets recorded in the study; single flush, dual flush and button hold toilets. There were 1984 single flush events, 8471 dual flush events and 741 button hold events recorded. Figure 5-10 shows the average flush volumes for the various kinds of toilets along with manufacturer's estimates of these values.

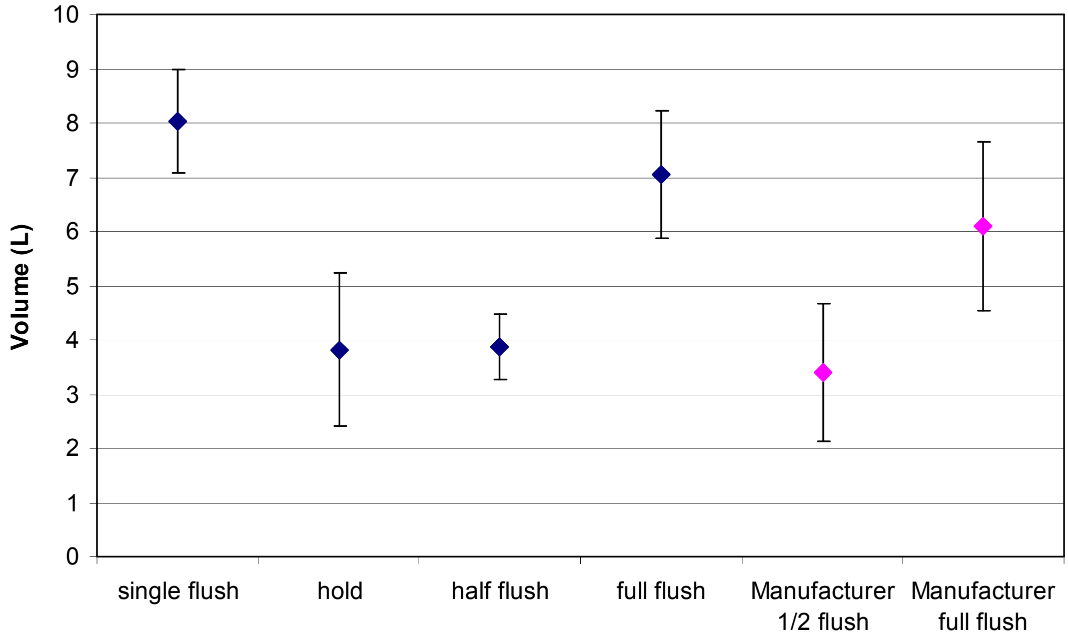


Figure 5-10 Average Toilet Flush Volumes

Single flush toilets have a flush volume of 8 ± 0.95 L (95% CI= 0.04 L) and hold down flush toilets have a flush volume of 3.8 ± 1.4 L (95% CI= 0.1 L). Dual flush toilets have a half flush volume of 3.9 ± 0.6 L (95% CI= 0.16 L) and the full flush volume is on average 7 ± 1.2 L (95% CI= 0.04 L). All toilet flushes have very tight confidence intervals as these were one of the most frequent end uses of water. The manufacturer's estimates for single flush toilets vary with the size of the toilet. Both households that had single flush toilets installed had 9 Litre cisterns although both of these toilets when investigated were set at a lower level than the full mark, hence the lower average value. The higher values can be related to holding the handle down or double flushing. There is no data available for the hold down toilets as to what average volume is used as it would vary dramatically between consumers. The variability can be clearly seen with the standard deviation of hold toilets being 1.4 Litres. The results collected for dual flush toilets show that they have larger flush volumes than manufacturer's estimate. This could be due to consumers holding the button down or some of the faucet use from washing hands being included in the flush volume. The ratio of half to full flush was found to be 65.6% to 35.4% which correlates well with the EBMUD study which found that the value is about 60:40.

The distribution of toilet flushing volume of all recorded flushes is shown in Figure 5-11.

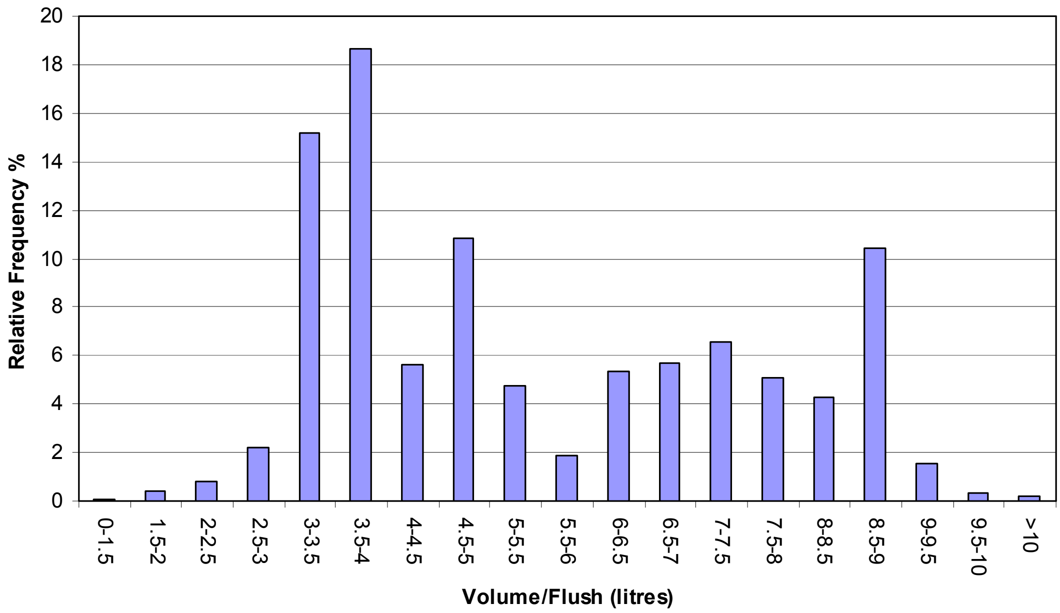


Figure 5-11 Frequency distribution of flush volumes

The frequency distribution shows the variability of toilet flush volumes. The spikes at 3- 4 L and again at 4.5-5 L show the prevalence of half flushes and their associated volume. The spike at 8.5 – 9 L shows where the volume of most single flush toilets. It is unlikely that those flushes recorded at volume below 2.5 Litres are actually toilet flushes and are most likely errors in data appliance aggregation.

The number of flushes/capita/day is dependent on the number of adults (small children were not included) remaining at home during the day. This was taken as those people remaining in the home for the majority of the week (4 days) during school hours. Figure 5-12 shows the relationship between the number of people at home during school hours and the number of flushes. If no one is home during school hours (0 people), then the number of flushes per capita remains at 1.58, which represents the number of flushes outside of those hours. The average flushes/capita/day is 2.62.

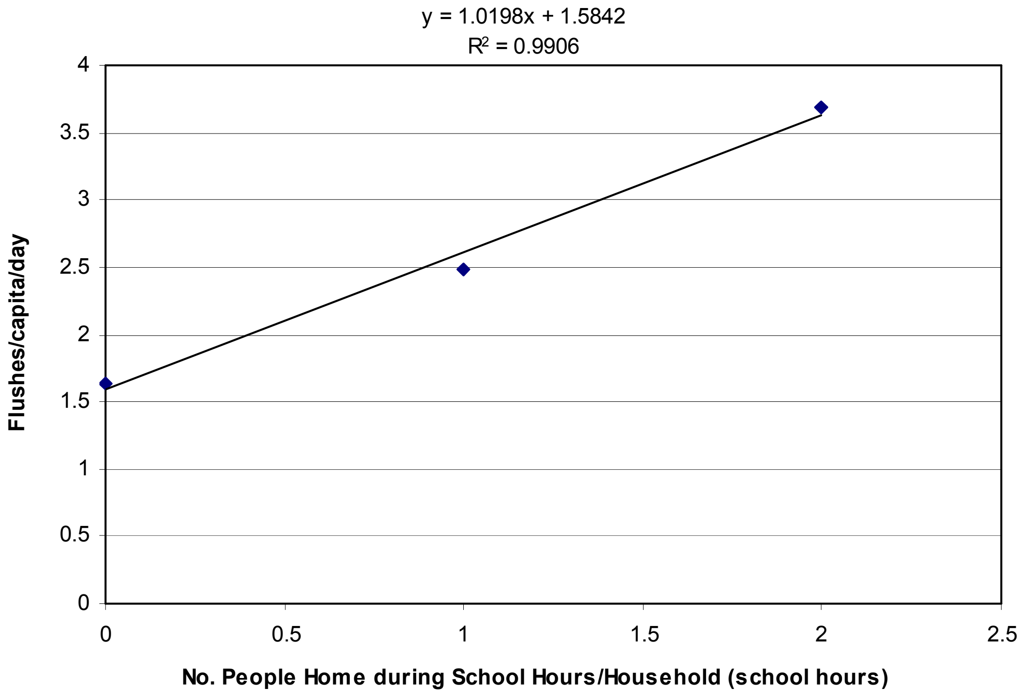


Figure 5-12 Effect of the number of people who remain home on flushes/capita/day

Table 5-6 Toilet Simulation

Simulation Details	Type	Percentage	Ratio	Volume/ Flush	Flushes/ Capita/Day	Capita/ household	Capita @ Home/School hours	No. households	No. days	Total Volume (ML)	Actual (ML)
Study Group	hold	0.1	1	3.82	2.602	3.1	1	10	138	0.0609	0.0611
	single	0.2	1	8.04							
	dual	0.7	0.65	3.86							
			0.35	7.05							
Toowoomba	hold	0.1	1	3.82	2.369446	2.4	0.77	40100	365	455.5797	
	single	0.2	1	8.04							
	dual	0.7	0.65	3.86							
			0.35	7.05							

The simulation shows that the derived formula is very useful for estimating total volume used by toilets. An error of only -0.02% was found when compared against the actual results for the study group. The estimation for total volume used by toilets in Toowoomba using this formula gives a value of 456 ML/year. This estimation is made on the basis that the same ratio of the types of toilets is found throughout Toowoomba. If all toilets in Toowoomba were converted to the hold down type, which used the least water, volume used by toilets would reduce to 318 ML/year giving a savings of 138 ML/year. Converting single flush toilets to dual flush toilets will reduce the total volume to 405 ML/year giving a savings of 50 ML/year. This simulation assumes that the hold down type toilets remain in service.

5.4 Bath

Bath tubs are another volume based fixture that can be estimated in much the same way as other volume based appliances. There were 173 baths recorded throughout the monitoring period from five households. Figure 5-13 shows the average volume and standard deviation of the baths recorded.

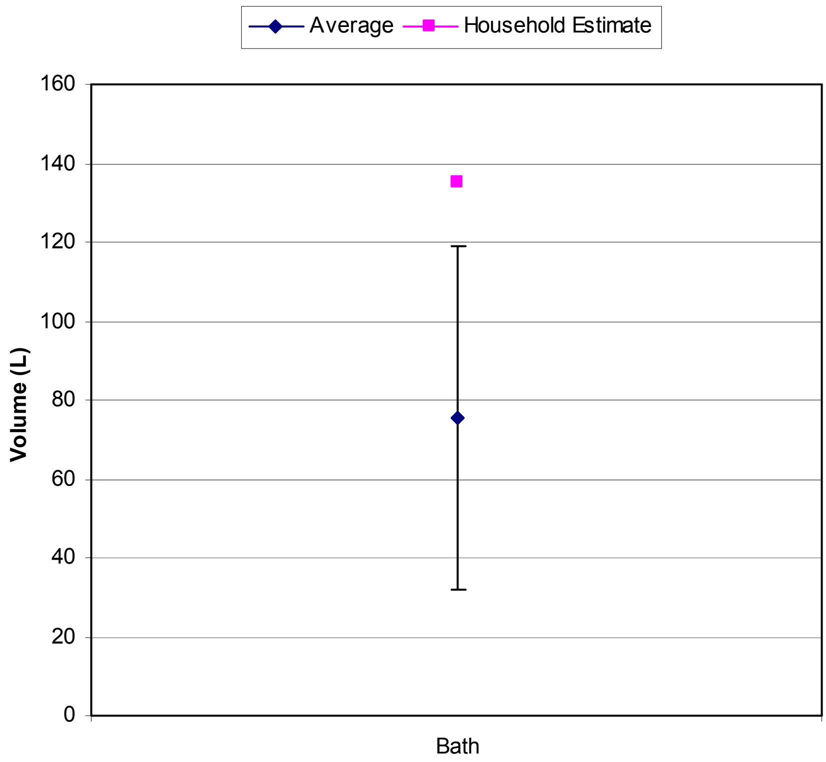


Figure 5-13 Average Volume/Bath

The average bath volume was 75.5 ± 43.5 L (95% CI = 6.48 L). Households were asked to estimate their bath use and volume/bath, as can be seen householders generally overestimated their bath volume. This overestimation was generally related to households that had very few baths/week. Most baths were attributed to those households with very young children with an average volume of less than 90L.The relative frequency of bath volumes is shown in Figure 5-14.

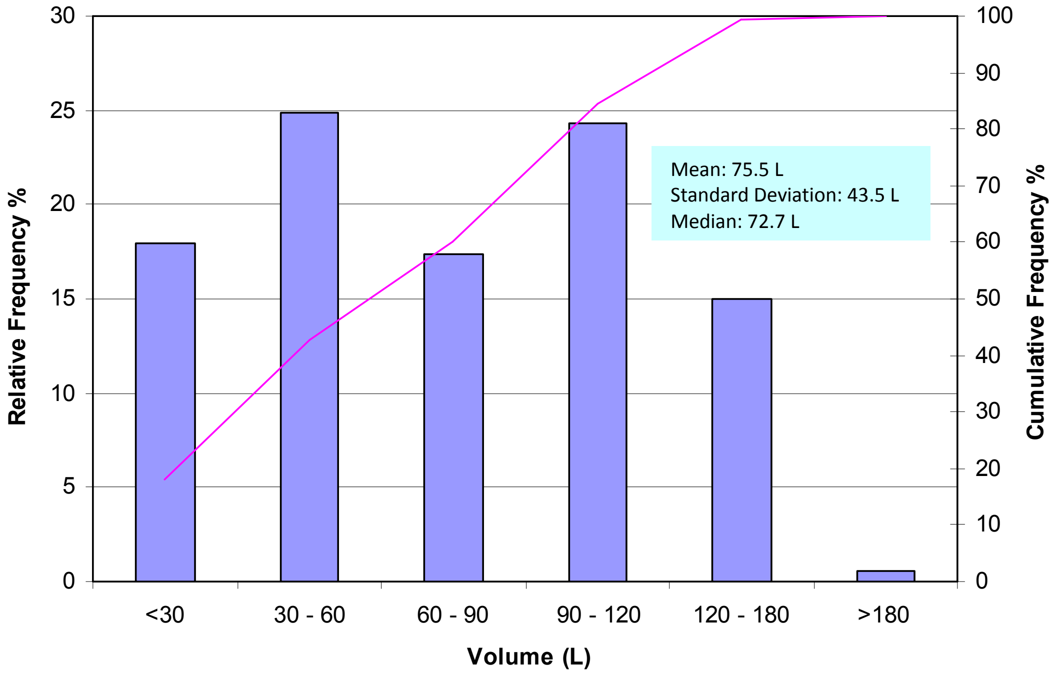


Figure 5-14 Relative Frequency of Bath Volumes

This frequency distribution shows that most baths that were taken were of relatively low volume which can be attributed to the bathing of small children. The larger bath volumes can be attributed to adults in the household having baths.

The number of baths/capita/week was found to be 0.46 for those people who said that they had baths. Householders estimated that their bath use was much higher than this at 0.96 baths/capita/week. However, some baths may have been inadvertently assigned to shower use as both have very similar flow profiles. Households who took baths were more populous households being 1.23 times larger than their non-bath taking counterparts. A calculation of total volume used in baths is shown below.

$$Volume_{Total} = \frac{volume}{bath} \times \frac{No.baths}{capita \times day} \times \frac{person}{household} \times No.households \times No.Days$$

$$Volume_{Total} = 75.5 \times 0.066 \times 3.8 \times 5 \times 138$$

$$Volume_{Total} = 13065L$$

The actual volume used in baths during the logging period was 13 200L giving a percentage error of 1%. Using this same formula, an estimate of Toowoomba's yearly water use by baths is shown below.

$$Volume_{Total} = \frac{volume}{bath} \times \frac{No.baths}{capita \times day} \times \frac{person}{household} \times No.households \times No.Days$$

$$Volume_{Total} = 75.5 \times 0.066 \times (2.4 \times 1.22) \times \frac{40100}{2} \times 365$$

$$Volume_{Total} = 107ML$$

5.5 Chapter Summary

This chapter has investigated those fixtures and appliances that are volume based, including washing machines, dishwashers, toilets and baths. The total volume used by volume based appliances is determined by the volume/event used and the number of events.

For washing machines, the volume/cycle was dependant on the type of washing machine with front loaders using less than half the volume of top loaders (60.6 L/cycle compared to 138.9 L/cycle). The number of cycles/capita/week was found to be dependant on the size of the household. Manufacturer's estimates of washing machine volume use were consistent for front loaders but were lower for the top loaders. This could be related to the higher age of these washers.

Dishwashers used 17.7 ± 2.37L/cycle on average. The number of events was found to be dependant on householder's habits and attitudes relating to the use of the dishwasher to wash pots and pans as well as other dishes. Manufacturer's estimate that dishwashers use 15 L/cycle.

Three different types of toilets were investigated in this study, single flush, dual flush and hold down toilets. Single flush toilets used the most volume at 8 ± 0.95 L/flush. Hold down toilets had a highly variable flush volume of 3.8 ± 1.4 L. Dual flush toilets were flushed at a ratio of 66:34 for half and full flush respectively. Half flush volumes were on average 3.9 ± 0.6 L and full flush volumes were 7 ± 1.2 L. The number of toilet flushes in each household was found to be dependant on the number of people residing at home during school hours.

The average volume/bath was found to be highly variable 75.5 ± 43.5 L. The baths/capita/day was found to be 0.46 for those households that indicated regular bath use.

Chapter 6 Flow Based Appliances/Fixtures

This chapter discusses the water used by fixtures such as showers and faucets whose volume is chiefly dependant on the flow rate of the device. The parameters affecting the volume of water used by each of these appliances is critically analysed based on the data collected during the study period. This chapter also includes a model that simulates the total amount of water used and water savings that can be achieved by switching to water efficient appliances.

6.1 Showers

Toowoomba Regional Council has a free shower rose exchange where residents can bring in their old showerhead and get it replaced for a low flow showerhead for free. More than 10,000 residents have already taken up the offer, which advertises that up to 64 litres can be saved per shower. Shower timers are also regularly given out to schools for free to encourage residents to cut their shower time down to four minutes.

The shower flow rate is dependant on the type of shower used in the home. There are three types of showerheads in this study; Ultra Low Flow (ULF), Low Flow (LF) and Normal showerheads. 178 events were recorded for ULF, 1989 for LF and 1235 for Normal showerheads. Figure 6-1 below shows a sample trace showing two showers, with some simultaneous faucet use. These showers are typical low flow showers which show a flow rate less than 9 Lpm.

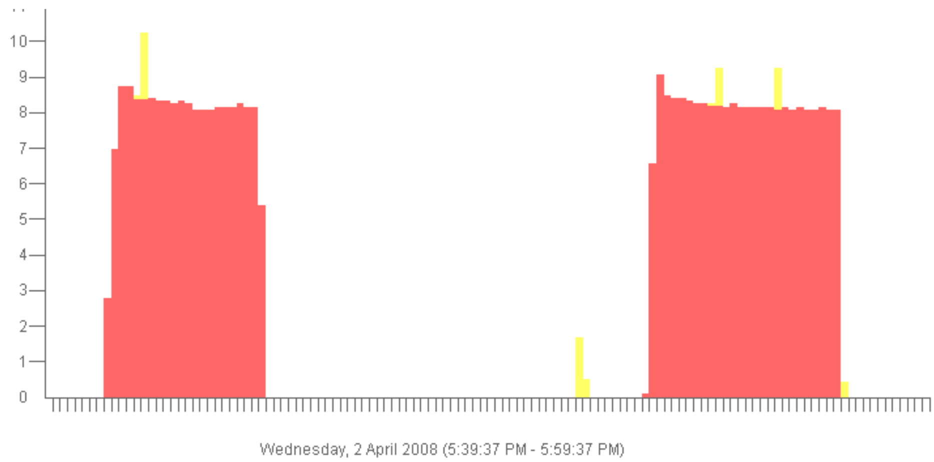


Figure 6-1 Shower Trace

The parameters affecting the volume of water in showers are:

- Showerhead Flow Rate
- Time/Shower
- No. of showers/capita/day

The average flow rates of the devices encountered in the study are shown in Figure 6-2.

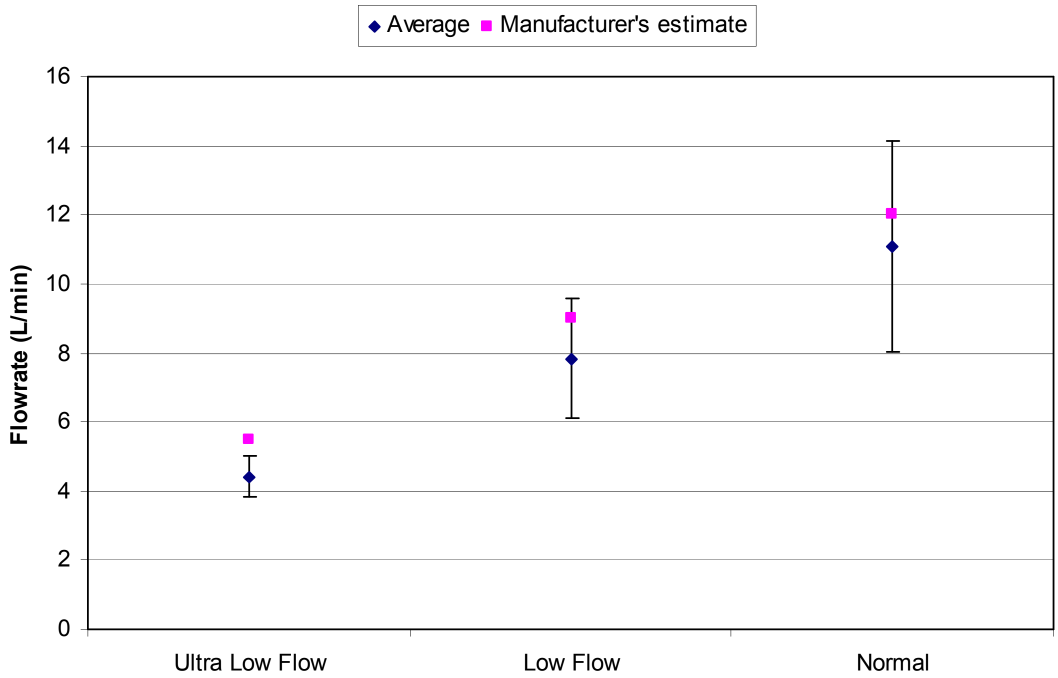


Figure 6-2 Shower Flow Rates

ULF showerheads have an average flow rate of 4.41 ± 0.6 L (95% CI= 0.09 L), Low Flow has an average flow rate of 7.8 ± 1.75 L (95% CI= 0.08 L)and Normal showerheads have an average flow rate of 11.1 ± 3.05 L (95% CI = 0.17 L). Showers exhibit one of the tightest confidence intervals as they are also one of the most frequent end uses of water. The average flow rate of each of these showerheads is lower than the manufacturer's estimates. This could be due to differences in the opening of the taps and differing pressure. Normal showerheads are capable of exceeding the manufacturer's specified flow rate as these shower heads are not restricted and can produce flows of up to 25 litres/minute. The low flow showerheads show that while most showers fall below the estimated flow rate, it is still possible to exceed this, albeit in only a few cases. The ultra low flow showerhead performed very well in this study, showing a much lower flow rate and with participants unable to exceed the manufacturer's estimate.

The time taken per shower head type is shown in Figure 6-3.

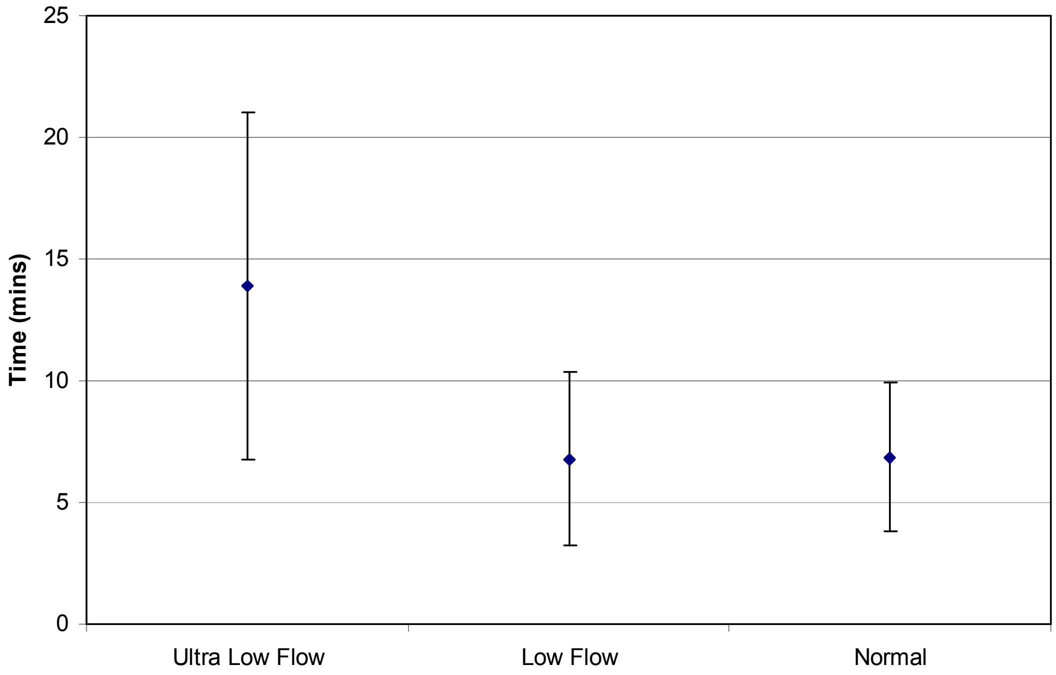


Figure 6-3 Shower Type vs. Durations

Ultra low flow showerheads have an average duration of 13.9 ± 7.1 minutes (95% CI= 1.04 minutes), low flow shower heads have a duration of 6.8 ± 3.6 minutes (95% CI= 0.16 minutes) and normal showerheads have a duration 6.9 ± 3.1 minutes (95% CI= 0.17 minutes). Although the ultra low flow showerhead has a much higher duration, only one person was using this type of showerhead so the duration is related more to the attitude of that person rather than to the type of showerhead. The duration of showers using low flow and normal showerheads is comparable between 6.7 - 6.8 minutes. The distribution of shower durations recorded is shown in Figure 6-4.

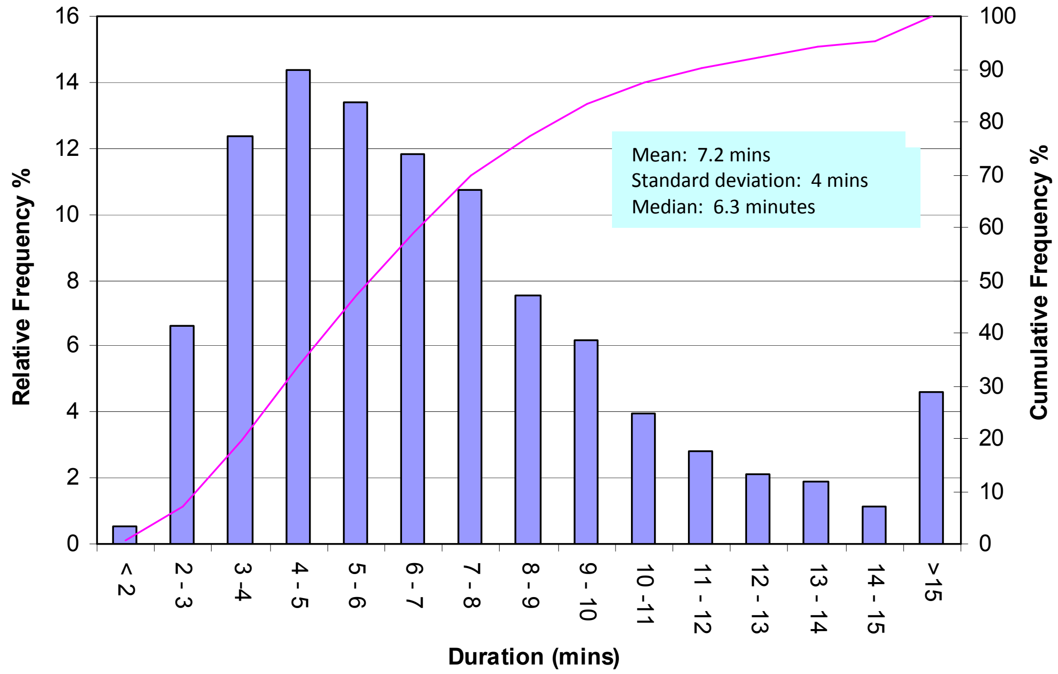


Figure 6-4 Frequency Distribution of Duration of Showers

The average duration for all showers is 7.2 ± 4 minutes, with a median time of 6.3 minutes. Most showers fall between 3 and 8 minutes, with a significant number exceeding the 15 minute mark. Toowoomba Regional Council encourages residents to have four minute showers to ensure that the most water can be saved; this is not reflected in the recorded data with 73% of showers recorded over this mark. The frequency distribution of volumes for each shower is shown in Figure 6-5.

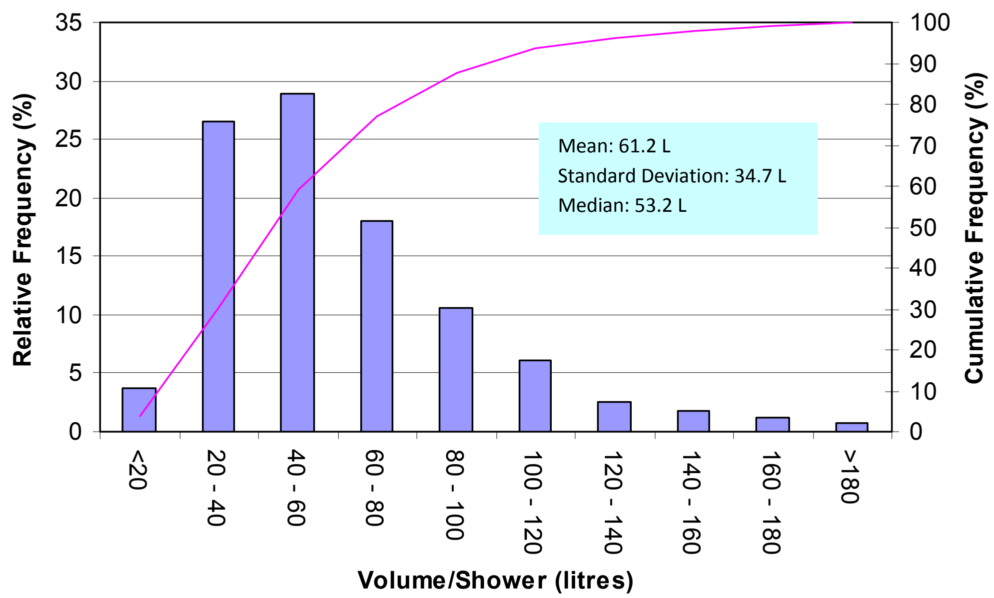


Figure 6-5 Frequency Distribution of Volume/Shower

The average volume used per shower is 61.2 ± 34.7 L, and a median value of 53.2 L. The majority of showers fall between 20 and 60 litres despite the high variation of durations that was found. 12.5% of showers taken use more than 100 litres. When comparing these volumes to those of baths, showers use less volume on average than baths. It is interesting to note that the volume frequency distribution does not show a peak that corresponds with the longer showers in Figure 6-4 suggesting that the longer showers are taken with low flow showerheads.

The showers/person per day as affected by season is shown in Figure 6-6.

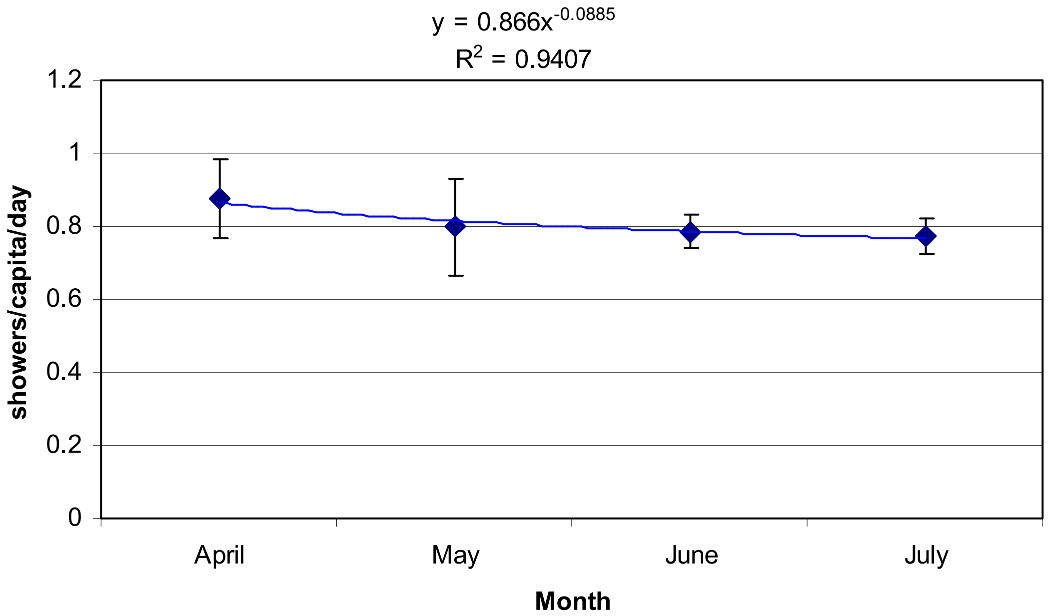


Figure 6-6 Seasonal Variation of Showers/Capita/Day

There is a slight drop in the number of showers taken from the warmer months through to the cooler months as shown by the trend line. This trend is not very significant so has been overlooked in favour of other more significant variables. The value for showers/capita/day seems low but does not take into account the effect of children sharing showers, navy showers (no turning off shower before next person gets in) or baths have on this figure. Figure 6-7 shows the influence that the number of children has on the number of showers taken per day.

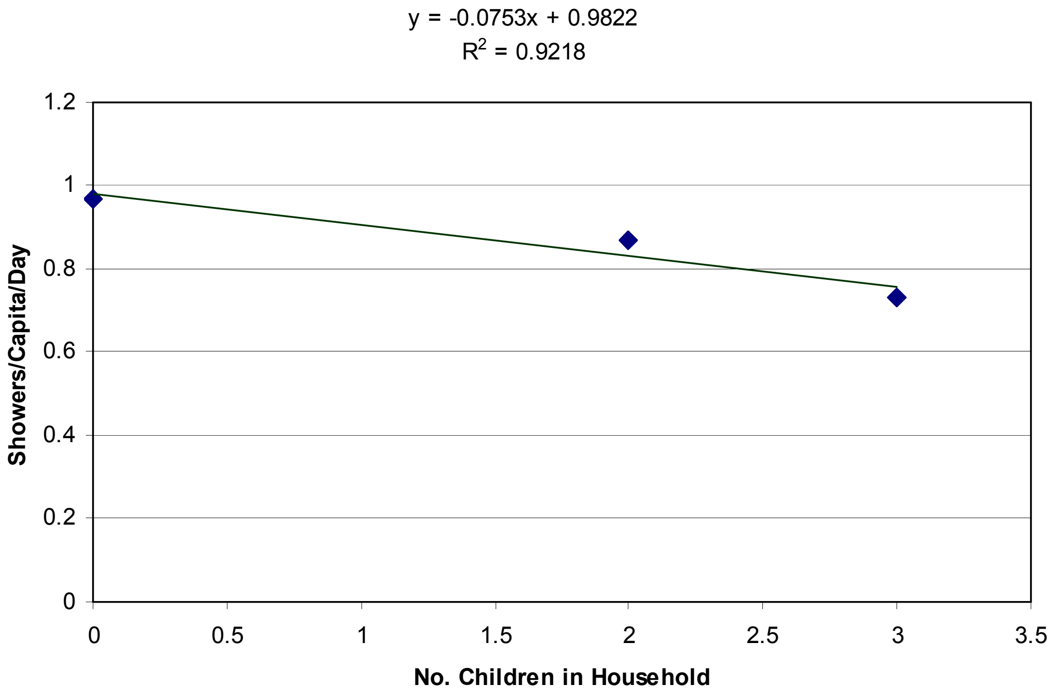


Figure 6-7 Effect of Children on Showers/Capita/Day

There is a decrease in the number of showers taken per day as the number of children present in the household increase. This trend can be represented by the given equation in which the number of showers *y*=-0.0753*(no. children*)+0.9822.

From these figures and the equation given above, the total volume used in showers can be calculated using the formula below.

$$Volume_{Total} = \sum(Shower\ Flow\ Rate \times \frac{Time}{Shower}) \times \sum(\frac{No.Showers}{capita \times day} \times \frac{capita(agegroup)}{household} \times No.households) \times No.Days$$

The number of children per household has been estimated in this simulation as being 2 less that the average persons/household value. An extensive survey will need to be undertaken to verify or dismiss this assumption. The type of shower head present in households in Toowoomba is assumed to be similar to the results from the 1999 Water Efficiency Survey conducted for the Capital Regional District (in Victoria) which found that water efficient showerheads were present in 69.2% of households.

Table 6-1 Shower Simulation

Simulation Details	Type	%	Flowrate (L/min)	Duration (mins)	Showers /Capita/Day	Children /household	Capita /household	No. households	No. days	Total Volume (ML)	Actual
Study Group	ULF	N/A	4.41		0.915183	0.89	2.89	9	138	0.2048	0.1976
	LF	0.6	7.84	6.78							
	Normal	0.4	11.1	6.86							
Toowoomba	ULF	N/A	4.41		0.95208	0.4	2.4	40100	365	2016.1001	
	LF	0.69	7.84	6.78							
	Normal	0.31	11.1	6.86							
Toowoomba - all change to low flow	ULF		4.41		0.95208	0.4	2.4	40100	365	1777.7377	
	LF	1	7.84	6.78							
	Normal		11.1	6.86							
									Savings (ML/year)	238.3624	

From this analysis, it can be seen that this method for calculating volume used by showers is useful. The calculated volume is 0.2048 ML and the actual volume attributed to shower use during the recording time is 0.1976Ml, giving a percentage error of 3.6%. Using these values, it is estimated that shower use in Toowoomba accounts for 2085 ML/year. If all showerheads in Toowoomba were changed to low flow type shower heads, Toowoomba would be able to save 308 ML/year based on this study.

6.2 Faucets

The use of faucets was the most common end use with 73,683 faucet events recorded during the monitoring period. The different uses of faucets are very hard to decipher as they have very similar traces. For example, faucet use in the kitchen and bathroom has similar flow rates, durations and volumes. Laundry taps generally have higher flow rates but depend on the user's individual use (how far they turn on the tap etc.). A sample trace showing faucet use is shown below. Figure 6-8 shows a sample faucet trace which shows a householder washing up, this particular person fills the sink halfway and rinses as they wash, hence the jagged profile with a large initial volume.

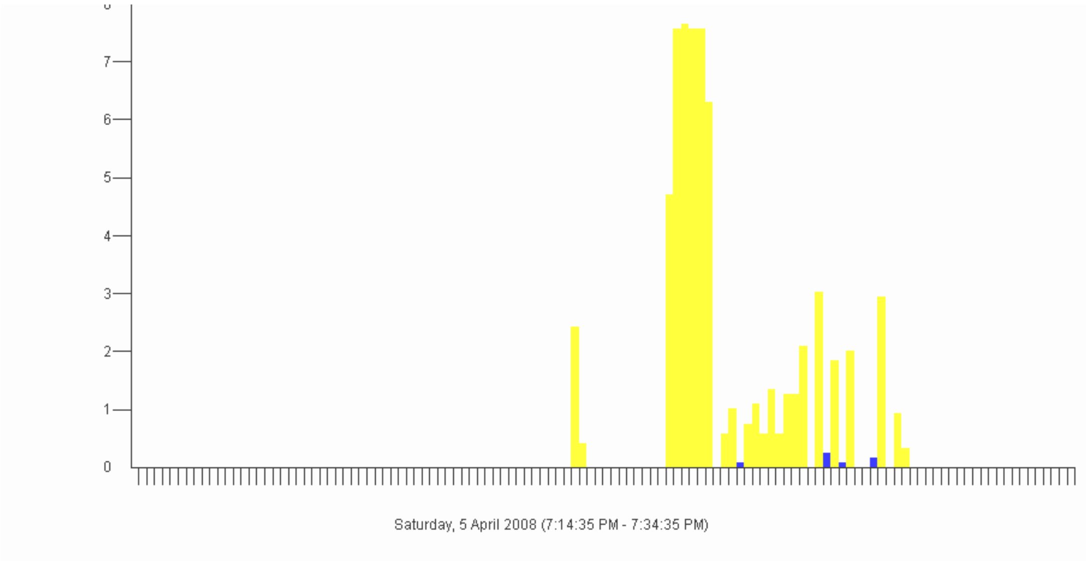


Figure 6-8 Sample Faucet Trace

The parameters that affect the volume used by faucets are similar to those that affect shower volume and are given below:

- Faucet Flow Rate
- Duration
- No. Events

The first relationship that was investigated in relation to faucet use was the effect of the static water pressure on the average flow rate. Figure 6-9 shows the average flow rate in each of the houses and the corresponding pressure. There is a very high variability of flow rates, with one household's variability 140 % of the average. From this figure it was concluded that there was no significant relationship between flow rate and static water pressure.

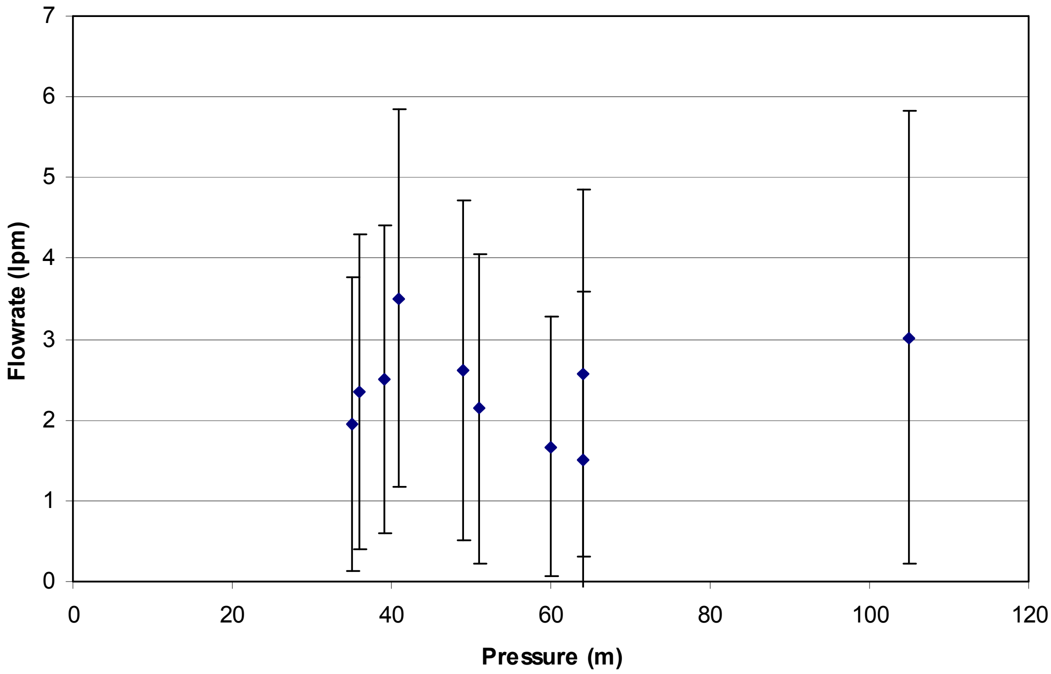


Figure 6-9 Effect of Pressure on Faucet Flow Rate

The use of faucet aerators was the next variable to be investigated. Figure 6-10 shows the average flow rate of those houses that have aerators and those that do not. Those households fitted with tap aerators have an average flow rate of 2.134 ± 1.967 L/min (95% CI= 0.013 L/min) and those without have a slightly higher average flow rate of 2.754 ± 2.252 L/min (95% CI= 0.02 L/min). The variability of flow rates is once again very evident in this figure. The full impact that aerators may have (savings up to 5 L/min) is not evident here probably due to the short duration of faucet events. If faucet duration was less than 10 seconds (the logging length) the pulse count is still spread over the whole 10 seconds. (e.g 5L/min event occurring for 5 seconds will be recorded by the data logger as a 2.5 L/min event occurring for 10 seconds).

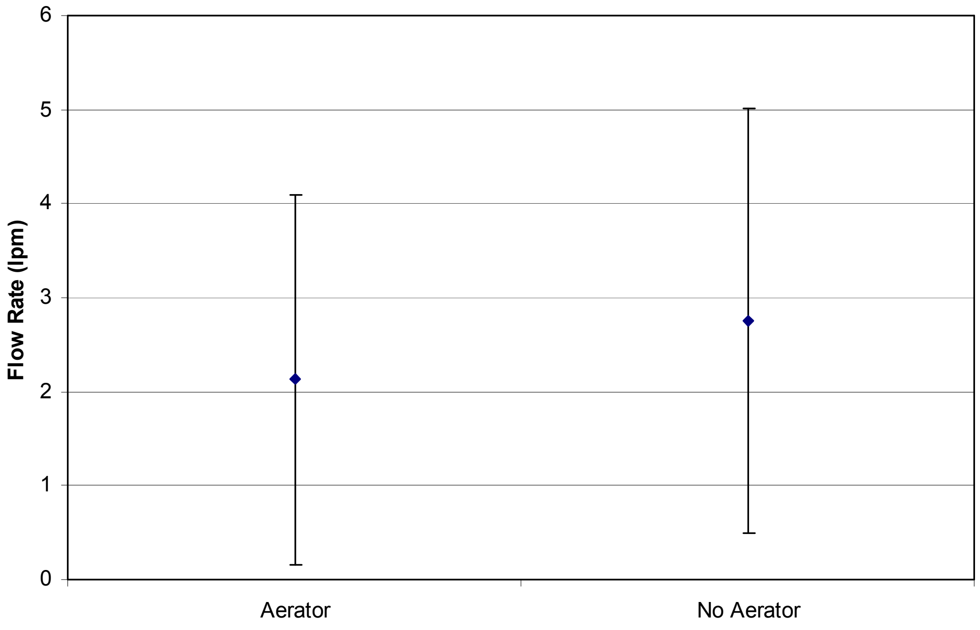


Figure 6-10 Effect of Aerator's on Faucet flow rate

Figure 6-11 shows the relative frequency of faucet flow rates. 56% of faucet events fall below 1.8 L/min. This figure shows that most faucet events are very low flow events with a median value of 1.44 L/min.

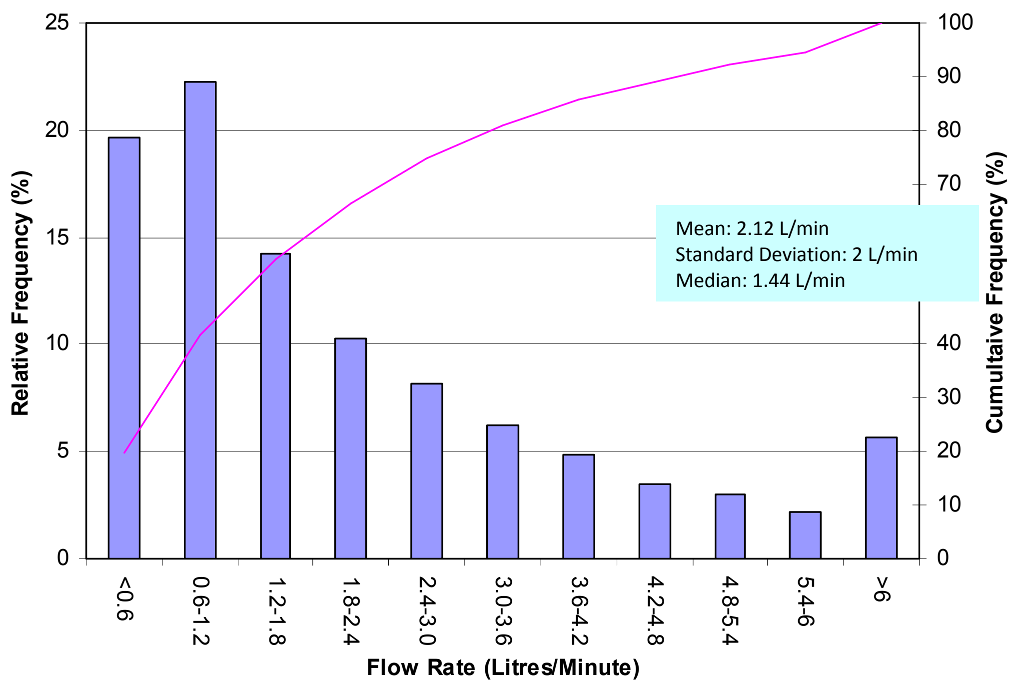


Figure 6-11 Faucet Flow Rate

The duration of faucet events is very short with an average duration of only 23.1 ± 23.73 seconds (95% CI= 0.4 seconds). The high variability shows that there are many very short events and some very high outliers which are distorting the data. Figure 6-11 shows each individual household's average duration, no relationship was found between the duration of faucet use and any other demographical or survey data.

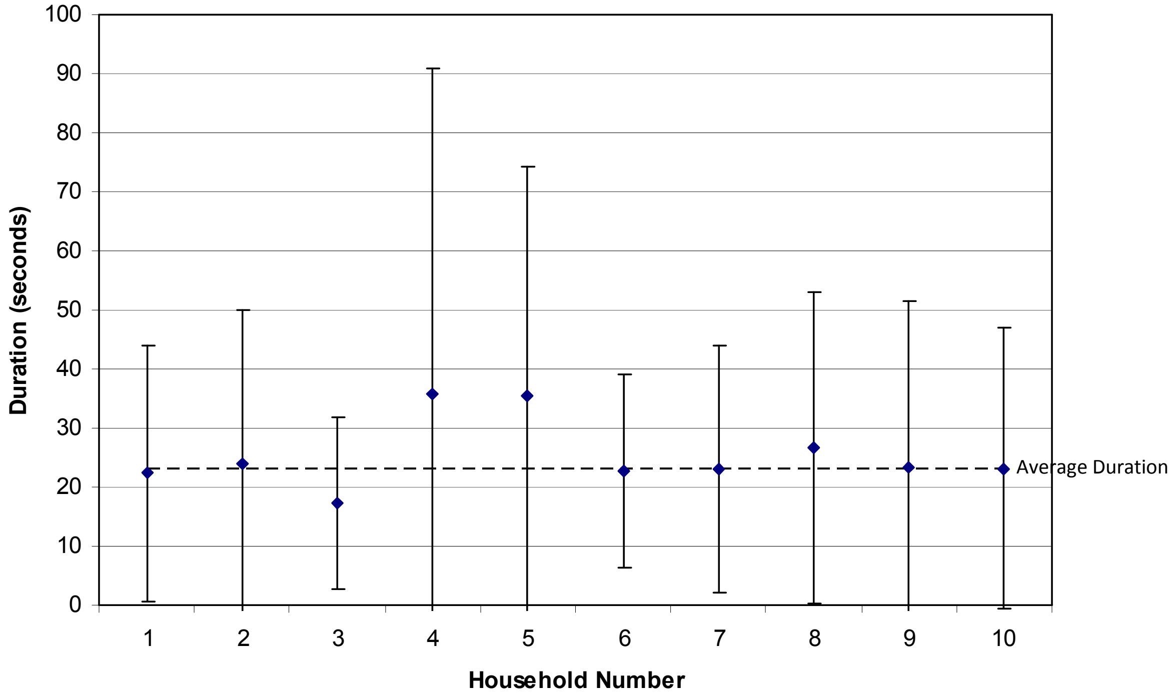


Figure 6-12 Faucet Duration

Figure 6-14 shows a frequency diagram that shows the relative frequency of the duration of faucet events. 49.5% of faucet events fell below 10 seconds with 83% falling below 30 seconds in duration.

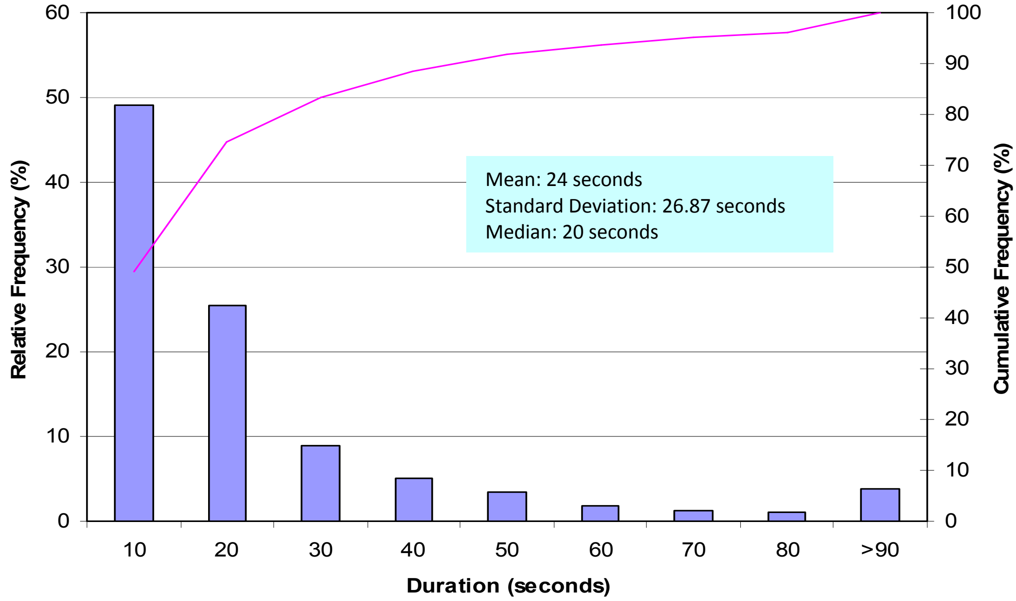


Figure 6-13 Duration Frequency Diagram

The number of events/capita/day was investigated and Figure 6-14 shows the events/capita/day for each household as related to the presence of a dishwasher and capita/household. The average number of events/capita/day is 16.43. This figure shows that no relationship exists between the number of events and the presence of a dishwasher or the number of people residing in the household. This is further reinforced by Figure 6-15 which shows the total volume/capita/day used by the different houses.

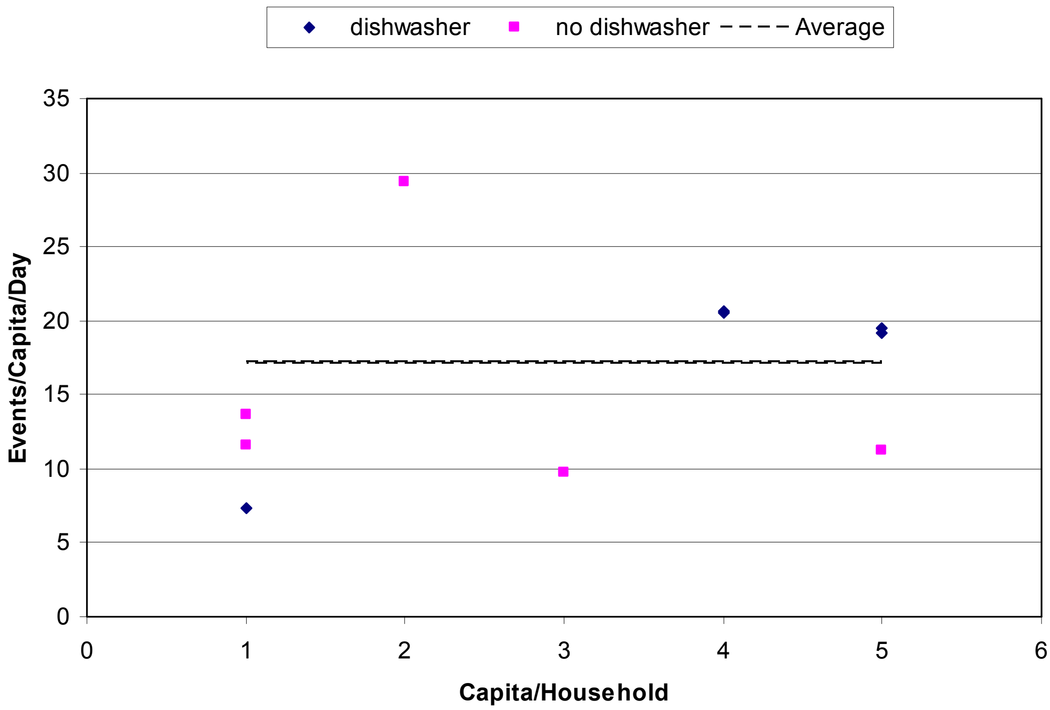


Figure 6-14 Faucet Events/Capita/Day

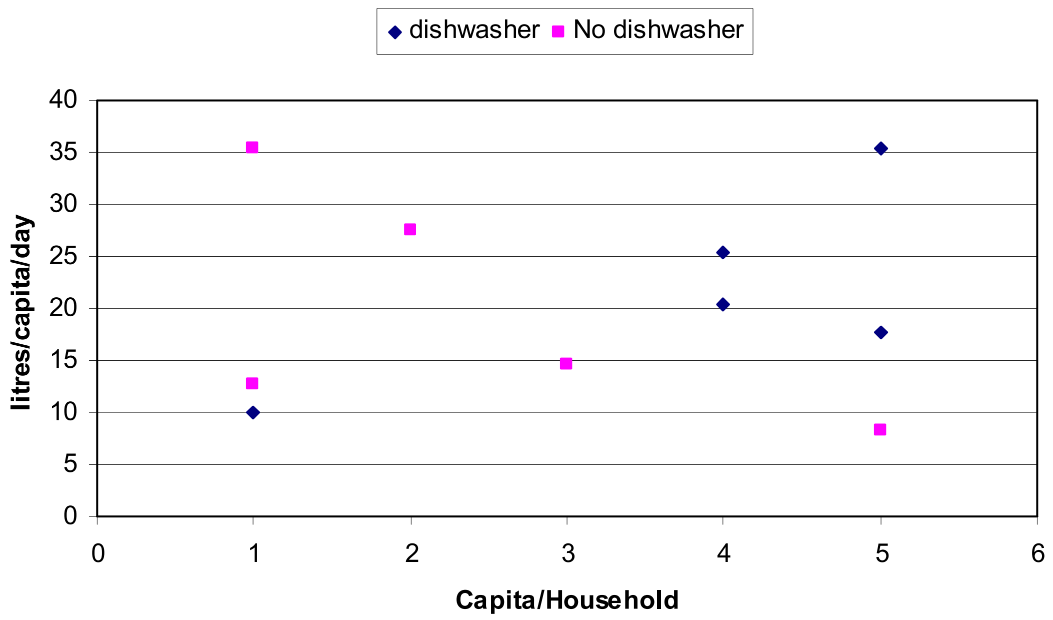


Figure 6-15 Faucet Volume/Capita/Day

Figure 6-16 below shows a frequency diagram for faucet volumes recorded throughout the study. 24% of faucet events are between 100ml and 200ml in volume, with 25% of volumes greater than 1 litre.

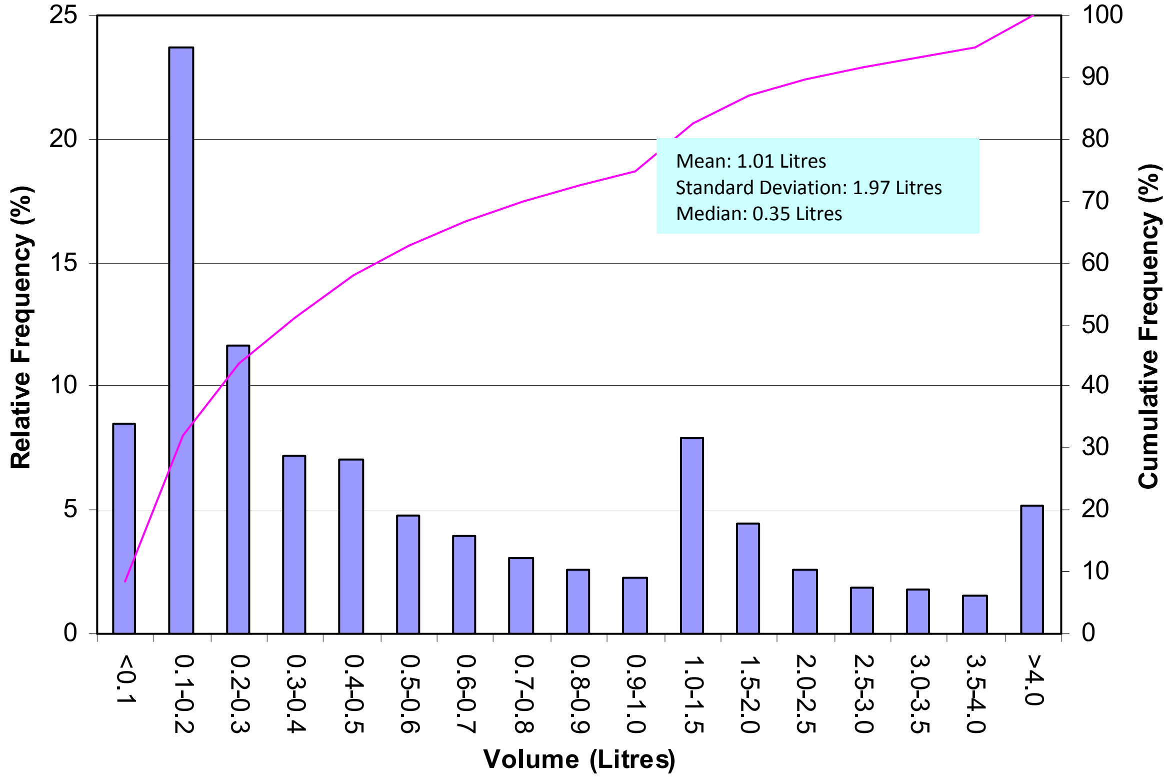


Figure 6-16 Volume Frequency Diagram

From this analysis, the total volume used in faucets can be estimated using the formula below.

$$Volume_{Total} = \sum(Faucet\ Flow\ Rate \times \frac{Time}{Event}) \times \sum\ (\frac{No.Events}{capita \times day} \times \frac{capita}{household} \times No.households) \times No.Days$$

As no trends or patterns were found in relation to the duration or number of faucet events, the average values have been used in this simulation. Table 6.2 shows these calculations.

Table 6-2 Faucet Simulation

Simulation Details	Type	Percentage	Flow rate	Duration	Events/capita/day	Capita/ Household	No. Households	No. days	Total Volume (ML)	Actual (ML)
	Aerator	0.6	2.134							
Study Group	No Aerator	0.4	2.754	0.385	16.43	3.1	10	138	0.0645	0.0743
	Aerator	0.6	2.134							
Toowoomba	No Aerator	0.4	2.754	0.385	16.43	2.4	40100	365	529.2837	
All aerator		1	2.134	0.385	16.43	2.4	40100	365	474.1778	

From this analysis, it can be seen that this method for calculating volume used by faucets is fairly useful. The calculated volume for the study is 0.0645 ML and the actual volume attributed to faucet use during the recording time is 0.0743Ml, giving a percentage error of -13.2 %. Using these values, it is estimated that faucet use in Toowoomba accounts for 529 ML/year. This is based on the assumption that the proportion of households in Toowoomba with faucet aerators is the same as that found in the study. If all faucets in Toowoomba had aerators installed, Toowoomba would be able to save 55 ML/year based on this study.

6.3 Chapter Summary

This chapter has investigated flow based fixtures, including showers & faucets. The volume used by flow based fixtures is dependant on the flow rate, the duration and the number of events. Three types of showerheads were investigated in this study; ultra low flow, low flow and normal showerheads. Ultra low flow showerheads have an average flow rate of 4.41 ± 0.6 L/min, low flow's have an average flow rate of 7.8 ± 1.75 L/min and normal showerheads have a much higher, more variable flow rate of 11.1 ± 3.05 L/min. The mean duration of all showers was found to be 7.2 ± 4 minutes with a median length of 6.3 minutes. The average volume per shower was found to be 61.2 L ± 34.7 L. The number of events is dependant on the number of children in the home; whereby the more children resulted in a reduction in showers/capita/day.

Faucet use was very hard to define as it was very variable due to its ability to come from many different taps within the home (kitchen, bathroom, laundry). It was found that those households fitted with aerators had a lower average flow rate than those without (2.134 ± 1.97 L/min and 2.754 ± 2.25 L/min respectively). This trend may have been more pronounced had the logging time been shorter. No relationships or trends were found for the duration or the number of faucet events.

Chapter 7 Effectiveness of Demand Management Initiatives

This chapter will investigate three elements of demand management: water restrictions, rebates on the retrofitting of water efficient appliances and water conservation education.

7.1 Water Restrictions

Water restrictions are a commonly used tool for managing water demand. Toowoomba was under Level 5 restrictions throughout this study. Under this level all outside watering is prohibited, including the washing of vehicles and the topping up of pools. The use of buckets directly filled from a tap are permitted for the washing of vehicle windscreens, mirrors and headlights, for the washing of wheelie bins and the washing of pets and their pens. The target water consumption per capita is 140 Lpcd.

7.1.1 Average Weekly Water Use

Figure 7-1 shows the average daily per capita use on a weekly basis throughout the study period. This was calculated by summing the total weekly water use by ten households (31 people) and averaging it for seven days to give a weekly average per capita daily use. This is important because it takes into account the higher water use that occurs over the weekends.

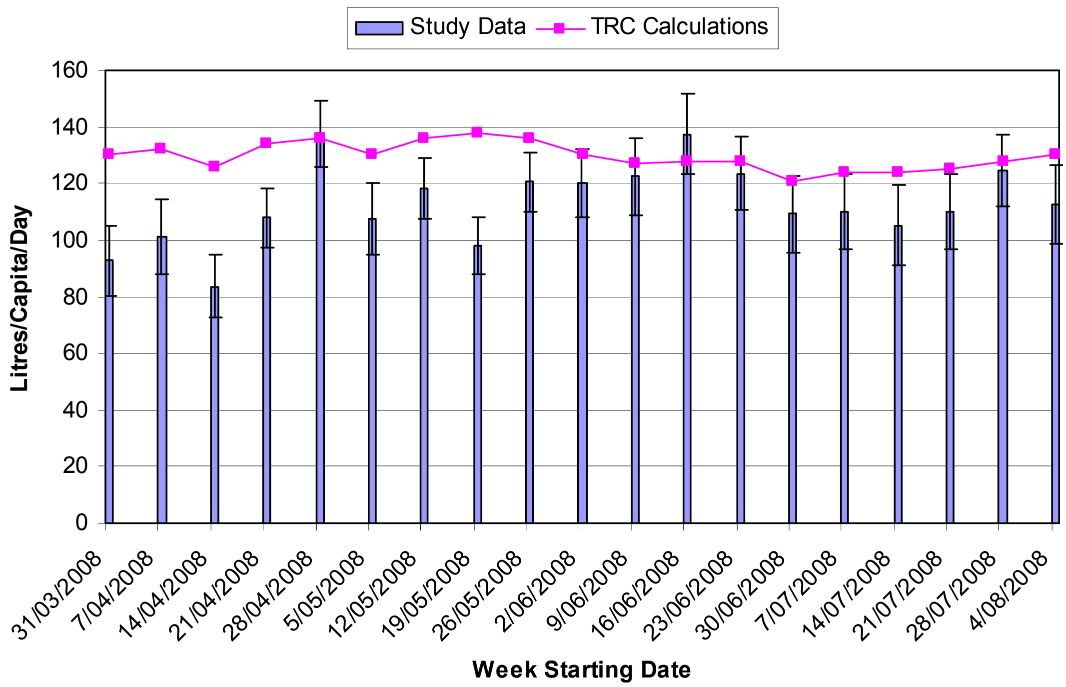


Figure 7-1 Weekly average per capita daily water use

Average weekly water use remains between 80 and 140 Lpcd. Water use is lowest in the week starting on Monday 14th April at only 83.8 Lpcd and is highest in the week starting on

Monday 28th April at 137.8 Lpcd. Water use during the beginning of the monitoring period are generally the lower values which suggests that householders were more aware of their water use and hence used less water. The consumption does not indicate any seasonal variations in water use, which is expected as most seasonal variation is due to outdoor water use. Water use can vary with seasons for a number of reasons, during hot summers people may take more showers, rainy weather could mean clothes washing is put off until a sunny day, but although these may be true, most seasonal variation is due to the outdoor water use. People water their gardens more during hot and dry days. For example, a similar study conducted in Perth which was not on water restrictions showed a much higher variability with high use of 658 Lpcd occurring during summer and a low use of 188 Lpcd during winter (Loh & Coughlan, 2003).

Figure 7-1 also shows the estimate of water consumption as determined by Toowoomba Regional Council. This is done by summing the total volume of water from production data which includes both surface water and bores, using a factor that attributes water consumption to the various sectors of Toowoomba (residential, non-residential and unaccounted for water) and dividing this by the number of people who reside in Toowoomba. The consumption calculated by TRC is higher than what has been recorded in the ten households under study. The target water consumption per person per day under level 5 restrictions is 140 litres and both of these values fall well within that target which is promising.

Level 5 water restrictions in Toowoomba were introduced on 26th September 2006, thus Toowoomba residents had been under water restrictions for close to 2 years during this study. Almost no outdoor water use was detected, although one household was suspected of watering their plants using a bucket. Other outdoor use was recorded but was related to the washing of pets and pet animal housings which is permitted. Of the ten households under study six had rainwater tanks. None of the rainwater tanks were connected to the indoor plumbing; hence this water was completely used for outdoor purposes. Water restrictions can deemed to be working from this study because only a very small amount of illegal water used was detected with most households utilising rainwater for outdoor use. However, no data was collected on the social and economic impact that water restrictions had on the participants. More information will need to be collected to determine the impact that water restrictions have on other elements of the community and not just on the water savings obtainable. Toowoomba's demand management program does consider ongoing permanent savings that can be achieved by the retrofitting of water saving appliances and fixtures.

7.2 Rebates and Retrofitting of Water Saving Devices

Toowoomba Regional Council currently offers many rebates on water saving devices these include:

- Rainwater tanks that are plumbed into at least one internal toilet and the laundry cold water tap

- The replacement of a single flush toilet with a dual flush toilet
- Recirculation device which circulates water in hot water lines back to the heater to be reheated
- Free Shower Rose exchange

The State Government currently offers a number of schemes that include:

- Home WaterWise Service
- Rebates on rainwater tanks
- Clothes Washing Machines
- Dual Flush toilets
- Swimming Pool covers
- Greywater systems
- Garden Products

This study found that significant indoor water savings can be achieved through the installation of high efficiency plumbing fixtures and appliances. It was found that the most water can be saved from the installation of water efficient washing machines (574 ML/year).

The next most water savings was attributed to the retrofitting of showerheads (238 ML/year) which are one of the least expensive conservation measures available (free to TRC residents) and the easiest to install. Water savings from the installation of low flow showerheads were estimated at 27 Litres/shower at the average duration of 7.2 minutes. Ultra low flow showerheads could save significantly more water than this but consumers may experience dissatisfaction with the low level of flow and hence extend their showers negating any potential water savings.

The water savings estimated by the replacement of single flush toilets with dual flush is very significant with substantial water savings possible if hold down toilets were retrofitted throughout the city. However, the household with the hold down toilet expressed dissatisfaction with the performance of this type of toilet so this may not be a viable option for consumers.

The installation of a rainwater tank that is connected to at least one toilet and the laundry tap could save up to 48.4 Lpcd. If all households in Toowoomba had a rainwater tank that was used for indoor use a total saving of 4.7 ML/day could be saved.

The effectiveness of rebates and retrofitting is not measured by the amount of water each device can save but by the uptake of these devices throughout the community. In this study, the most common water saving fixture was the dual flush toilet with seven households using this device. Water efficient washing machines, showerheads and faucet aerators were present in six of the households involved with the study. This represents a fairly good uptake rate of these devices which reflects the good work that TRC and the State Government are doing to encourage the use of water saving devices. The rebate focus on those appliances that do save the most water (washing machines, toilets and showers) show that they are targeting the areas where they will be the most effective. More information is needed to examine the uptake of water efficient devices throughout Toowoomba to ensure that this study represents the whole region.

7.3 WaterWise Education

Education plays a large role in water demand management as it aims to change the attitudes and habits of people to save water. Some initiatives of TRC include:

- Let's Slow the Flow program
- Shower Timers
- WaterWise Garden examples
- Education Resource Book for schools
- Television advertisements

All these initiatives aim to influence the behaviour of participants in relation to their water use.

The length of showers is significantly higher than the four minutes that is encouraged by Toowoomba Regional Council and the Queensland Water Commission as shown by Figure 7-2. The majority of showers in fact are above 4 minutes in duration. The water that can be saved if all showers were using low flow showerheads and of 4 minutes in duration would be 967 ML/year, even if shower heads were not low flow, the water saved would still be significant at 832 Ml/year. This represents a huge saving in water attributed to only an attitude and behavioural change.

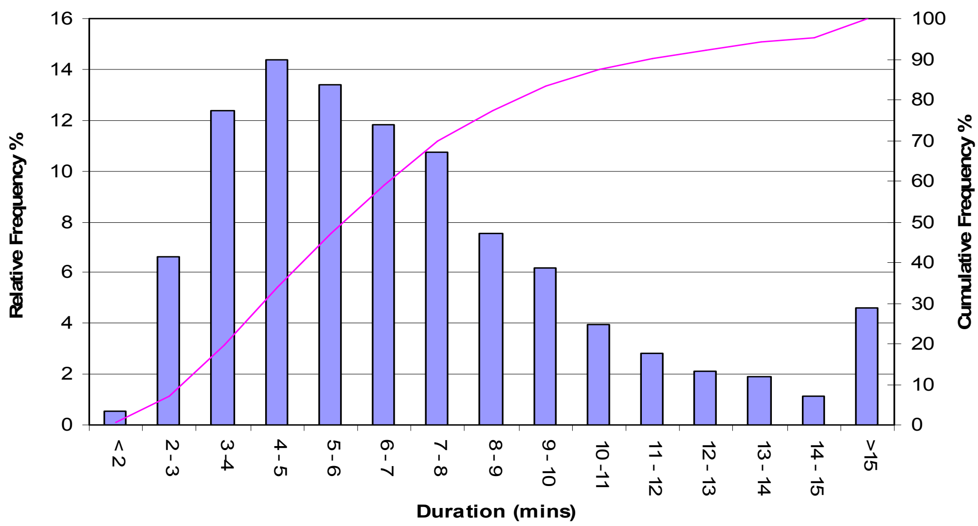


Figure 7-2 Duration of Showers

Washing machine water efficiency is also based on economies of scale and consumers need to be encouraged to use their washing machine to its full capacity to ensure that the water savings are not negated by the increase in the number of loads done. If consumers cut down their washing by just one load per household per week, a savings of 248 ML/year is possible while maintaining the same washing equipment. If this done in conjunction with changing to water efficient washing machines the total savings could be closer to 700 ML/year.

The behaviour of participants in this study was impacted dramatically by the installation of the monitoring devices as was evident by the lower water use during the first few weeks of the study. It is therefore suggested that TRC investigates implementing an ongoing monitoring program that encourages residents to be accountable for their water use and water use behaviour. This could take the form of self monitoring e.g. reading their water meter everyday to determine the household's daily use and comparing this to water use targets. From this study, it can be seen that WaterWise behaviour is crucial in managing water demand as it is a key input into calculating the total volume used by appliances and fixtures.

7.4 Chapter Summary

This chapter has discussed the effectiveness of demand management initiatives that relate to this study. Level 5 water restrictions have almost eliminated all outdoor water use but more research needs to be done on the social and economic impact that strict water restrictions has on a community. The current consumption target of 140 Lpcd is being easily achieved. Current rebate programs for the retrofitting of water efficient appliances and fixtures are targeted to the areas that will save the most water (i.e. showers, washing machines & toilets). The uptake of these devices in this pilot study was good with 60% of households having water efficient appliances and fixtures installed. More research will need to be done to determine if these results represent the uptake of water efficient devices for the whole of Toowoomba. WaterWise education is an important and integral part of demand management programs and can have as much effect on water consumption as the retrofitting of devices.

Chapter 8 Conclusions and Recommendations

This pilot study has proved that smart meters can provide detailed data about end use. This data can be used to reveal the effectiveness of water conservation appliances and fixtures. This project has provided insights into the variables that affect water consumption by appliances and fixtures. This information can be used to better educate the public about water conservation and how they can make a difference.

It was found that the residential water use averaged 112 ± 22.7 Lpcd with almost all days falling below the 140 Lpcd target. Most water was consumed in the shower, followed by washing machines. The peaking factors found differed significantly to those given by QUDM due to the effect that water restrictions have on demand. The diurnal demand pattern was influenced mainly by the shower use during the week and washing machine use during the weekend.

The total volume used by volume based appliances such as washing machines, toilets, dishwashers and baths depends on;

- Volume/event and
- Events/Capita/Day.

Front load washing machines were found to use less than half the amount of water per cycle as top loading washers. Larger households benefited from economies of scale meaning there were less cycles/capita/day in larger households. Dual flush and hold down toilets as expected used much less water than single flush toilets. The volume used by dishwashers and baths were very dependant on the attitudes and behaviours of the residents with no correlation between volume and any demographic information collected.

The total volume used by flow based fixtures such as showers and faucets depends on;

- Flow Rate,
- Duration and
- Events/Capita/Day.

The flow rates of the fixtures were dependant on the type of device installed. Low flow and ultra low flow showerhead, as expected, had much lower flow rates compared to normal showerheads. The average duration of showers was found to be 7.2 minutes, significantly higher than the 4 minute showers that are encouraged by TRC. The number of showers/capita/day depended on the number of children present in the household. The higher the number of children the lower the number of showers/capita/day. Faucets were very difficult to define as the events recorded were highly variable. Those households with faucet aerators did show a slightly lower average flow rate. The duration of faucet events was once again highly variable with most events occurring for only 10 seconds. This distorts the actual flow rate of the events, making the recorded flow rate lower than what the actual flow rate would be.

This study found that water restrictions were effective at eliminating outdoor water use. The retrofitting of water saving devices and the rebates offered for these aligned well with the actual water savings made. From the analysis of each fixture and device within the study households the importance of WaterWise education in effective demand management was revealed. The volume used by fixtures and appliances in the home has as much to do with the householder's attitudes and habits that relate to water conservation as the water efficiency of the appliance.

8.1 Recommendations

The results from this study make it clear that water conserving appliances are a useful tool for saving water. These results provide evidence of the effectiveness of interior water conservation measures and justification for continued support of cost-effective programs across the country. These programs need to be combined with an effective education program about WaterWise behaviours and their effect on water conservation.

Clearly more research is needed to verify these results as the more sites that can be included in similar projects, the better and more reliable the results will be for generalizing to wider populations. A whole year of data will need to be evaluated to determine any seasonal trend that may be evident. If water restrictions are lifted, outdoor water use data should also be collected to verify seasonal trends and peaking factors under normal conditions. A further survey of each participant's attitude to water use may also be useful to link certain behaviours to water efficiency (or water inefficiency).

Information regarding the penetration of water efficient appliances, WaterWise behaviour and the effect that water restrictions have on residents is necessary to gain an understanding of the effectiveness of current demand management programs in relatrion to their social impacts as well as impacts they may have on water use. This could be done by surveying residents with the specific objectives being to:

- Obtain resident's views of water use and their perceptions about water efficiency
- Identify consumer behaviour and actions with regard to their water use, and seek the identification of trends over time
- Determine people's awareness about TRC water efficiency initiatives
- Determine the water efficient devices present in the average household in Toowoomba

This information would be invaluable in determining attitudes, behaviours and penetration of water efficient devices. This information could then be applied to the simulations contained within this project to better estimate total water use and possible savings.

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Appendix A – Project Specification

FACULTY OF ENGINEERING & SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Nicola MEAD**

TOPIC: INVESTIGATION OF DOMESTIC WATER END USE

SUPERVISORS: Dr. Vasantha Aravinthan
A/Prof Mark Porter
John Betts – Branch Manager Water and Wastewater- Strategy and Coordination
Toowoomba Regional Council
Bruce Gaydon – Water Demand Management Coordinator
Toowoomba Regional Council

SPONSORSHIP: Toowoomba Regional Council

PROJECT AIM: This project seeks to establish a methodology to investigate end water use in residential properties. It will define the major factors that affect domestic water consumption based on preliminary data collected, and provide guidelines for the successful expansion of the study in Toowoomba.

PROGRAMME: **(Issue A, 11 March 2008)**

1. Research the background information relating to water end use measurement and analysis, focusing on ‘smart’ metering systems.

2. Install ‘smart’ metering systems in 10 households in Toowoomba.

3. Collect water use data from the ‘smart’ meters, and household information related to household fixtures, appliances and attitudes of use from the 10 households.

4. Establish the methodology for disaggregating water events associated with different fixtures and appliances using “Trace Wizard” software and create a manageable database to handle this information.

5. Analyse the water use profiles of total and disaggregated water usage, report the results and use this information to determine a diurnal demand pattern based on this preliminary data.

6. Further analyse the water use trends and patterns taking into account variances that may be due to other factors such as water pressure, weather & implemented demand management programs and propose correlations (if any) that should be tested by a larger study.

7. Provide guidelines for expansion of the study, taking into consideration any identified trends, to help select an appropriate representation of Toowoomba properties for use in the larger study.

8. Submit an academic dissertation on the research.

AGREED:

__________________ (Student) ___/___/___

__________________ (Supervisor) ___/___/___

__________________ (Supervisor) ___/___/___

__________________ (Supervisor) ___/___/___

__________________ (Supervisor) ___/___/___

Examiner/Co-examiner: ______________________________

Appendix B – Invitation Package

Invitation Letter

Dear Toowoomba City Council Employee

You are invited to participate in a special Home Water Use Study sponsored by the Toowoomba City Council and University of Southern Queensland. The study will investigate home water use patterns and trends that are specific to Toowoomba. This invitation is being extended as a pilot study.

If you are selected, specially modified water measuring equipment will be installed at your existing water meter's location. It is estimated that the study will take about 12 months and require about 1 hour of your time in total. You will need to be present for an initial review of your appliances and fixtures and to answer a short survey on your water use habits and attitudes. Please refer to the fact sheet attached for more information.

TCC will use the results of the Home Water Use Study to plan future conservation activities. Your participation is key to the success of this important research study. **If you would like to be considered for participation in this study we ask that you please complete the short survey form attached and return it to Nikki as soon as possible.** If you have any questions, please don't hesitate to ask.

Thankyou for your time and cooperation.

Sincerely,

Nicola Mead

Vacation Practice Student - Engineering Administration

Toowoomba City Council

Tel: 07 4688 6705

Email: nicola.mead@toowoomba.qld.gov.au

Web: www.toowoomba.qld.gov.au

Home Water Use Study Fact Sheet

What is the Study?

The project will involve studying the water use of between 5-10 homes within the Toowoomba service area. Data of water use by home appliances and fixtures will be collected and analysed.

Why conduct the study?

The purpose of this study is to gain an insight into the trends and patterns of water use that are specific to Toowoomba. The study will determine the amount of water used by different household appliances and fixtures. This data will be used in the development and planning of demand management programs. The study will also measure how flows vary between seasons and throughout the day, which will help in the planning of water infrastructure and flow patterns.

Who will administer the Study?

The Toowoomba City Council in conjunction with the University of Southern Queensland.

How will the study be conducted?

Old meters will be replaced with new more sensitive meters on to which a data logger will be attached. These will be located in the current meter box outside of the property. The data logger will record daily water use for analysis and this will be downloaded remotely every fortnight. No monitoring equipment will be placed inside the home.

When will the study take place?

The study is anticipated to start in January 2008 and continue till January 2009.

How much of my time will be needed?

The entire study will require about 1 hour of your time. The homeowner will need to be present during the installation and calibration of the smart meter, during which time a survey will take place regarding water use habits. Data can be downloaded from the meter without the need for residents to be at home.

What cooperation is required by me?

If eligible and selected for the study you will be asked to sign an agreement to provide the survey data needed. Your water meter's location will need to be readily accessible. For best results, the participant should plan on being based at the property for the duration of the monitoring period, ie not going on extended holidays or moving house.

For more information:

Please contact:

Nicola Mead

Vacation Practice Student - Engineering Administration

Toowoomba City Council

Tel: 07 4688 6705

Initial Participation Questionnaire

Name:
Address:
Home Phone:
Work Phone:

☐ I am interested in further pursuing possible participation in the water use study. If I become eligible and am chosen to participate in the study, I agree to cooperate with the research effort.

Please complete the following section:

Total No. of full time occupants: ________________
Children (0-12yrs) ________________
Teens (13-19yrs) ________________
Adults (20+) ________________

Estimated age of home: _________years

Please circle:
Do you have a rainwater tank? (Y/N)

Is it plumbed into the house fixtures? (Y/N)

Do you have water saving fixtures installed in your house? (Y/N)

If so what:
Dual Flush Toilets
Showerheads
Tap Aerators
Other (please specify) _______________________

Do have any water saving appliances (4 star or above rating) in your house? (Y/N)

If so what:
Top Loading Washing Machine
Front Loading Washing Machine
Dishwasher
Other (please specify) ______________________

Thanks for taking the time to fill out and return this questionnaire. The final group of participants will be selected from those who have showed interest. You will be notified within 4 weeks as to whether you have been chosen for the study.

Appendix C – Measuring Equipment Specifications

Monita
R Series
Data Logger

AEGIS

For remote alarming and monitoring in all environments

Applications:

- Key account metering
- Irrigation metering
- Event monitoring
- Remote metering
- Difficult to access sites
- Process and machine monitoring
- Flow monitoring
- Pipelines

Features:

- Designed for industrial use
- 4 programmable inputs
- Waterproof to 1 metre
- SMS & e-mail data collection
- Stores 2 million records
- 10 year battery life*

www.aegis.net.au
Australia 1300 723 447
www.aegis.net.nz
New Zealand 0800 023 447

Manufactured under a Quality System complying to ISO9001 : 2000 (QEC Lic 5948)

Monita

R Series Data Logger

PRODUCT OVERVIEW

The Monita R Series Data Logger has been designed to meet the harsh environmental realities of monitoring industrial and utility equipment. Powered by a long life battery and waterproof to 1 metre, it is robust enough to be installed in inspection pits or exposed to the weather, without the need for specailised tools or running cables.

Once installed the Monita thinks for itself, returning information to multiple users via e-mail or SMS providing data and reporting alarms such as zero usage or maximum demand events automatically.

Extremely flexible, the Monita has four digital inputs and can be programmed to record data in intervals ranging from 1 second to 99 minutes and has memory capacity to store up to 2 million records. The Monita software suite provides easy to use tools for data analysis and export to databases and spreadsheets.

Field proven in applications as diverse as water level sensing, utility metering and security monitoring, the Monita R Series Data Logger is the obvious choice for your data collection and operation monitoring needs.

SPECIFICATIONS

Meter Inputs

Up to 4 unpowered floating Voltage free inputs

Short cable mode:-	Max input cable length 4 metres
Min pulse width (N/O)	2 milliseconds
Min Pulse separation	9 milliseconds
Long cable mode:-	Max input cable length 10 metres
Min pulse width (N/O)	10 milliseconds
Min Pulse separation	50 milliseconds
Input impedance	>10k Ohms

Edge detection - open to closed (NO) or closed to open (NC)

Communications

Serial:	Infrared interface
Wireless:	Internal Dual band cellular 900/1800 Mhz or 850/1900 Mhz GSM modem Short Message Service (SMS) GPRS Class B (4+1) up to 85.6 kbps as e-mai

Logging Features

Memory	2 million records
Alarms	Low or Zero usage in a period High usage in a period Return of state (when used as alarm input) Tamper detection
Clock	Real time with time and date stamp facility
*Battery Life	Typically 10 years but is dependant on logging intervals and call frequency

Physical

Dimensions	82mm Ø x 170mm
Weight	470 grams
Environmental Protection	IP67
Operating Temperature	-20°C to +75°C for all logger functions -20°C to +55°C for GSM functions

Australia:
Toll Free: 1300 723 447
sales@aegis.net.au
200 Rooks Road
Vermont, Vic. Australia 3133
Tel: (61 3) 8872 6666
Fax: 1300 123 447

www.aegis.net.au

New Zealand:
Toll Free: 0800 023 447
sales@aegis.net.nz
Khyber Pass Business Centre
195 Khyber Pass Road
Grafton, Auckland, New Zealand
Tel: (64 9) 356 8293
Fax: (64 9) 356 8292

www.aegis.net.nz

AEGIS

Brisbane Melbourne Sydney Auckland

CT5-S 20mm totaliser positive displacement flowmeter with high rate 72.5/litre pulse output

FEATURES

- **Volumetric rotary piston principle, measures accurately in any position.**
- **Mechanical totaliser.**
- **72 counts/litre reed switch contact closure output for precision data collection and flowrate readings**
- **Designed to meet AS3565.1-1998**
- **Accuracy ± 2 % (q-min to q-max) Repeatability ±0.15%**

The CT5-S 20mm water meter is suitable for measurement of cold water upto 50°C with a working pressure upto 1500 kPa. The meter offers great accuracy and a long operating life for domestic drinking water applications.

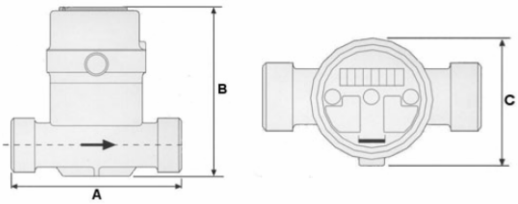
The mechanical counter register is positioned for easy reading and displays from 0.02 to 9,999,999 Litres. The precision engineered rotary piston measuring chamber ensures accurate measurement even at very low starting flow rates. Meters can be installed in any position without affecting accuracy and require no onsite calibration. An inline filter element prevents blockages and an internal check valve stops backflows (can optionally have dual check-valves).

CT5-S flowmeters are fitted with a high resolution reed switch contact closure output. At the request of various water authorities, with Manuflo technology, 72.5 pulses per Litre output signal is achieved, which is the highest amount of pulses per Litre for a domestic water meter (whilst retaining the mechanical register). This allows capture of precision water measurement information to data-loggers and to other data collection devices. Very accurate data can then be obtained for water usage totals and flowrate habits of consumers. Electrical connection is via a 1.5 metre 2-core shielded cable.

All meters are supplied with a gasket seat coupling connection kit (optional ball seat available). CT5-S flowmeters are manufactured from high quality materials to meet Australian specification requirements.
The CT5-S 20mm provides the best pulse output rate for domestic water meters, with 72.5 pulses/litre.

SPECIFICATIONS

Size (mm)		**20**
Pulse output rate	**Litres/pulse**	**72.5**
Mechanical register	**Minimum Litres**	**0.02**
	Maximum KL	**9999.9999**
Starting flow rate		**0.033**
Min. registration	**Qr ±5% LPM**	**0.05**
Min. trans. flow	**Qt ±2% LPM**	**0.41**
Nom. continuous flow	**Qn ±2% LPM**	**41.6**
Max. intermittent flow	**Qs ±2% LPM**	**83.3**
Weight with couplings	**Kg**	**1.9**



Other Specifications
Headloss @ Qn <25kPa., Max. pressure rating 1500kPa, Max water temperature 50°C,
Accuracy Qt to Qs +/-2%, Repeatability +/-0.15%.
Reed switch pulse V.max:24V, I.max:50mA, with anti-bounce and current-limiting resistor fitted.
Cable 2-core, 1.5 metre length.

Pipeline must be full at all times for correct measurement. Suitable for clean water only. Purge the pipeline prior to install. Once installed, to avoid damage to measuring chamber, bleed the liquid into the pipeline and flowmeter.

DIMENSIONS mm

Model No:	CT5-S
Length A mm	152
Height B mm	145
Width C mm	92

ORDERING CODES

Part	Size (mm)	Description of coupling set
CT5-S	20	Gasket seat ¾"Bsp(m)
CT5-S-G	20	Ball seat ¾"Bsp(f)

ManuFlo®™
Flow Measurement Products
a division of
MANU ELECTRONICS PTY LTD

Rev: 03/04

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Sydney, Australia
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www.manuelectronics.com.au

Appendix D – Audit Questionnaire

Demographics

How many years have you lived at this address? ________yrs

Is it rented or owned?

If rented: excess water charge? ______

Number of fulltime residents (2008):

	Male	Female
TOTAL	________	________
(0-2)	________	________
(3-14)	________	________
(15-24)	________	________
(25-44)	________	________
(45-65)	________	________
(65+)	________	________

How many occupants remain at home during the weekday? ____
the weekend? ____

Time spent away from home/day:

Person	Av. Hours
_______	________
_______	________
_______	________
_______	________
_______	________

Do you have regular visitors? Give details e.g. regular/occasional, meals, all day, overnight….

____

Frequency: ______________
Duration: ______________
Time of Day: ______________

What type of property? E.g bungalow, double storey etc.

____

Age of property: ____yrs
Number of bedrooms_____
Number of bathrooms____
Rainwater Tank (Y/N)
Shed_____ (outside sink (Y/N))

Income:
< $30000
≤ $50000
≤ $75000
> $75000

Kitchen

Dishwasher: Make ______________
Model ______________
Cycle used ______________

Do you rinse before placing in Dishwasher? (Y/N)

Do pots& pans get put in dishwasher? (Y/N)

How often does the dishwasher get used? _____/day

What time of day would the dishwasher normally be run? __________

Sink:
Volume of sink ____________ L
Volume of second sink ____________ L

Start: _______

Tap: Make _____________
Model _____________
Aerator? (Y/N)
Flowrate _____________ L/sec

How many times do you hand-wash dishes? ____ per day/____per week

Do you rinse food (e.g vegies & fruit)? (Y/N)

Do you use the plug when rinsing? (Y/N)

How full do you fill the sink (%)? _______

How many meals are eaten in the house during the week? ________ /day
on the weekend? ________/day

Icemaker on Fridge? Make/Model __________
How often used? __________

Start: _______

Garbage Disposal? Make/Model __________
How often used? __________

Laundry

Washing Machine: Make ________________
Model ________________
Size ________________

Top load/Front Load
Cycle used ________________
Water Temp ________________

How many loads of washing would you do per week? _________

What size would they be? Small _____/week
Medium _____/week
Large _____/week

What time of day would they normally occur? ______

Do you send clothes to the dry cleaner? (Y/N) Frequency? _______/month

Do you use a launderette? (Y/N) Frequency? ______/month

Laundry Tub: Volume ____________L
(length__, width ___, depth___)

Start: _______

Faucet: Make _____________
Model _____________
Aerator? (Y/N)
Flowrate _____________ L/sec

How often is this tub used? ______/week

Time taken for hot water? ___________

Bathrooms

How many bathrooms do you have? __________
How many toilets? __________
Estimated shower duration: Person Time

Person	Time
________	_______
________	_______
________	_______
________	_______
________	_______
________	_______

What time of day would showers normally occur? ________

Are any showers taken away from the home? E.g. gym, school, work (Y/N)
Frequency? ________/week

Is any shower water harvested? (Y/N)

How often do people in the home take baths? ______

Bathroom 1: Description (main, guest, kids)_________

Showerhead: Type ___________

Flow-rate ___________

Start: _______

How often does this shower get used? _________/week

Time taken for hot water? ________mins

Sink Tap: Make _____________

Model _____________

Aerator (Y/N)

Flow rate _____________ L/sec

Main use (e.g. hand, face, teeth, baby) _________

Start: _______

Bath Tap: Make _____________

Model _____________

Aerator (Y/N)

Flow rate _____________ L/sec

Volume of Tub Length _____________

Width ______________

Depth ______________

Fill level (%) _________

Start: _______

Frequency of use? ________/week

Toilet: Make _________

Model _________

Dual Flush (Y/N)

Volume (Full-flush) _________

Volume (Half-flush) _________

Half Start: ______

Full Start: _______

Bathroom 2: Description (main, guest, kids)_________

Showerhead: Type ___________
Flow-rate ___________

Start: _______

How often does this shower get used? _________/week

Time taken for hot water? ________mins

Sink Tap: Make _____________
Model _____________
Aerator? (Y/N)
Flowrate _____________ L/sec
Main use (e.g hand, face, teeth, baby) _________

Start: _______

Bath Tap: Make _____________
Model _____________
Aerator? (Y/N)
Flowrate _____________ L/sec
Volume of Tub Length _____________
Width _____________
Depth _____________
Fill level (%) _________

Start: _______

Frequency of use? ________/week

Toilet: Make _________
Model _________
Dual Flush (Y/N)
Volume (Full-flush) _________
Volume (Half-flush) _________

Half Start: ______

Full Start: _______

Other:

Start: ________

Air-conditioner:

Make ______________
Model ______________
Hours of use ______________
Time of use ______________
Temp set at ______________

Hot Water System: Make ______________

Model ______________
Volume ______________
Type (Gas/Electric/Solar/Other_____)
Location ______________
Distance to remotest point ______

Rain Water Tank:

Volume ______________
Connections: Toilets
Washing machine
Outside tap
Drinking water

Pets:

How many dogs? ______
How often do they get washed? _____/month
Do the kennels get washed down? (Y/N) ______/week

Pool:

Size: ______
How often is it refilled? _____

Appendix E – Participation Agreement

THIS PARTICIPATION AGREEMENT ("Agreement") is made and entered into this day of 2008

BETWEEN: TOOWOOMBA CITY COUNCIL, a Local Government established under the provisions of the *Local Government Act* 1993 and having its office at 153 Herries Street, Toowoomba in the State of Queensland ("Council")

AND: , the homeowner/tenant (*delete one*)
of in the said State ("Participant")

The Participant and Council agree as follows:

1. THE HOME WATER USE STUDY

The Home Water Use Study ("Study") is conducted by Council in conjunction with the University of Southern Queensland. The purpose of this Study is to determine the way in which residential customers use water.

The Study involves monitoring water use in relation to ten (10) homes situated in the Council service area with an electronic device that records information ("Data Logger") installed at the water meter.

The term of the Agreement is one (1) year. The Study will commence after the Agreement is signed by the Participant and Council and will continue for 12 months.

2. THE ROLE AND RESPONSIBILITIES OF COUNCIL IN THE STUDY

2.1 Council officers will visit the Participant's property in order to install, maintain, and if required, remove the water use monitoring equipment and to collect information.

2.2 Council officers will arrange a time that is suitable to the Participant to enter the premises to interview the Participant and to conduct an initial survey of water usage fixtures and appliances.

3. REQUIREMENTS FOR PARTICIPATION

The Participant voluntarily agrees to join in the Study.

The Participant will assist Council to arrange a suitable time for an initial visit, interview and survey as described in Part 2.

The Participant will provide information in relation to water use and consumption as requested by Council.

The Participant will not disturb, tamper with, or remove any of the water monitoring equipment installed for the Study.

The Participant will provide Council with information on household characteristics, including but not limited to the number and age of household members, water usage fixtures and appliances, water use practices and other information pertaining to the Study as requested.

4. STUDY INFORMATION AND CONFIDENTIALITY

All study information obtained from this Study will be the property of Council. The Council will not provide study information to any other party except for the purpose of Council endorsed research into water consumption and use.

The information collected in relation to water use will be used for statistical and planning purposes, and may be made available in the public domain.

Council will not disclose to the public any study information that identifies the Participant or any associate of the Participant in any manner whatsoever.

5. RELEASE

The Participant releases and agrees to hold harmless the Council, its officers, employees and contractors, from any and all claims, losses, harms, costs, liabilities, damages and expenses (collectively "Claim") directly or indirectly resulting from or related to Participant's participation in the Study, except to the extent that the Claim arises out of a negligent or wilful act or default of Council, its employees and/or its agents.

I,…………………………….………………………of……………………… ………………………………………am the owner/tenant *(delete one)*. I have read and understood the terms of this Agreement and agree to participate in the Study in accordance with the terms of the Agreement. I also consent to a Council officer entering my premises for the purposes outlined in Clause 2.2 above, on this day: (date)___________________

SIGNED by the PARTICIPANT: WITNESS:

DATE:

SIGNED for and on behalf of TOOWOOMBA CITY COUNCIL by:

In the presence of a Justice of the Peace/ Commissioner for Declarations:

DATE: