A Benchmark Analysis of Water Savings by Mandated Rainwater Tank Users in South East Queensland (Phase 2)

Meng Nan Chong[1], Shivanita Umapathi[1], Aditi Mankad[2], Ashok Sharma[3] and Ted Gardner[1]

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The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

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Griffith University - visit http://www.griffith.edu.au/

Enquiries should be addressed to:

The Urban Water Security Research Alliance
PO Box 15087
CITY EAST QLD 4002

Ph: 07-3247 3005; Fax: 07-3405 3556
Email: Sharon.Wakem@qwc.qld.gov.au

Authors: 1 - CSIRO Land and Water (ESP, Brisbane); 2 – CSIRO Ecosystem Sciences (ESP, Brisbane); 3 – CSIRO Land and Water (Highett, Victoria).

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FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

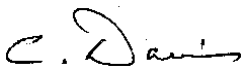
As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.



Chris Davis
Chair, Urban Water Security Research Alliance

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PROJECT SYNOPSIS

This report presents the results of a study to validate the 70 kilolitres per household per year (kL/hh/yr) mains water savings target for South East Queensland (SEQ), as per the Queensland Development Code MP 4.2–Water savings targets (QDC MP 4.2) (DLGP, 2008).

A previous desktop analysis of mains water savings from internally plumbed rainwater tanks (IPT) in Pine Rivers, Redland and Gold Coast areas of SEQ found that the savings averaged 50 kL/hh/yr across the SEQ region (Beal *et al.*, 2011). The savings varied markedly across different local government areas, ranging from 20 to 95 kL/hh/yr. This preliminary research was conducted using 2008 water billing records when external water restrictions were still in place for Moreton Bay Regional Council, thus the full potential for water savings from mandated tanks as a supplementary urban water supply option was unlikely to be achieved in that area. The analysis was based on pair-wise comparison of water billing data of similar homes with and without rainwater tanks. Reasons postulated for the high variation in mains water savings included rainwater tank yield (i.e. rainfall, tank volume and connected roof area), socio-demographic factors (i.e. household occupancy), water efficient household appliances and fixtures (i.e. front-loading washing machines) and householders' water use behaviour.

Further research was undertaken to assess the full potential of mandated rainwater tanks in achieving the QDC MP 4.2 water saving target and to resolve some of the data anomalies and regional variations highlighted in the preliminary research. Two distinct phases of the study have been developed:

- ***Phase 1*** of the research was an analysis of the baseline characteristics of mandated rainwater tank users in South East Queensland, undertaken through a telephone survey.
- ***Phase 2*** of the research involved a benchmark analysis of water savings by mandated rainwater tank users in South East Queensland using water billing records of known households with mandated tanks in comparison with average mains water usage across the similar regions.

The purpose of this report is to describe *Phase* 2 of the study including results of *Phase* 1.

Phase 1 of this study was completed in December 2010 and the results presented in Chong *et al.* (2011). In *Phase* 1, the contribution of biophysical and social factors in achieving water saving targets, previously discussed by Beal *et al.* (2011) study were investigated in detail through a telephone survey of 1,134 households. The outcomes from the *Phase 1* study have facilitated undertaking of this *Phase 2* benchmark analysis of the potential mains water savings from dwellings with mandated rainwater tanks. In particular, variations in actual household occupancy rates obtained in *Phase* 1 have been used to refine the methodology for determining water savings.

The methodology used for the *Phase 2* analysis is similar to the Building Sustainability Index (BASIX) protocol developed by Sydney Water. Water billing records of 691 households for 2009 and 2010 for Caboolture, Pine Rivers, Redland and Gold Coast were analysed in order to assess the mains water savings from known mandated rainwater tank users in SEQ.

EXECUTIVE SUMMARY

The benchmark analysis highlighted in this report is part of wider research to investigate the potential mains water saving from mandated rainwater tanks installed in Class 1 dwellings in SEQ. Under the QDC MP 4.2, all Class 1 buildings constructed after 2007 in SEQ are required to save 70 kL of mains water per year.

One acceptable solution for achieving a reduction in mains water use is through the installation of a 5 kL rainwater tank connected to 100 m^2 roof area and plumbed to the washing machine cold water tap, toilets and at least one external tap. While this was the typical inclusion with new houses, other options are available, these being a greywater treatment plant, communal rainwater tanks, dual reticulation of recycled water or treated stormwater, or a combination of these.

Beal *et al.* (2011) conducted a preliminary desktop study for three SEQ regions to investigate the potential mains water saving from internally plumbed rainwater tanks (IPT) installed in post-2007 houses. The study was based on the mains water consumption data obtained from the relevant local authorities. The desktop analysis involved a pair-wise statistical analysis of 2008 water billing data, to compare randomly paired households with and without rainwater tanks in the similar local government areas (LGAs) of Pine Rivers, Redland and Gold Coast. It was found that the estimated average mains water savings in 2008 was 50 kL/household/year (kL/hh/yr).

The current study was conducted in two phases. *Phase 1* was carried out by conducting a baseline characteristics analysis to identify biophysical and socio-demographic characteristics of mandated rainwater tank users in SEQ (Chong *et al.*, 2011). In total 1,134 households with mandated rainwater tanks were surveyed from four LGAs within SEQ, which are Caboolture, Pine Rivers, Redland and Gold Coast, to determine various biophysical and socio-demographic characteristics, as well as to obtain their consent to access water billing records for the period of 2007 - 2012. Information was collected from householders on: (1) basic compliance of new dwellings with installation of mandated rainwater tanks to the QDC MP 4.2 requirements; (2) physical and demographic characteristics at the household level and its comparison to the existing ABS 2006 census district data; and (3) householders' attitudes, behaviours, and risk and threat perceptions towards water usage and savings.

In *Phase 2* of the study (i.e. in this report), a benchmark analysis similar to Sydney Water's BASIX approach was conducted to estimate the potential mains water savings from dwellings known to have internally plumbed rainwater tanks. Similar to the Beal *et al.* (2011) study, water consumption data was obtained for the four LGAs: Caboolture, Pine Rivers, Redland and Gold Coast. This benchmark analysis compared average mains water usage by the known mandated rainwater users group to the respective council's average mains water consumption. The differences between the two study groups are assumed to generate the mains water savings by households with mandated rainwater tanks.

The study found that the average annual mains water savings per household in 2009 was 58.8 kL/hh/yr (for the 691 matched households with Phase 1's baseline characteristics). Average annual water savings varied across the four LGAs, with a range from 24.5 (Pine Rivers) to 88.5 kL/hh/yr (Gold Coast).

As for 2010, the average mains water saving was 58.2 kL/hh/yr. Average annual water savings varied across the four LGAs, with a range from 39.7 (Pine Rivers) to 81.0 kL/hh/yr (Gold Coast). Such a variation could be driven by factors such as rainwater tank yield factors related to climate and roof area connectivity, socio-demographic factors (WaterWise awareness and water use behaviour in the household) and the use of water efficient household appliances and fixtures.

Results obtained from the Computer Aided Telephone Interviews (CATI) in *Phase 1,* which included the households' occupancy data, were used to match and convert each household's mains water consumption rate to per capita water consumption in litres per person per day (L/p/d) from January 2009 to December 2010. A total of 691 households were matched from the 1,134 survey participants in *Phase 1* and analysed for their normalised per capita water consumption rate.

The results show an average per capita savings in 2009 of approximately 49.5 L/p/d in mains water usage for IPT households across the four council areas in this study. The analysis showed a lower mains water saving of 20.9 L/p/d to 31.9 L/p/d for Pine Rivers and Caboolture respectively, whereas Redland and Gold Coast showed a higher saving of 72.4 L/p/d and 72.6 L/p/d, respectively during the year. A similar analysis has been reported for 2010.

IPT households show a significant reduction in mains water consumption, especially in the Gold Coast and Redland regions. Results showed that the per capita reduction in mains water consumption per day ranged from 4 to 50% for 2009 when benchmarked against the respective SEQ regional average water consumption data. Similarly for 2010, per capita reduction in mains water consumption per day ranged from approximately 7 to 41% in the LGAs studied.

In this benchmark analysis, actual individual household occupancy rates obtained from the *Phase 1* study were specifically matched to their water billing records whereas, the Beal *et al.* (2011) study used 2006 Australian Bureau of Statistics (ABS) Census District Data for average household occupancy rates. Thus, the estimated mean per capita values for mains water saving from dwellings with IPT are considered to be more accurate, as they were generated from the normalisation of actual water billing record data to the occupancy rate for every matched household. Both the mean and median values for water savings were estimated but, in general, the mean values were used throughout this report as they are more relevant for comparison with the published SEQ regional average water consumption data.

It is clearly demonstrated that dwellings with IPT can reduce the direct reliance on mains water supplies in all the studied LGAs. The potential mains water saving demonstrated in this study provide support to the water balance modelling approaches conducted for assessing allotment scale rainwater usage.

The results presented in this *Phase 2* report are the outcomes of the ongoing research on the estimation and validation of the mains water savings from dwellings with mandated rainwater tanks.

1. INTRODUCTION

In SEQ, the challenges in providing adequate and reliable sources of water for the urban community have been elevated due to potential climate change impacts and population growth. This has been a major concern that has prompted state water planning authorities to develop sustainable water planning strategies and management practices to address such important urban water issues. Different water strategies have been proposed and one of the approaches for urban communities in SEQ is via the use of decentralised water sources to reduce the direct reliance on mains water sources. The current SEQ Water Strategy (2010) has proposed and emphasised the potential benefits of collection, treatment and reuse of locally available water sources on a *fit-for-purpose* basis to meet non-mains water demand. Such approaches include the implementation of decentralised water systems such as rainwater tanks, greywater systems and groundwater bores.

Among these decentralised systems, rainwater tanks have become an integral feature of almost every detached dwelling in SEQ, either through the WaterWise Rebate Scheme in 2006 or mandated through the QDC MP 4.2-Water savings targets. Under the new QDC MP 4.2, all detached residential dwellings built in SEQ after 1 January 2007 (including properties applying for extension permits) must achieve a mains water saving target of 70 kL per year. One acceptable solution for achieving the water savings target is through the installation of a 5 kL rainwater tank connected to 100 m^2 roof area and plumbed to the washing machine cold water tap, toilets and at least one external tap. Other options available are: a greywater treatment plant, communal rainwater tanks, dual reticulation of recycled water or treated stormwater, or a combination of these. The internal fixtures supplied from the tank must also have a continuous supply of water and, therefore, a back-up supply of mains water using a trickle top-up or automatic switching valve system was stipulated (DPI, 2010).

Since the instigation of QDC MP 4.2, it was estimated that there were approximately 60,000 dwellings built in SEQ with a rainwater tank (ABS, 2010). Considering the associated economic cost of tank installation and the potential benefits of achieving the mains water saving target of 70 kL per year from dwellings with IPT, it is thus worthwhile to assess the potential mains water saving actually being achieved from the implementation of these tanks.

The purpose of this *Phase 2* study is to provide a benchmark analysis of mains water savings by comparing the average mains water usage of the mandated rainwater users group to the respective SEQ regional average mains water consumption. The benchmark analysis protocol was adopted from the Sydney Water's BASIX approach (NSW Department of Planning, 2008). Water billing records of 691 survey respondents from *Phase 1* study were matched and normalised individually to their specific household occupancy rate over the 2-year period for Quarter 1 (Q1, period from January to March) 2009 to Quarter 4 (Q4, period October to December) 2010. Further work on the on-going validation of the water savings target through to 2012 will be planned to monitor the mains water savings from IPT dwellings. This research is an important step in achieving a more integrated understanding of mains water savings from mandated rainwater tanks in SEQ. The following section highlights some of the research already conducted in this area.

1.1. Literature Review

1.1.1. Past Research on Rainwater Tank Yield

Coombes and Kuczera (2003) predicted the annual rainwater tanks yields ranging from 18 to 144 kL in Brisbane, depending on tank size, climate and household occupancy. However, in this instance the modelling was based on pre-drought rainfall data and assumed that rainwater was also used for hot water systems. In contrast, Marsden Jacob Associates (NWC, 2007) presented a number of modelled scenarios for Australian urban environments indicating that rainwater tanks could reduce mains water consumptions by 42 kL/hh/yr if externally plumbed only. Where tanks are plumbed into both internal and external fixtures, then the yield could increase to 71 kL/hh/yr. The important considerations in achieving mains water savings highlighted in both studies were connected roof area, end usage, occupancy rate and raintank size. Beal *et al.* (2011) have indicated similar factors that have potential influences on predicting rainwater tank yields. It is also important to note that predictions related to

potential water savings were affected by the climatic or local conditions input into the various models (e.g. pre-drought household water use) (Mitchell, 2007).

Subsequent research was carried out in New South Wales by the Department of Planning, in response to drought conditions and water shortages (NSW Department of Planning, 2008). It attempted to overcome these conditions by implementing water demand management strategies and household level installations of water-efficient showerheads, tap flow regulators and dual flush toilet cisterns, in order to minimise mains water use. The BASIX approach was used as an online mechanism to implement minimum sustainability performance for all new dwellings in New South Wales. To calculate whether the BASIX program had been successful, Sydney Water linked BASIX data to quarterly water consumption data of participating households, and used a water use benchmark figure of approximately 324 kL/hh/yr based on the average household water consumption in New South Wales. Results showed that the BASIX target of 40% reductions was achieved with an average water consumption of 192 kL/hh/yr.

Interestingly, the Sydney Water study also established that when BASIX data were adjusted for *actual* household occupancy (i.e. not using an *estimated* occupancy), the average savings in water consumption increased from 40% to 42%. While in this instance the difference is not substantial, there is still a clear margin of error. The analysis demonstrates the importance of knowing actual household occupancies in order to calculate and compare household water consumption more accurately for newly constructed dwellings. This is particularly important given the trend for newer dwellings to have higher household occupancies than existing households in all major cities within Australia (NSW Department of Planning, 2008). Given the similar context of Sydney Water's work, which is comparable to the mandated rainwater tanks requirements for new dwellings in the SEQ region, the BASIX analysis approach is adopted for estimating mains water saving from IPT dwellings in the decentralised systems project.

1.1.2. Research Leading to the Present Study

As part of UWSRA's research program, Beal *et al.* (2011) estimated and compared the mains water use in new dwellings with existing dwellings in SEQ, using a comparable approach to the Turner *et al.* (2004) study. Beal *et al.* (2011)'s study involved the use of a paired statistical approach involving a large database (>28,000 dwellings) of mandated rainwater tank households across three SEQ local council areas: Pine Rivers (within the Moreton bay Regional Council), Redland City Council and Gold Coast City Council. The purpose of their study was to conduct a preliminary desktop assessment of the potential reductions in main water use from households with internally plumbed rainwater tanks in SEQ. The researchers used council water billing data to estimate mains water reductions from IPT. Beal *et al.* (2011) hypothesised that water consumption in dwellings with internally plumbed rainwater tanks would be significantly different to the water consumption from dwellings without internally plumbed rainwater tanks. Houses approved and constructed after 1 January 2007 were considered for this analysis as it was assumed that they would have an internally plumbed rainwater tank. Houses constructed prior to this date were filtered for tank rebates uptake before being used as the control group (i.e. no tank). Their final results indicated that an average reduction in mains water use across the three council areas was 50 kL/hh/yr.

1.1.3. Limitations of Past Research

Beal *et al.* (2011) used a pair-wise statistical analysis to measure the mains water saving at dwellings with mandated rainwater tanks against those without tanks, where each 'No Tank' property was chosen randomly for pairing with similar IPT households in the same SEQ council area. As expected, the data available for No Tank properties was much greater than for properties with IPT, which resulted in fewer paired household sets. Unfortunately, due to the small sample sizes and unavailable data in some LGAs, lower statistical power was observed for a range of data.

Also, owing to the desktop nature and limitations of the data availability, there were a number of key assumptions that were made in the analysis that could have diluted the outcomes of the water savings estimation. The possible influencing assumptions included: (1) classification of the water billing data into dwellings according to the QDC MP 4.2 effective date; (2) critical factors that influence residential water consumption (garden size, water efficient fixtures etc); and (3) socio-demographic

factors (e.g. household occupancy, family makeup, income). Therefore, the primary drivers for the present study were generated from Beal *et al.* (2011).

1.2. Purpose of Present Study

The aim of the wider study of which this *Phase 2* research forms a part is to provide a sound and methodical approach to validating the mandated rainwater tank savings target of 70 kL/hh/yr under the QDC MP 4.2 for SEQ. It is anticipated that the current study will provide some contextual understandings for previous work done by Beal *et al.* (2011) in achieving the mains water savings through mandated rainwater tanks.

The purpose of this *Phase 2* study is to provide a benchmark analysis of potential mains water savings by households with a mandated rainwater tank, in comparison with published average SEQ regional mains water consumption rates for the same LGAs. The differences between the two study groups are assumed to generate the relative mains water saving in the households with mandated rainwater tanks.

The target areas for this analysis are four LGAs within SEQ: Caboolture and Pine Rivers (within the Moreton Bay Regional Council), Redland City Council and Gold Coast City Council, to mirror the sample area used in Beal *et al.* (2011) study. The benchmark analysis protocol used in this study is similar to the Sydney Water BASIX approach (NSW Department of Planning, 2008). The method involved matching the individual household occupancy data with the water consumption data at the household level in order to determine the per capita water consumption from the Q1 of 2008 to the Q4 of 2010. This information is likely to be the key in determining whether mains water consumption is being reduced by the implementation of mandated rainwater tanks, and if so, then to what extent. The successful completion of this benchmark analysis in *Phase 2* of this study will provide a step-wise improvement in the on-going attempt to more accurately estimate and validate the mains water savings target of 70 kL/hh/yr for post-2007 dwellings with mandated rainwater tanks.

2. METHODOLOGY

2.1. Study Setting and Time Period

The study area comprised four LGAs in the SEQ region: Caboolture, Pine Rivers, Redland and Gold Coast. The 2006 Australian Census described these four LGAs as containing over 40% of SEQ urban population (DIP, 2009). Beal *et al*. (2011) also targeted these four LGAs in their investigation for mains water savings from rainwater tanks. A phone survey under the *Phase 1* study was conducted between July and August 2010 and the biophysical data analysis conducted between January - March 2011 was used for the benchmark analysis in this *Phase 2* study. The results of this *Phase 1* research are described in Chong *et al.* (2011).

Figure 1: SEQ council areas analysed for mains water savings from dwellings with mandated rainwater tanks.

*Note: Pine Rivers and Caboolture are a part of the Moreton Bay Regional Council which is in turn grouped as a Central SEQ region (together with Brisbane City, Logan City, Ipswich City and a few others).

Only properties built after 2007 were included in the study to ensure only households with mandated IPT were analysed. All the targeted LGAs are along the eastern seaboard within close proximity to Brisbane City Council. These regions were selected due to the availability of necessary data for this benchmark analysis.

2.2. Participants

2.2.1. Recruitment

The participants groups, who were recruited during *Phase 1* study and provided their consent to access their mains water billing records from Caboolture, Pine Rivers, Redland and Gold Coast, were considered suitable for *Phase 2* of the study. Out of 15,615 targeted households, only 1,134 householders from the selected four LGAs responded to the survey after having satisfied the screening criterion to ensure that the household had an IPT. The water consumption data for the consenting households were obtained from the QWC database. Some households were further excluded from the analysis due to inconsistent or incomplete water billing data. A total of 691 households across all four council areas were ultimately found to be suitable for inclusion in the analysis (Figure. 2).

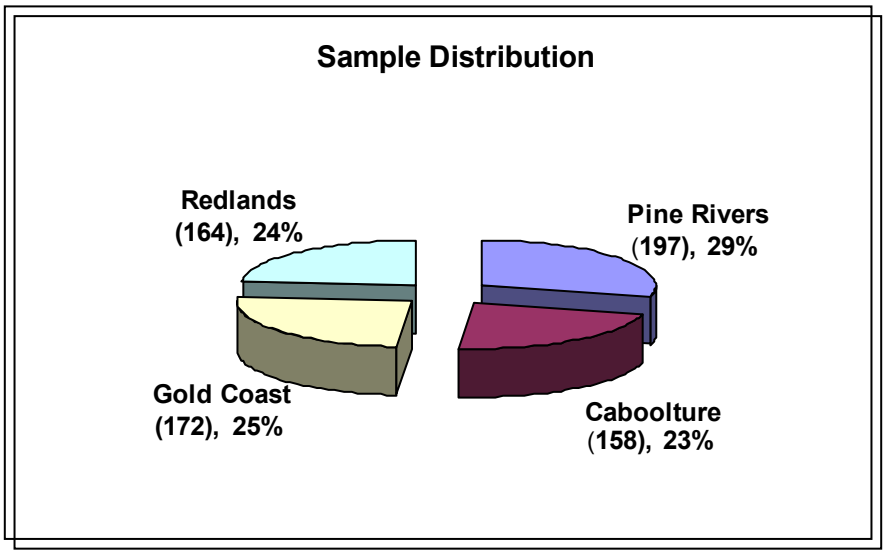


Figure 2: Percentage distribution of the total survey respondents who have given consent to obtain water consumption data from QWC.

2.2.2. Occupation and Occupancy

As all the properties being studied were constructed post 2007, it was difficult to determine when occupation took place. It was also necessary to know the occupancy rate for every household in order to obtain more accurate results compared to previous preliminary desktop analysis study (Beal *et al.* (2011), where the average occupancy rate from ABS 2006 data was assumed across the four LGAs. In the *Phase 1* study, telephone CATI surveys conducted for new households (built after 2007) were used to confirm the occupancy data (including date of house being occupied).

2.3. Assessment Procedure

A comprehensive data analysis was conducted using the QWC water billing data of households and respective occupancy numbers of individual household. A benchmark analysis approach similar to Sydney Water's BASIX approach (NSW Department of Planning, 2008) was applied for assessing mains water savings. Figure 3 shows the schematic diagram on the use of the benchmark analysis approach to estimate the potential mains water savings from mandated dwellings.

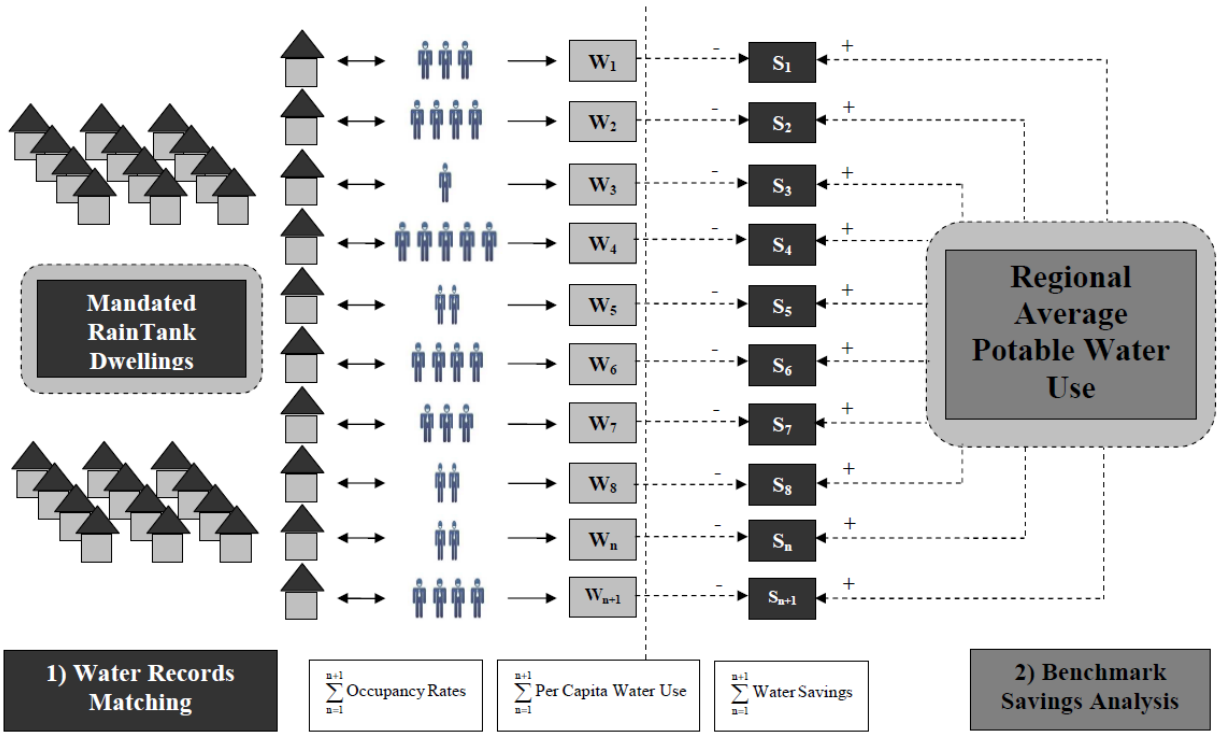


Figure 3: Schematic diagram for the benchmark analysis in estimating the potential mains water savings from dwellings with mandated rainwater tanks.

From Figure 3, the mains water consumption records for each mandated dwelling were matched to their individual household occupancy number obtained from the telephone survey. This was followed by the normalisation of mains water consumption to yield the per capita mains water usage (W_X) of each matched dwelling. The normalised per capita mains water usage data set (W_X) was then individually subtracted from the average mains water use for the respective LGA to generate the individual mains water savings (S_X). It should be noted that the positive sign notation (+) was used to indicate the resultant mains water savings from mandated dwellings. Thus, any negative values (-) that resulted from the benchmark analysis indicate the mains water consumption at the particular mandated dwelling is actually higher than the regional average mains water consumption value. Subsequently, the annual mains water savings from the mandated dwellings was estimated from the summation of each of the individual mains water savings (S_X) values.

The resultant mains water savings was expressed in L/p/d. In order to convert the savings into kL/hh/yr, the mean occupancy rate estimated from the mandated dwellings group was used. Based on the matched water records, it was estimated that the average number of people per household was 3.18 (Redland), 3.20 (Caboolture), 3.21 (Pine Rivers) and 3.34 (Gold Coast).

Although median values showed a lower mains water consumption (i.e. higher water savings) for IPT households in these regions, the mean value was used in the study because the aim was to assess whether the total savings from IPT households could achieve the mean mains water savings target of 70 kL/hh/yr as per the QDC MP 4.2 requirement. The 2009 and 2010 data set was used to provide a more accurate picture for the water consumption due to minimal discrepancies in the data.

2.4. Data Challenges

Although many challenges faced in the previous study by Beal *et al.* (2011) have been addressed in this analysis, there were a few challenges in obtaining complete data sets for some households over some quarters in 2008. Most of the incomplete data sets lie in 2008 calendar year due to the possibility of new dwellings not yet being occupied or partially occupied at that time.

QWC did not have separate average water consumption data for Pine Rivers and Caboolture council areas. Instead, average water data consumption data (L/p/d) for all regions that were part of the Central SEQ Regional Council was provided. Since both Pine Rivers and Caboolture are a part of Central SEQ, the average water savings in IPT households for both regions were calculated against the average water consumption in the Central SEQ region.

The other challenges associated with the available data are as follows:

1. SEQ annual water consumption data for Redland was not available for 2008 and only limited water consumption (billing) data was available for the same year for IPT dwellings.
2. Quarterly water consumption average (per person per day) for IPT households was obtained through QWC for all regions except for Caboolture where half-yearly water consumption averages (for IPT households) were available for year 2008. This could have made the analysis less accurate for Caboolture in 2008.
3. Similar to 2008, the quarterly average water consumption (per person per day) data for the first half of 2009 was available as a half-yearly average for Caboolture.
4. Water consumption data for IPT households was unavailable for Gold Coast in the first quarter of 2008.
5. Many households were shown to have incomplete data for 2008 across all four regions (Pine Rivers, Caboolture, Gold Coast and Redland).

A more complete data set of matched water billing records was available for the full calendar year of 2009 (Q1 to Q4) and 2010 (Q1 to Q4). Only an incomplete data set was available for 2008 (Q1 – Q4). This was attributed to an incomplete set of water billing data for most of the matched mandated tank households as they were likely to have been moving into their new properties throughout 2008. To avoid any bias in results from 2008, this data set was removed for any further mains water saving analysis.

3. RESULTS AND DISCUSSION

3.1. Normalised Water Consumption Data for IPT Dwellings

The mains water consumption data provided by QWC for each of the four council areas is based on usage per person per day, with estimated household occupancy derived from estimated populations in the respective council area. The average quarterly water consumption data for IPT dwellings was provided on the basis of consumption per household. In order to achieve more accurate and comparable results, the water consumption data per IPT household was used to calculate the average consumption per person per day in each of the 691 households. Thus the data set for average water consumption in IPT dwellings was normalised to individual occupancy in order to obtain more precise results in calculations and to make more reliable comparisons with average mains water consumption in those council areas.

The average mains water consumption per person per day in the four council areas as provided by QWC is shown in Table 1. The published SEQ average mains water consumption in 2009 for Pine Rivers, Caboolture, Gold Coast and Redland ranged from 140.4 L/p/day (for Pine Rivers and Caboolture: Central SEQ regions), to 201.5 L/p/d (Redland) and up to 211.4 L/p/d (Gold Coast).

Table 1: Average per capita mains water consumption (L/p/d) in SEQ and selected council areas.

Year	SEQ region	Central SEQ group	Gold Coast City Council	Redland City Council
2009	161.0	140.4	211.4	201.5
2010	154.8	143.3	192.0	183.1

Table 2: Mean water consumption (L/p/d) and average persons per household in the four SEQ council areas.

Region with mandated rainwater tanks	Sample Size	Mean water usage 2009 (L/p/d)	Mean water usage 2010 (L/p/d)	Mean person per household from Beal *et al.* (2011)	Mean person per household in this study
Pine Rivers (Moreton Bay Regional Council)	197	119.4	109.4	3.00	3.21
Caboolture (Moreton Bay Regional Council)	158	108.5	108.2	-	3.20
Gold Coast City Council	172	138.8	125.7	3.20	3.34
Redland City Council	164	129.1	121.9	2.90	3.18

The calculated average per capita water consumption (L/p/d) for each council area for 2009 is shown in Table 2. The large variation in average mains water consumption across the SEQ region seen in Table 1 was not observed for IPT dwellings across the four council areas. Table 2 shows that the mean mains water consumption for IPT dwellings in 2009 was the lowest in Caboolture (108.5 L/p/d), followed by Pine Rivers (119.4 L/p/d), Redland (129.1 L/p/d) and Gold Coast (138.8 L/p/d).

In this study, the occupancy data obtained via telephone interviews in *Phase 1* of the study gives more accurate results in determining the water consumption in these SEQ council areas. The average occupancy for Pine Rivers, Caboolture, Redland and Gold Coast can be seen in Table 2, which is based on the phone survey. The actual average occupancy is clearly higher than what was considered in the earlier analysis by Beal *et al.* (2011), where occupancy rates of 3.0 for Pine Rivers, 3.2 for Gold Coast and 2.9 for Redland were based on the 2006 ABS Census data.

3.2. Benchmark Analysis of Mains Water Savings for IPT Households

In this section, results of the benchmark analysis conducted to estimate the potential mains water savings from IPT households are presented and discussed. The average mains water usage for the mandated rainwater users' group were compared with the published SEQ average mains water consumption data. The differences between the two data sets provide an estimation of the magnitude of mains water saving for IPT households.

A total of 691 households were matched from the 1,134 survey participants in *Phase 1* and analysed for their normalised per capita water consumption. The estimated mean values for mains water saving from IPT dwellings were considered to be more accurate than the earlier preliminary analysis of Beal *et al.* (2011) as they were derived from the actual water billing record data normalised to the specific occupancy rate for every matched household. Both the mean and median values were estimated. The mean values were used throughout this report as a more relevant comparison to the mean water consumption data published for the SEQ region.

Figure 4 shows the comparison of estimated water consumption in IPT households (L/p/d) with average QWC water consumption data (L/p/d) for each study area for 2009. Figure 4 (a) shows the mean water consumption figures and the median water consumption figures are shown in Figure 4 (b). The differences between the average mains water usage for IPT households and the respective SEQ average mains water consumption data gives the benchmark water saving for each council area.

Table 3 highlights the annual mains water savings in IPT households for 2009 by comparing the published average annual mains water consumption and benchmark consumption. Average annual mains water consumption per person per day based on QWC published data was found to be the highest for Gold Coast (211.4 L/p/d) and Redlands (201.5 L/p/d) compared to Pine Rivers and Caboolture (140.4 L/p/d).

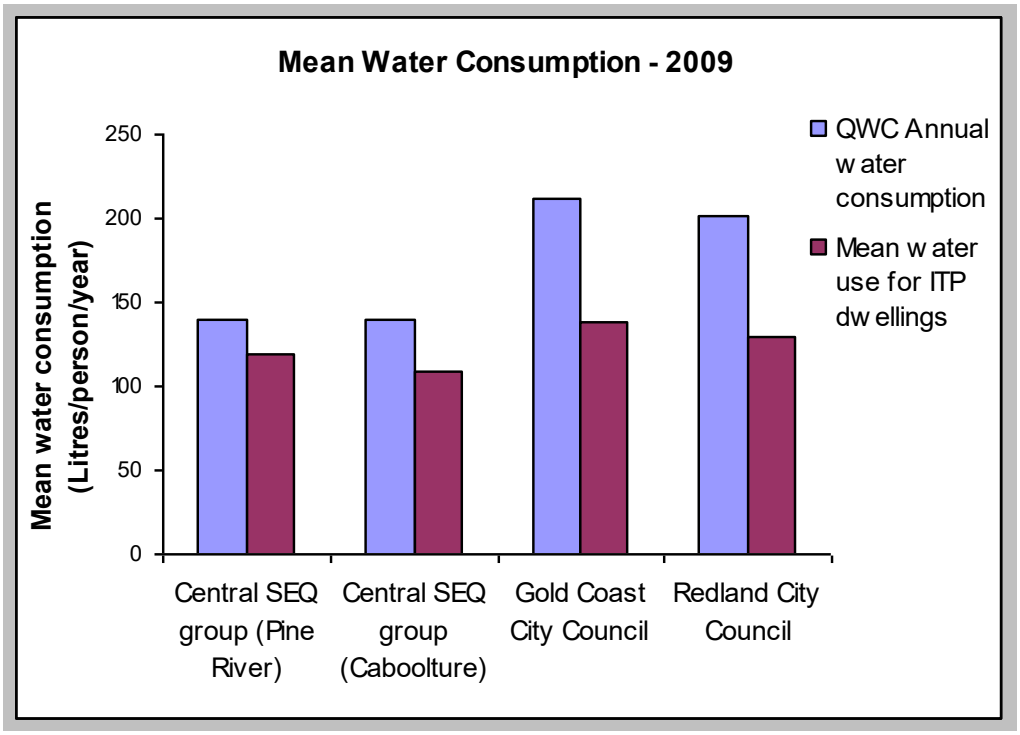
A similar trend is also observed in IPT households, where the mains water consumption was 138.8 L/p/d for Gold Coast and 129.1 L/p/d for Redland compared to 119.4 L/p/d for Pine Rivers and 108.5 L/p/d for Caboolture.

This resulted in an average savings in main water usage for IPT households across the four council areas in this study of approximately 49.5 L/p/d in 2009. Significant mains water savings were demonstrated for Gold Coast (72.6 L/p/d) and Redland (72.4 L/p/d) in particular. The average mains water savings for Pine Rivers and Caboolture were 20.9 L/p/d and 31.9 L/p/d respectively, which were significantly lower than the water savings for Gold Coast and Redland. These data reflect the continued low water consumption in Pine Rivers and Caboolture in 2009 in the aftermath of the severe water restrictions placed on those regions in 2008.

Table 3: Average water savings in IPT households in comparison with annual consumption and benchmark consumption for 2009.

Council area (Sample Size)	Pine Rivers (197)	Caboolture (158)	Gold Coast (172)	Redland (164)
Average persons per household	3.21	3.20	3.34	3.18
QWC Annual mains water consumption (L/p/d)	140.4	140.4	211.4	201.5
Average water consumption in IPT households (L/p/d)	119.4	108.5	138.8	129.1
Average water savings in IPT households (L/p/d)	20.9	31.9	72.6	72.4
Average savings per IPT household per year (kL/hh/yr)	24.5	37.3	88.5	84.0
Average savings over all samples (691)	**58.8 kL/hh/yr**			

Since the ultimate aim of this study is to validate the 70 kL per year mains water savings target under QDC MP 4.2, the reported annual mains water savings in L/p/d in Table 3 were converted to kL/hh/y based on the average occupancy rates per household extracted from *Phase* 1 of this study. Thus, for year 2009, the average annual mains water savings per household per year across the four council areas were found to range from 24.5 kL/hh/yr (Pine Rivers) to 88.5 kL/hh/yr (Gold Coast), with an average mains water saving (for 691 households) being 58.8 kL/hh/yr.



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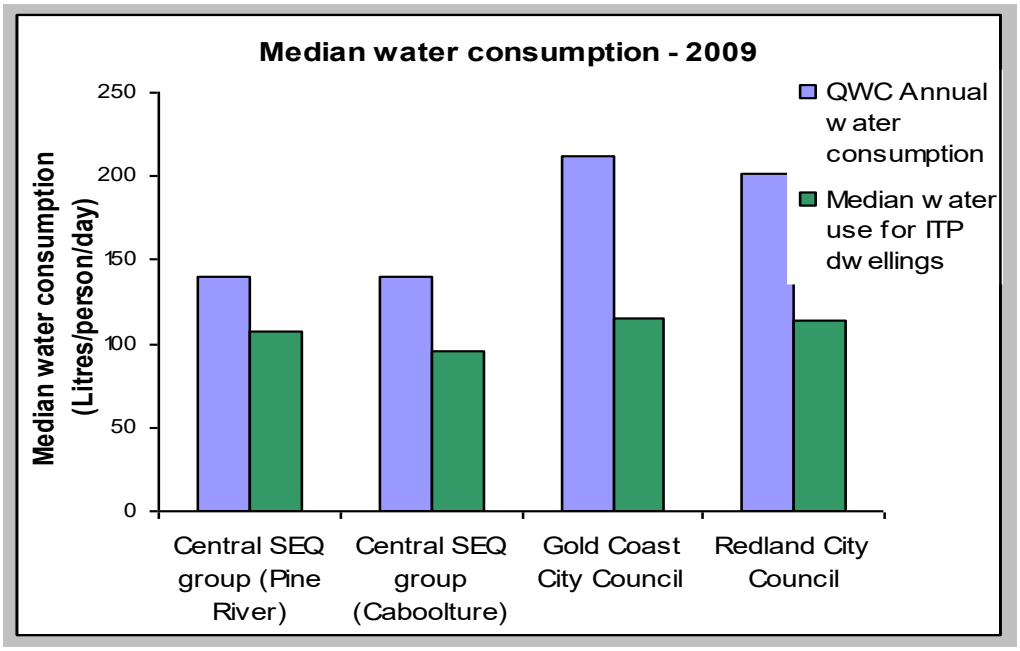


(b)

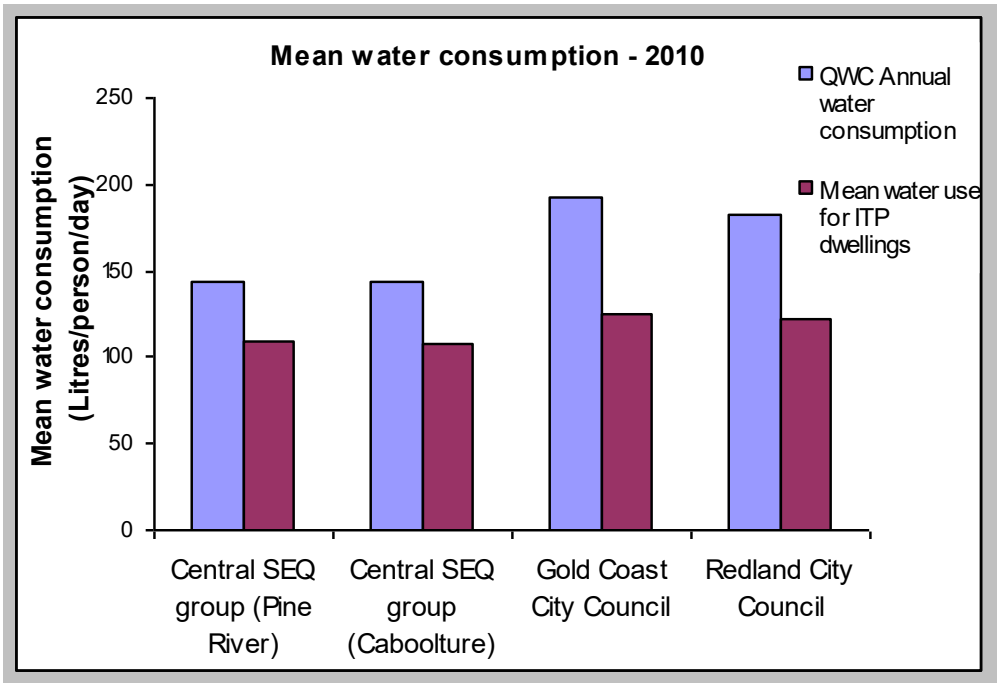
Figure 4: Estimated water consumption in comparison with benchmark water consumption in 2009. (a) Mean; (b) Median.

Figure. 5 shows the average mains water consumption for IPT dwellings in 2010. A similar trend of mains water saving was observed for 2010 as shown in Table 4. The average annual mains water savings per household per year across the four council areas were found to range from 39.7 kL/hh/yr (Pine Rivers) to 81.0 kL/hh/yr (Gold Coast). The overall average water savings across the four regions (for 691 households) were 58.2 kL/hh/yr.

Table 4: Average water savings in IPT household in comparison with annual consumption and benchmark consumption for 2010.

Council area (Sample Size)	Pine Rivers (197)	Caboolture (158)	Gold Coast (172)	Redland (164)
Average persons per household	3.21	3.20	3.34	3.18
QWC Annual water consumption (L/p/d)	143.3	143.3	192.0	183.1
Average water consumption in IPT households (L/p/d)	109.4	108.2	125.7	121.9
Average water savings in IPT households (L/p/d)	33.6	34.8	66.3	61.2
Average savings per IPT household per year (kL/hh/yr)	39.7	40.9	81.0	71.0
Average savings over all samples (691)	**58.2 kL/hh/yr**			

The published SEQ average mains water consumption in the corresponding SEQ council areas ranged from 143.3 L/p/d (for Pine Rivers and Caboolture), 183.1 L/p/d (Redland) to 192 L/p/d (Gold Coast). The average mains water consumption for IPT households in 2010 was also well below 140 L/p/d for all of the studied LGAs, ranging from 108.2 L/p/d for Caboolture to 125.7 L/p/d for the Gold Coast. The benchmark analysis between the two data groups in Table 4 (IPT dwellings against published SEQ average) showed the mains water savings in 2010 of 33.6 L/p/d (Pine Rivers), 34.8 L/p/d (Caboolture), 61.2 L/p/d (Redland) and 66.3 L/p/d (Gold Coast) - an average savings in main water usage for IPT households across the four council areas in this study of approximately 49.0 L/p/d in 2010. Thus, in general, it was found that the average mains water consumption for IPT dwellings was quite consistent across 2009 and 2010.



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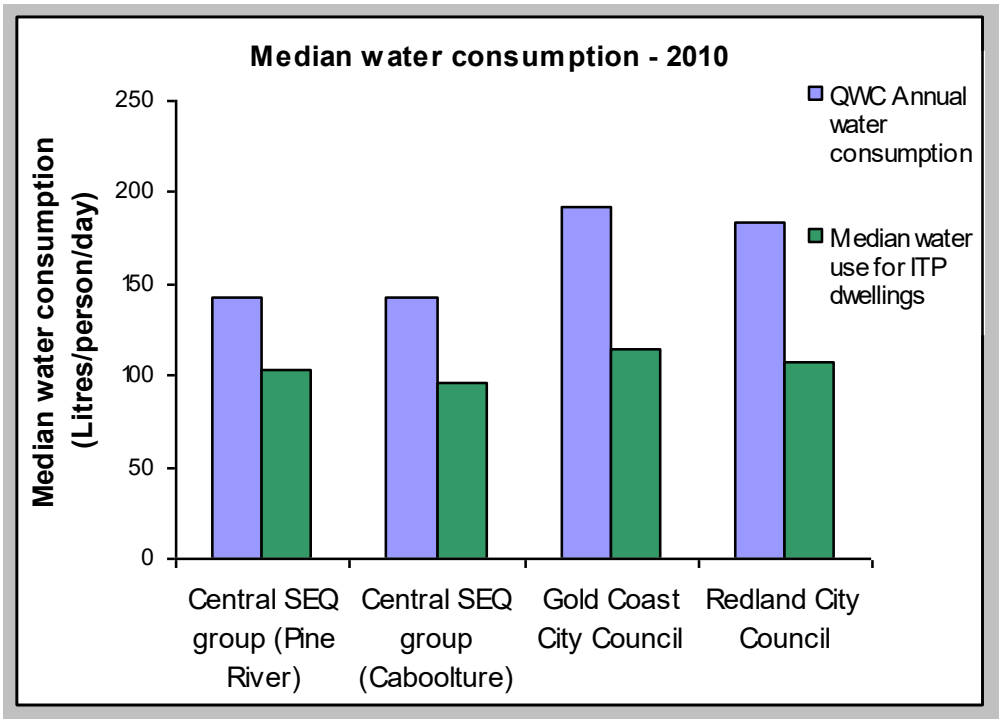


(b)

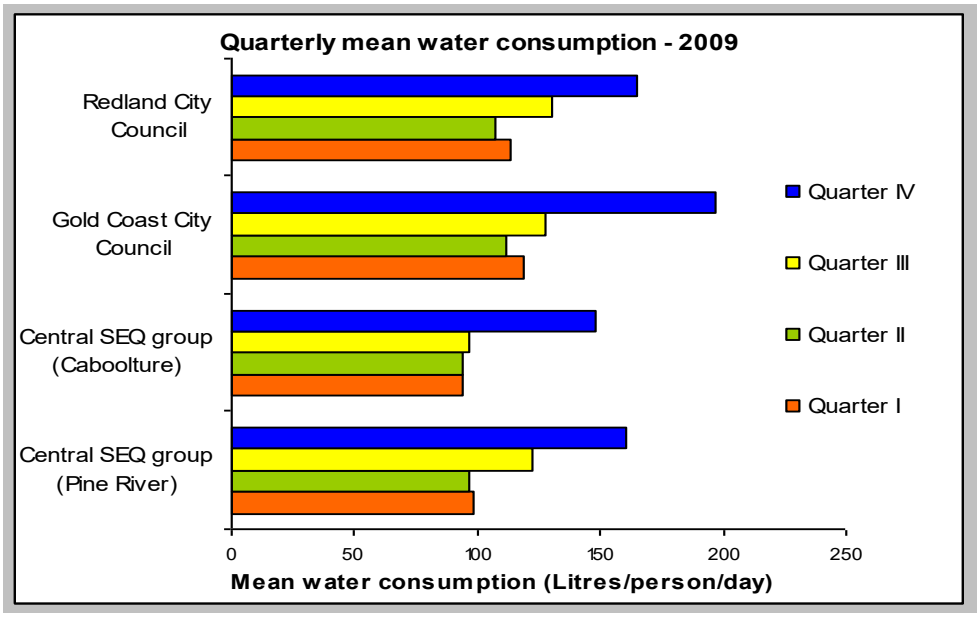
Figure 5: Estimated water consumption in comparison with benchmark water consumption in 2010 (a) Mean; (b) Median.

These results demonstrate that households with IPT significantly reduced the direct reliance on mains water supplies in all the studied LGAs. Variation between LGAs could be driven by factors such as rainwater tank yield including factors related to rainfall, socio-demographic factors (water wise awareness and household water conservation behaviour) and water efficient household appliances and fixtures.

The full potential mains water saving has yet to be examined as the current study only involved benchmarking the water savings against the published SEQ average mains water consumption data, where the bulk data set can consists of mixed dwellings with and without IPT, water efficient appliances and other water features.

3.3 Quarterly Mean Water Consumption

Figures 6(a) and (b) show the average quarterly mains water consumption in 2009 for Pine Rivers, Caboolture, Gold Coast and Redland. It was observed that all four LGAs showed a higher mains water usage in the Q4 of 2009. This was possibly due to the onset of summer season, with Gold Coast showing the highest mains water consumption rate among the studied LGAs.



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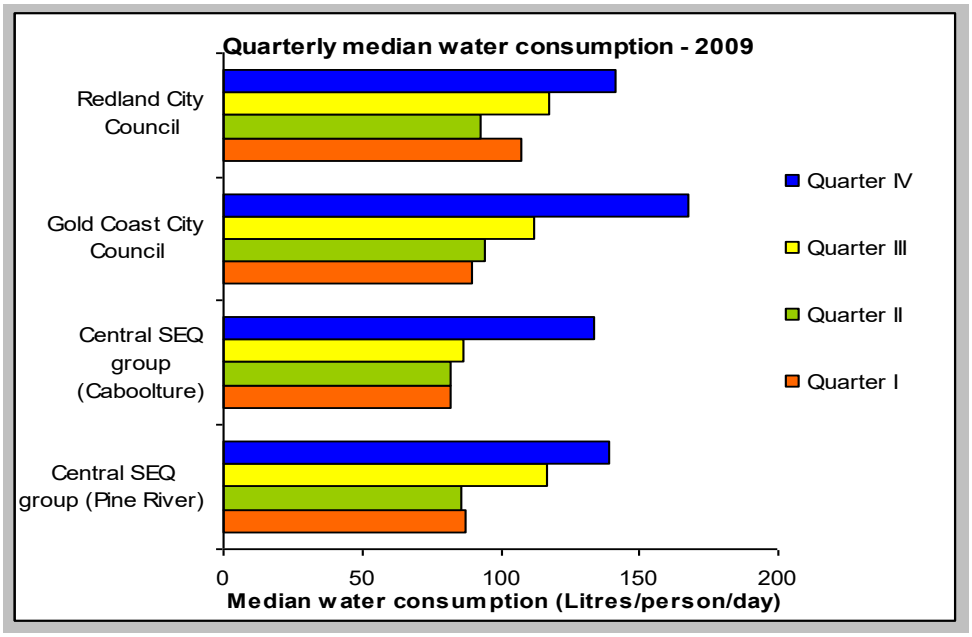
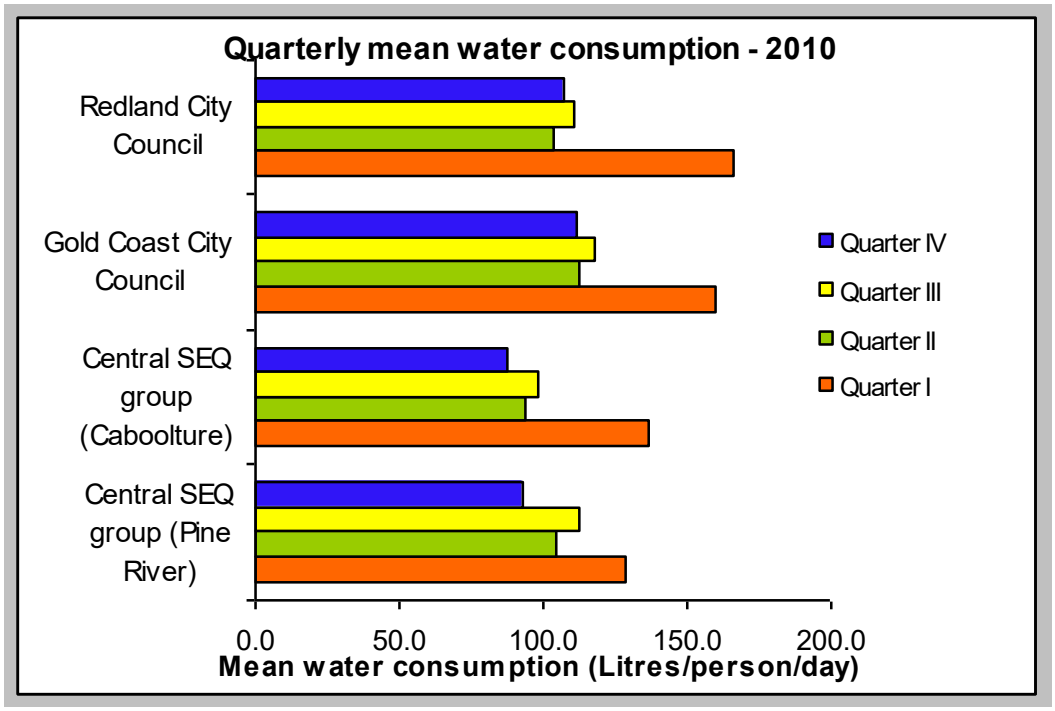


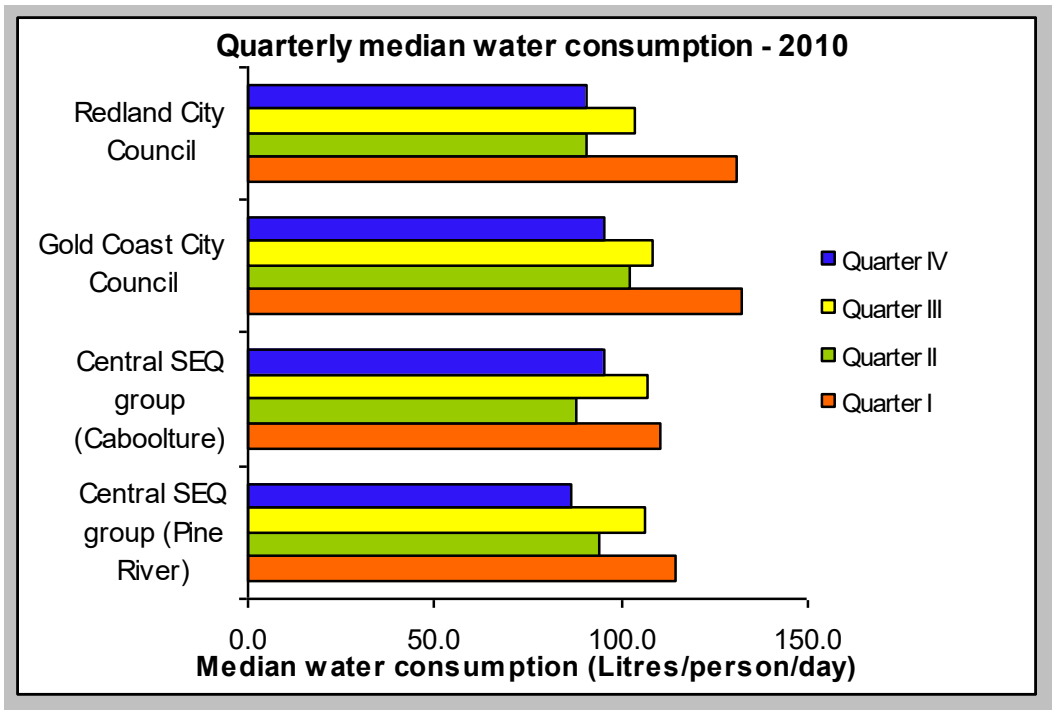
(b)

Figure 6: Comparison of estimated average quarterly water consumption in IPT households across all four SEQ council areas in 2009 (a) Mean; (b) Median.

Similarly, Figures 7(a) and (b) show the average quarterly mains water consumption in 2010 for Pine Rivers, Caboolture, Gold Coast and Redlands. Interestingly, it was found that the mains water use pattern for the quarters in 2010 are quite different from quarters in 2009 where the inverse of higher water consumption rate towards late 2010 was observed.



(a)



(b)

Figure 7: Comparison of estimated average quarterly water consumption in IPT households across all four SEQ council areas in 2010 (a) Mean; (b) Median.

Table 5 shows the summary of the estimated percentage of mains water savings for IPT households per quarter, as well as their corresponding figures in L/p/d, across the four studied LGAs for 2009 and 2010.

IPT households show a significant reduction in mains water consumption, especially in the Gold Coast and Redland regions. Results showed that the per capita reduction in mains water consumption per day ranged from 4 to 50% for 2009 when benchmarked against the respective SEQ regional average water consumption data. Similarly for 2010, per capita reduction in mains water consumption per day ranged from approximately 7 to 41% in these studied LGAs.

Both the Gold Coast and Redland regions showed a significant reduction in mains water consumption (>60 L/p/d) against the published SEQ regional benchmarks for 2009 and 2010. Average mains water savings were generally lower for both the Pine Rivers and Caboolture. The average water savings were consistently around 30 L/p/d for 2009 and 2010. It should be noted that, for the last quarter of 2009 in Pine Rivers, the average mains water consumption at IPT households was greater than the published average mains water consumption for that region (i.e. Central SEQ region). These numbers are shown in brackets in Table 5.

Interestingly, it should be noted that the percentage reductions in mains water consumption seems to be higher in Gold Coast and Redland, with a previous history of no to low-level water restrictions (as opposed to Pine Rivers and Caboolture where both had severe water restrictions). This is consistent with the findings of Beal *et al.* (2011).

Beal *et al.* (2011) noted the influence of water restrictions on mains water consumption and savings from IPT households. Historically, there were a number of water restriction levels culminating in the severest (Level 6) during the height of the drought through to early 2008. Following substantial rainfall in mid 2008, and a return to an average rainfall year in 2009, restrictions eased from high level to medium level, and then to the current Permanent Water Conservation (PWC) measures. Water restrictions varied between councils. The Gold Coast and Redland were under relaxed outdoor watering restrictions in 2008 and early 2009. The most severe water restrictions in the study area occurred in the Moreton Bay Regional Council area, which encompasses Pine Rivers and Caboolture. Importantly, outdoor watering using mains water was limited, with hand-held hoses able to be used after 1 August 2008. In contrast, Gold Coast City Council had no restrictions between February and November 2008 due to high rainfall events overtopping Hinze Dam. Consequently, there was no limitation to outdoor watering with mains water. Properties in Redland Shire Council were on Level 2 restrictions which allowed outdoor watering using mains water to occur with a hand-held hose for both established and new gardens.

Table 5: Percentage mains water savings per person (per IPT household) per day and reductions based on average SEQ water consumption.

Quarter	Pine Rivers % Savings (L/p/d)	Caboolture % Savings (L/p/d)	Gold Coast % Savings (L/p/d)	Redland % Savings (L/p/d)
2009 Quarter 1	27% 36.7 L/p/d	30% 41.1 L/p/d	50% 121.3 L/p/d	42% 83.2 L/p/d
2009 Quarter 2	29% 33.4 L/p/d	27% 35.5 L/p/d	39% 71.6 L/p/d	41% 75.6 L/p/d
2009 Quarter 3	14% 19.5 L/p/d	32% 45.0 L/p/d	37% 74.0 L/p/d	34% 68.6 L/p/d
2009 Quarter 4	(-4%) (5.9 L/p/d)	4% 6.0 L/p/d	11% 23.6 L/p/d	27% 62.0 L/p/d
2010 Quarter 1	13% 18.9 L/p/d	7% 10.3 L/p/d	21% 41.2 L/p/d	12% 23.1 L/p/d
2010 Quarter 2	25% 34.6 L/p/d	33% 45.2 L/p/d	38% 70.4 L/p/d	41% 73.2 L/p/d
2010 Quarter 3	18% 24.1 l/p/d	28% 38.1 L/p/d	33% 58.5 L/p/d	34% 58.2 L/p/d
2010 Quarter 4	31% 42.3 L/p/d	35% 47.3 L/p/d	40% 73.8 L/p/d	37% 64.2 L/p/d

Note: Percentage value is based on the water savings obtained in IPT households in comparison with the overall average mains water consumption in that region. Value in brackets denotes the average mains water consumption at IPT households is greater than the average mains water consumption in that particular region.

Beal *et al*. (2011) showed smaller differences in water consumption between IPT and No Tank properties in council areas with high-level water restrictions (no or low outdoor watering). Conversely, the differences in mains water savings are greater for those homes located in low or no water restriction areas where these differences could be maximised by permitting outdoor water use to be sourced from mains water.

However, an interesting finding in this *Phase 2* study is that although the mains water consumption rate was found to be significantly higher during the summer months (Q4 2009 and Q1 2010), this did not lead to higher associated mains water savings, especially for Pine Rivers and Caboolture. This could be due to other social descriptors such as the attitudes and behaviours towards sustainable water practices, risk and threat perceptions on water shortages in SEQ which will be explored further in our wider research study.

4. CONCLUSION

Under the QDC MP 4.2, all Class 1 dwellings constructed after 1 January 2007 in SEQ are required to save 70 kL of mains water per year. This mains water saving target can be achieved through the use of household rainwater tanks, communal rainwater tanks, greywater tanks, dual reticulation and stormwater reuse.

Previously, Beal *et al.* (2011) had conducted a preliminary desktop study for three SEQ regions to investigate the potential mains water saving from IPT installed at post-2007 houses. In their study, they had estimated the mains water savings using 2008 council water billing data as 50 kL/hh/yr. However, the estimated mains water savings from 2008 water billing data analysis showed some inconsistencies with water balance modelling. The possible reasons for such a variation included water restrictions, tank yield, tank volume, rainfall, rainwater collection area, presence of water savings fixtures in households and other household demographic and water use behavioural factors.

This study was initiated to address some of the limitations present in Beal *et al* (2011). The study was undertaken in two phases. *Phase 1* was carried out by conducting a baseline characteristics analysis of mandated rainwater tank users in SEQ. A total of 1,134 survey households with mandated rainwater tanks from four LGAs of Caboolture, Pine Rivers, Redland and Gold Coast were polled on various biophysical and social descriptions, as well as for their consent to access their water billing records for the period 2007 - 2012.

The key difference between this and the Beal *et al*. (2011) study was that the specific household occupancy rates (from *Phase 1*) were matched to the individual water billing records in the current study; while the previous study used the average household occupancy rate from the 2006 Australian Bureau of Statistics (ABS) Census District Data.

The study demonstrated that IPT households could reduce their direct reliance on mains water supplies in all the studied LGAs, with variations among LGAs. The average annual mains water savings per household per year across the four LGAs in 2009 was estimated at 58.8 kL/hh/yr, ranging from 24.5 kL/hh/yr (Pine Rivers) to 88.5 kL/hh/yr (Gold Coast).

Average per capita savings in main water usage for IPT households across the four council areas in this study were approximately 49.5 L/p/d in 2009. Significant mains water savings were demonstrated for Gold Coast (72.6 L/p/d) and Redland (72.4 L/p/d) in particular. The average mains water consumption savings for Pine Rivers and Caboolture was 20.9 L/p/d and 31.9 L/p/d, respectively.

Similarly, average mains water savings were estimated to be 58.2 kL/hh/yr for 2010. This is equivalent to an average per capita savings in main water usage for IPT households across the four council areas in this study of approximately 49.0 L/p/d in 2010.

IPT households showed a significant reduction in mains water consumption, especially in the Gold Coast and Redland regions. Results showed that the per capita reduction in mains water consumption per day ranged from 4 to 50% for 2009 when benchmarked against the respective SEQ regional average water consumption data. Similarly, for 2010, per capita reduction in mains water consumption per day ranged from approximately 7 to 41% in the LGAs studied.

The variations in water savings between studied LGAs could be driven by factors such as rainfall pattern, rainwater tank yield associated with the rainfall pattern, socio-demographic factors (WaterWise awareness and household water use behaviour) and water efficient household appliances and fixtures.

In conclusion, the results shown in this report provide further evidence of the geographic variation in mains water savings from IPT households across the SEQ region and the impact of a range of biophysical, demographic and behavioural factors. Further research is needed for more accurately estimating and validating the mains water savings from mandated rainwater tanks.

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