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# End use water consumption in households: Impact of socio-demographic factors and efficient devices

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5  
6       **End use water consumption in households: impact of socio-demographic**  
7       **factors and efficient devices**  
8

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32

33 Abstract

34

35 Assessing water savings in households using efficient devices and how savings vary between  
36 different sectors of the community requires high resolution end use water consumption data  
37 (i.e. disaggregating water use for showers, toilets, clothes washers and garden irrigation etc.).

This paper reports selected findings from the *Gold Coast Residential End Use Study (Australia)*, which focussed on the relationship between a range of socio-demographic and household stock efficiency variables and water end use consumption levels. A mixed methods approach was executed using qualitative and quantitative data. The study provided evidence as to the potential savings derived from efficient appliances as well as socio-demographic clusters having higher water consumption across end uses. The payback period for some water efficient devices was also explored. The study has implications for urban water demand management planning and forecasting.

46

47 **Key words:** smart metering; conservation attitudes; urban water, water demand management;  
48 water efficiency; water end use; water micro-component

49

50

51

52

53

55     **1. Introduction**

56     ***1.1 Improving urban water security***

57         The strong emphasis on ensuring a secure water supply for the population of Australia  
58         has been brought to light by the increasing frequency, severity and duration of drought events  
59         throughout the nation. Drought, coupled with growing populations has lead to numerous  
60         instances of many water supply reservoirs in South-East Queensland (SEQ) dropping below  
61         20% over the last decade. This has forced State and Local government to implement  
62         alternative water supply schemes, along with a range of demand management interventions,  
63         in order to improve urban water security. Innovative water re-use (e.g. Willis et al., 2010a;  
64         Willis et al., 2011a) and decentralised supply solutions (e.g. Talebpour et al., 2011) are  
65         becoming increasingly viable technologies to meet city water needs but there are often many  
66         financial, behavioural and regulatory barriers to their diffusion in practice (Partszch 2009;  
67         Krozer et al., 2010; Giurco et al., 2010; Willis et al., 2011b). Planning studies employing  
68         holistic Integrated Water Resource Management (IWRM) models (e.g. Dvarioniene and  
69         Stasiskiene, 2007) have been applied and demonstrated that high efficiency water fixtures  
70         and appliances are a least cost planning strategy for water conservation and a good starting  
71         point for policy makers before higher cost water supply or demand solutions are  
72         commissioned (Stewart et al. 2010).

73

74     ***1.2 Domestic water consumption and conservation***

75         In the case at the Gold Coast, Australia – a city of 510,000 people – residential water  
76         consumption accounts for approximately 66% of the City's total supply (2007/2008).  
77         Residential water consumption has previously been determined to be influenced by seasonal  
78         changes and Water Demand Management (WDM) strategies such as water metering  
79         (compared with unmetered homes), water restriction levels, water efficient devices, water

80 consumption information devices and education (Beal et al. 2010; Inman and Jeffrey, 2006;  
81 Mayer et al., 2004; Nieswaidomy, 1992; Willis et al. 2010b). Although prior research in these  
82 areas has occurred, it is well established that there is a requirement for specific country and  
83 location based research due to a range of reasons, including: (1) different community  
84 attitudes and behaviours; (2) water appliance stock efficiency profiles; (3) environmental  
85 conditions; and (4) water pricing structures; (5) government water restriction regime; and (6)  
86 conservation message intensity. All such contextual factors have an influence on the  
87 effectiveness of WDM strategies (Corral-Verdugo et al., 2002; Turner et al., 2005; Stewart et  
88 al., 2011; Willis et al., 2011b). To evaluate the effectiveness of WDM strategies high quality  
89 data is required (Stewart et al., 2010). The development of smart metering technologies and  
90 end use analysis techniques allowed for the acquisition of such data in this study.

91

### 92 ***1.3 Advent of smart water metering, monitoring and management***

93 The measurement, benchmarking and management of a process, product, project or  
94 system is an expected requirement in almost all industry sectors in the modern age (Stewart  
95 and Spencer, 2006; Stewart et al., 2009; Panuwatwanich et al., 2010). Such evaluation  
96 activities ensure the continual improvement of a business or industry sector, and are finally  
97 being applied in the water industry due to the advent of smart water metering technologies,  
98 which allow the collection of empirical evidence on *where in the home* and *how often* water is  
99 used, thereby allowing planners and conservationists to determine the relative water savings  
100 achievable from WDM strategies. Smart metering and management systems are essential  
101 enablers to the better measurement and management of valuable urban water supplies and the  
102 distribution systems that deliver this potable water to the household (Stewart et al. 2010).  
103 Conventional water meters in residential households in Australia only count the volume of  
104 water used and there is no facility to determine when and which water end use event is

105 occurring (such as in showers, toilets, clothes washers, garden irrigation etc.). Water  
106 consumption is characteristically recorded quarterly, resulting in just two to four data points  
107 describing a whole year's water consumption (Britton et al., 2008). Smart metering couples a  
108 higher resolution water meter with data logging equipment which allows for continuous water  
109 consumption recording. Data resulting from smart metering applications allows water  
110 managers to investigate the effectiveness of WDM strategies and household water  
111 consumption patterns amongst different socio-demographic groups (Beal et al., 2010; Stewart  
112 et al., 2010).

113

#### **114 *1.4 Overview of Gold Coast residential end use study***

115 The Gold Coast Residential End Use Study (GCREUS) commenced in 2007 as an  
116 Australian Research Council (ARC) funded collaborative research investigation by Griffith  
117 University, Gold Coast Water and the Institute for Sustainable Future (University of  
118 Technology, Sydney). The purpose of this study was to identify end use water consumption  
119 in Gold Coast homes and to evaluate the effectiveness of WDM strategies namely the  
120 application of water efficient devices and education as well as understanding water use  
121 differences between varying socio-demographic groups. Smart metering was implemented to  
122 ascertain end use water consumption data, to enable comparative analysis between varying  
123 household socio-demographic clusters and to understand the water saving potential of  
124 efficient devices. These aspects represent two objectives of the GCREUS study explored in  
125 this paper.

126

#### **127 *1.5 Engineered water efficiency***

128 Engineered efficiency or the development of higher efficiency water using devices  
129 has seen effective reductions in water consumption. In Tampa, USA Mayer et al. (2004)

130 determined that the retrofitting of water efficient devices can result in a reduction of up to  
131 49.7% of water use per capita; a highly significant reduction. Inman and Jeffrey (2006) report  
132 that the comprehensive replacement of household appliances (such as showers, toilets and  
133 clothes washers) with highly water efficient appliances can reduce indoor water consumption  
134 by between 35-50%. Not only does this reduction in demand serve to preserve water supply  
135 security for future generations but reduces the life cycle cost of potable water treatment and  
136 distribution, as well as energy intensive wastewater treatment (Barrios et al. 2008; Mahgoub  
137 et al. 2010) and ultimately the ecological footprint of the city or nation (Friedrich et al, 2009;  
138 Hubacek et al. 2009).

139

#### 140 ***1.6 Influences of socio-demographic factors***

141 There are several previously reported socio-demographic factors that can influence  
142 water consumption. The result of the socio-demographic variable investigations by the  
143 ARCWIS (2002) indicated that owner occupied properties, higher income families and  
144 households with swimming pools consumed more water for irrigation. Loh and Coghlan  
145 (2003) reported a strong relationship between income level and outdoor water use. The  
146 occupancy and make up of dwellings, lot size and the age of water using devices have also  
147 been found to influence water consumption with larger lot sizes generally consuming more  
148 water (Mayer and DeOreo, 1999).

149

#### 150 ***1.7 Research objectives***

151 The objectives of this paper are to:

- 152 a) Determine a household and per capita water consumption end use break down for a  
153 sample of Gold Coast households;

154 b) Explore the relationship between household stock survey efficiency rating clusters and  
155 water end use consumption levels; and,

156 c) Ascertain demographic information of water users and determine if socio-demographic  
157 factors influence water consumption.

158 The multifaceted objectives of the GCREUS study required the application of a mixed  
159 methods research design to obtain the required data types.

160

## 161 **2. Method**

162

163 To achieve the desired objectives of the study, a mixed methods data collection  
164 procedure including a stock survey of water using fixtures/appliances in households, end use  
165 water consumption study and a questionnaire survey, were concurrently undertaken with 151  
166 households on the Gold Coast City, Australia.

167

### 168 ***2.1 Mixed method study design***

169 The study adopts a mixed method design through collecting, analysing and mixing  
170 quantitative and qualitative research approaches and processes. This mixed methods approach  
171 allows the use of multiple methods to address research objectives (Creswell and Plano-Clark,  
172 2007). A mixed method approach was embarked upon as an array of data types are required  
173 to meet the developed research objectives. Namely, natural science data in the form of end  
174 use water consumption data, quantitative statistical survey data for demographic information,  
175 quantitative stock survey information, and, qualitative water behaviour data were required.

176

### 177 ***2.2 Sample***

A sample of 151 homes was recruited across Gold Coast City, Australia, including the Pimpama-Coomera and Mudgeeraba suburbs. As noted by Willis et al. (2009), regions were selected according to differing socio-demographic makeup. Comparative investigation of demographic factors including household makeup (i.e. family structure and residents per household) and ownership status assisted in confirming the selected regions. Age of infrastructure was also considered with all homes subsequently being developed in the past five years (Willis et al., 2009).

185

186 2.3 Water consumption end use study

187 The relationship between smart metering equipment, household stock inventory  
188 surveys and flow trace analysis is shown in Figure 1. Essentially, a mixed method approach  
189 was used to obtain and analyse water use data. Two aligned main processes were adopted:  
190 physical measurement of water use via smart meters with subsequent remote transfer of high  
191 resolution data; and documentation of water use behaviours and compilation of water  
192 appliance stock via individual household audits and self-reported water use diaries.

193

194 [Insert Figure 1]

195

The collection of end use water consumption data requires the application of a smart metering set-up. The GCREUS study smart metering set-up includes high resolution Actaris CTS-5 water meters, 72 pulses per litre or a pulse every 0.014L of water used, connected to Aegis Data Cell D data loggers which are set to collect pulse counts every ten seconds. Downloaded raw data files were in the ASCII format, which were then modified into .txt files for subsequent trace flow analysis.

202           End use data in .txt file form was analysed by Trace Wizard<sup>®</sup> software version 4.1.  
203       Stock appliance audits (i.e. type and characteristics of each household appliance or fixture)  
204       were used to help identify flow trace patterns for each household. Once a template was  
205       created for each household, data for a sampled two-week period was analysed. Trace  
206       Wizard<sup>®</sup> software was used in conjunction with the stock appliance audits to analyse and  
207       disaggregate consumption into a number of end uses including toilets, irrigation, shower,  
208       clothes washer and taps (faucets). Readers should note that only the replacement of the  
209       existing water meter with a high resolution smart meter and data logger at the front of the  
210       property was the only necessary equipment modifications in order to undertake the end use  
211       disaggregation process. An MS Excel™ spreadsheet was generated as a final output for a  
212       more detailed statistical trend analysis and the production of charts.

213

#### 214       ***2.4 Questionnaire survey***

215           Questionnaire surveys were developed to obtain socio-demographic information of  
216       each household to allow for clustering and analysis between varying demographic indicators.  
217       Surveys were distributed to each smart metered household with information entered into  
218       SPSS (i.e. statistical analysis program).

219

#### 220       ***2.5 Household appliance stock survey and water behaviour investigation***

221           Household stock surveys have previously been undertaken to gain a snapshot of water  
222       consuming devices in regions (Roberts, 2003). A household water audit was undertaken for  
223       the GCREUS study to determine water using devices within the household, to assist in  
224       carrying out end use data analysis with Trace Wizard<sup>®</sup>, and to obtain a qualitative  
225       understanding of when people undertook certain water consuming activities in their home. A  
226       research officer visited homes and noted down model and serial numbers for clothes washers,

227 dishwashers and toilets; determined the efficiency of water shower heads; the inclusion of tap  
228 flow restrictors and recorded volumes of rainwater tanks (if applicable). The research officer  
229 also asked questions as to when clothes washing or showering generally occurred, inquired  
230 about the number of showers or baths, irrigation use and a whole range of other questions  
231 surrounding water use behaviour within the home.

232 The Water Efficiency Labeling and Standards (WELS) website<sup>1</sup> was consulted to  
233 obtain relevant water usage volumes for different fixtures particularly clothes washers,  
234 shower heads and dishwashers to assist in data analysis and to determine the relative water  
235 efficiency of devices.

236

### 237 ***2.6 Water end use analysis and comparison***

238 End use data analysis was undertaken with Trace Wizard© to establish when and  
239 where water was being used in each home within the Gold Coast sample. Based on a winter  
240 2008 data collection for the sampled Gold Coast households ( $n=151$ ) the average water  
241 consumption was 157.2 litres per person per day (L/p/d) (Willis et al., 2009). Figure 2  
242 displays the end use water consumption across the 151 households. Showering accounted for  
243 the highest use being 33% or almost 50L/p/d with clothes washing being the next highest end  
244 use at 19% or 30L/p/d. Irrigation was lower than previously conducted end use studies being  
245 only 18.6L/p/d or 12% of total per capita consumption. This would be attributed to a few  
246 reasons, such as: (1) winter season has lower average demand for irrigation; (2) above  
247 average rainfall over data collection period; and (3) general trend of lower irrigation demand  
248 due to changed social habits, smaller lot sizes, working families, etc. .

249

250 [Insert Figure 2]

---

<sup>1</sup> <http://www.waterrating.gov.au>

251

252 An overview of water end use for the GCREUS study and previous end use studies  
253 can be seen in Table 1. The finalised end use values, socio-demographic survey data and  
254 water audit data were all entered into SPSS to enable a comparative analysis between varying  
255 socio-demographic groups and household water device efficiency.

256

257 [Insert Table 1]

258

259 **3. Results**

260

261 ***3.1 Influence of socio-demographic factors***

262 Analysis determined that a range of collected socio-demographic factors influenced  
263 end use water consumption levels, namely, location of household, lot size, Rain Water Tank  
264 (RWT) ownership, household income and household makeup. Some of these relationships are  
265 explored in this paper and are presented succinctly below.

266

267 ***3.1.1 Socio-economic region of households***

268 Several regions in differing areas of the Gold Coast were selected to ensure that the  
269 combined water end use sample was representative. For the purpose of the GCREUS study,  
270 four socio-economic groups in distinct regions were selected and compared: (a) low (Cassia  
271 Park:  $n=42$ ); (b) low to middle (Mudgeeraba:  $n=36$ ); (c) middle (Crystal Creek:  $n=38$ ); and  
272 (d) middle to high (Coomera Waters:  $n=35$ ). The total per capita consumption for region (a),  
273 (b), (c) and (d) were 152.3, 155.6, 156.3 and 165.8 L/p/d, respectively. Figure 3 displays the  
274 end use water consumption for these four socio-economic regions.

275 Previous water consumption research indicates that individuals that are wealthier,  
276 older and live in new and larger homes consume more (Kim et al., 2007; Kenney et al.,  
277 2008). While the total per capita consumption values provide some evidence to support these  
278 existing findings, further examination of individual end use categories enables better  
279 understanding on which end uses are potentially more influenced by socio-economic region.  
280 Figure 3 demonstrates that generally lower socio-economic groups tended to use slightly  
281 more water than those in higher socio-economic groups across most end use categories. One  
282 obvious and significant outlying variable to this trend is irrigation. Coomera Water residents,  
283 the highest of the recorded socio-economic regions, were the highest consumers per capita for  
284 irrigation, using 27.8L/p/d with Cassia Park, the lowest socio-economic group consuming the  
285 lowest irrigation volume of 12.1L/p/d; this represents a significant 15.7L/p/d difference  
286 ( $p<0.001$ ). This opposing trend of higher socio-economic region translating to higher  
287 irrigation end use consumption could be attributed to lot size or higher concern/social  
288 pressure for garden/turf aesthetics.

289

290 [Insert Figure 3]

291

292 *3.1.2 Lot size and rainwater tank ownership*

293 The effect of lot size (total land area) and rainwater tank (RWT) ownership on  
294 outdoor irrigation was examined ( $n=121$ ). Figure 4 illustrates increased irrigation with  
295 increasing lot size for households without RWTs ( $n=86$ ). This result is consistent with that  
296 found by Loh and Coghlan (2003). Interestingly, houses with RWTs ( $n=35$ ) actually  
297 decreased irrigation consumption from the mains supply as lot sizes increased. Meaning that,  
298 irrigation was highest for smaller lot sizes with RWTs with those of large lot sizes consuming  
299 the least. The reason for this phenomenon is still unknown and may be due to error caused by

300 a lower sample in the higher lot size clusters. One hypothesis is that the larger lot owners may  
301 have invested in higher volume RWT with pump features and irrigation lines whilst those in  
302 smaller lots may not utilise their tanks since they are small with no pump facility making  
303 householders less inclined to use this source of water. A larger sample size across all lot size  
304 clusters would be required to confirm this hypothesis.

305

306 [Insert Figure 4]

307

308 *3.1.3 Household income*

309 108 households stated the incomes of individuals within their residences on the  
310 survey. These households were divided into three categories based on weekly household  
311 income to investigate the influence of household income on water consumption. The  
312 categories were defined as: (a) less than (\$AUD) A\$1200 per week ( $n=31$ ); (b) between  
313 A\$1200 and A\$2000 per week ( $n=45$ ); and (c) more than A\$2000 per week ( $n=36$ ). Figure 5  
314 indicates that as income increased, so does water consumption. Interestingly, the water  
315 consumption of the middle to upper household income clusters was very similar and no  
316 significant difference could be interpreted. Lower income households were shown to  
317 consume approximately 8% less than the average water consumption for the Gold Coast City  
318 sample (i.e. 157.2L/p/d as per Table 1), however lower socio-demographic profiles (which  
319 consider factors beyond income) were shown in section 3.1.1. to use more water for end uses  
320 other than irrigation – in this case, the lower irrigation component leads to lower overall  
321 usage.

322

323 [Insert Figure 5]

324

325     *3.1.4 Household makeup comparisons*

326         The impact of household makeup on end use water consumption was also  
327         investigated. Households ( $n=126$ ) were divided into four categories, namely: (a) single  
328         person ( $n=5$ ); (b) couple ( $n=34$ ); (c) small family with four or less people ( $n=64$ ); and (d)  
329         large family with more than four people ( $n=23$ ). Total per capita consumption was  
330         211.4L/p/d, 183.5L/p/d, 140.6L/p/d and 135.6L/p/d for household makeup typologies a, b, c  
331         and d, respectively. Figure 6 indicates that there is a general decrease in consumption per  
332         capita as family size increases. Clothes washer and toilet end use consumption oppose this  
333         trend with these end uses being higher in large families than small families. This may be due  
334         larger families being more likely to have very young children requiring extensive washing  
335         and a higher utilisation of the toilet due to increased time spent at home.

336

337                          [Insert Figure 6]

338

339     *3.2 Stock efficiency versus end use consumption*

340         Table 1 demonstrates that shower use and clothes washing account for the highest end  
341         uses of water on the Gold Coast, being 33% and 19% of total average consumption,  
342         respectively. Further analysis was undertaken to examine trends for water saving when  
343         considering the engineered efficiency of water use devices.

344

345     *3.2.1 Influence of showerhead efficiency*

346         Sample average per capita shower end use was 49.7L/p/d or 32% of total water use  
347         which was 157.2 litres per household per day (L/hh/d). This was the highest water consuming  
348         activity on the Gold Coast as often reported elsewhere. It is well established that the  
349         installation of high efficiency, low flow showerheads can save considerable volumes of water

350 (Mayer et al., 2004). The Australia WELS requires products to be registered and labelled  
351 with their water efficiency in accordance with the standard set under the national WELS and  
352 Standards Act 2005 (Commonwealth of Australia, 2008). These standards list that three star  
353 rated water efficient showerheads (formerly AAA) use as little as 6-7L/min, medium efficient  
354 showerheads (AA) consume between 9-15L/min and the standard non-efficient showerheads  
355 (A) can use as much as 15-25L/min. Different dwellings have a high variation in the  
356 efficiency of their showerheads and often showerheads differ within households. Due to the  
357 variation of showerhead efficiencies within dwelling bathrooms a weighting system was  
358 applied in this study. The weighting system provided each bathroom showerhead with a  
359 rating as follows: (a) 'AAA' rated showerheads allocated a score of 5: (b) 'AA' rated  
360 showerheads a rating of 3; and (c) 'A' rated showerheads and less a score of 1. Each dwelling  
361 total score was averaged ( $w$ ) based on number of showerheads. The weighting system  
362 allowed for the categorisation of households into three shower efficiency clusters which  
363 match the AAA, AA and A, WELS ratings, namely Low, Medium and High efficiency. Table  
364 2 details the showerhead efficiency cluster results.

365

366

[Insert Table 2]

367

368

Table 2 provides evidence that by changing low efficient showerheads (A) to high

369

efficient showerheads (AAA) in each household in the Gold Coast could result in annual per

370

capita water savings of 11.3kL or 48%. Annual household savings were slightly higher being

371

52.1kL or 58%. Readers should note that the per capita saving is more representative and

372

transferable to other situational context as the household sample size varies for the three

373

clusters from 3.0 (medium) to 3.8 (low). The ratio of savings between the Low to Medium

374

and High efficiency categories indicates that a changeover to AAA rated showerheads yields

375 greater savings. The savings identified herein were at the higher end of the range determined  
376 in other studies such as Melbourne at 27%, Perth at 22% and in South-east Queensland (SEQ)  
377 at 31-54% (Roberts, 2005; Loh and Coghlan, 2003). As detailed in a later section,  
378 showerhead retrofits represent one of the least cost water demand management initiatives  
379 available to water businesses and government.

380

### 381 *3.2.2 Influence of clothes washer efficiency*

382 The end use water consumption for clothes washing for the Gold Coast sample was  
383 determined as 30L/p/d. Clothes washing consumption was the second highest water use after  
384 showering. WELS star rating for clothes washers was based on loading type, load capacity,  
385 water consumption per wash, brand and model name. The Commonwealth of Australia  
386 (2008) state that water efficient washing machines can use a third of the water required by an  
387 inefficient model. The WELS website details the rate of water consumption per wash for each  
388 brand and model of clothes washing machine on the Australian market. Household water  
389 audits established the specific model details (i.e. brand, model, year, etc) to assist in  
390 determining clothes washer load volumes. Household clothes washers were allocated  
391 efficiency categories based on per load water consumption; Table 3 demonstrates the results  
392 of the comparative clothes washer water end use levels for each efficiency cluster category.

393

394 [Insert Table 3]

395

396

397 Table 3 demonstrates that replacing a low efficiency clothes washer with a high  
398 efficiency model can save a staggering 14 kilolitres per person per annum (kL/p/a). Annual  
399 household savings are also equally significant at 58.9kL/hh/a. Again, the Low clothes washer

400 efficiency cluster had the highest average household occupancy at 3.9 with Median and High  
401 at 3.0 and 3.1, respectively. These higher occupancy rates have resulted in the higher ratio  
402 values when examining the household savings. The more conservative per capita savings are  
403 considered more representative and transferable to other situational context. Readers should  
404 take account of the potential influence of occupancy rates when applying both per person and  
405 per household saving values. Higher occupancy can result in some lowering of the total per  
406 capita water use as there is some economies of scale effect, however there is also potentially  
407 higher clothes washing requirements related to the addition of more younger children.

408

409 Finally, these calculated savings are higher than those listed on the WELS web site  
410 and in previously reported Melbourne and SEQ water efficiency studies. In summary,  
411 replacing traditional washing machines with those with a high star rating is a highly  
412 recommended water demand management activity.

413

414 *3.2.3 Influence of rainwater tanks on irrigation end use*

415 Irrigation has long been identified as a high water end use, accounting for up to 54%  
416 in some regions (Loh and Coghlan, 2003). RWTs are considered by some water demand  
417 management professionals as an effective way to reduce the demand on potable supplied  
418 water. The GCREUS included a number of households ( $n=39$ ; 25.8%) with an installed  
419 RWT. It should be noted that these RWT were not internally plumbed and were mainly for  
420 outdoor use purposes only (i.e. irrigation, pool top-up, etc.). Whilst RWT metering was not  
421 included in the scope of this study, household water audits identified whether a tank was  
422 installed, enabling comparison between irrigation end use volumes for households with or  
423 without a RWT (Table 4).

424

425 [Insert Table 4]

426

427       Table 4 provides evidence that the introduction of a RWT can significantly impact on  
428       irrigation water end use consumption. The installation of a RWT can result in annual per  
429       capita and per household savings of 3.4kL/p/a and 13.5kL/hh/a, respectively. The ratio  
430       increase in irrigation consumption on homes with RWT was slightly higher at the household  
431       level due to the higher average occupancy of this cluster (i.e. 3.4 verses 2.9). Applying the  
432       per capita savings and the regions overall average household occupancy resulted in a slightly  
433       lower household savings due to installation of an external-only RWT at 11.3kL/hh/a.

434

435       The end use snap shot was conducted in the winter period of a sub-tropical region.  
436       Irrigation in this region is typically highest in spring when there is relatively high day  
437       temperatures and low rainfall. To gain a better understanding on the potable water savings  
438       benefits of RWT, seasonal variations need to be explored further in future research (i.e. also  
439       examine the autumn, spring and summer periods). The study herein provides some evidence  
440       to the argument that RWT may be an effective strategy where water supply security is not  
441       guaranteed. Given that RWT installations are generally much more expensive than other  
442       residential demand management options, their capital payback periods need to be explored in  
443       detail in order to reveal their potential financial benefit to the householder.

444

445       3.2.4 *Combined household efficiency savings*

446       The combined influence of introducing water efficient showerheads, clothes washers  
447       and installing RWTs was modelled to estimate total potential household savings by  
448       retrofitting/installing to higher efficiency appliances/fixtures. The estimated savings, resulting  
449       from the introduction of this array of demand management measures, amounted to

450 approximately one third of total water consumption. While these are significant water  
451 savings, it is considered prudent for both consumers and water managers to determine  
452 monetary aspects. Additionally, whilst outside the scope of this paper, in the age of climate  
453 change mitigation, the energy implications of WDM decisions should also be investigated as  
454 water savings may come at a higher energy cost.

455

#### 456 *3.2.5 Financial benefits of efficient appliances*

457 Often the understanding of relative water savings attributed to water efficient devices  
458 is not enough to encourage consumers to outlay the capital cost to upgrade fixtures.  
459 Information about the payback period associated with upgrading appliances is another way of  
460 displaying information to encourage uptake. Based on the 2008/2009 financial year water  
461 billing price (i.e. A\$(AUD) 1.87/kL) the retrofitting of a low to high efficiency showerhead  
462 can potentially deliver a 2009 annual water consumption monetary saving of A\$69 increasing  
463 to A\$136 by 2018, for Gold Coast City residential households. Based on a A\$100-160 capital  
464 cost for the supply and installation of water efficient showerheads, a 2 year payback period  
465 was determined. While not factored herein, this payback period would be considerably lower  
466 (i.e. less than 1 year) when considering the cost of the electricity saved for heating a  
467 considerable portion of the water used in the shower. This is an extremely good payback  
468 period and provides evidence to support the recent Gold Coast Water and Queensland  
469 Government strategies to retrofit appliances across SEQ in the recent drought (e.g. GCW &  
470 SEQ Home Water wise Service). Shower retrofit programs are undoubtedly a least cost water  
471 demand management option that also reduces household hot water related electricity demand  
472 and subsequently GHG emissions.

473 Replacement of low efficiency washing machines to those with higher efficiency also  
474 has the potential to deliver annual water savings of A\$86 in 2009, increasing to A\$170 in

475 2018. This equates to a cumulative saving of A\$1364 per household over this 10 year period.  
476 Hence, a 7 year payback period was calculated based on a conservative capital cost of A\$900  
477 for a water efficient washing machine. Again, this represents a reasonable payback period  
478 supporting the upgrade of washing machines.

479 The use of RWTs could potentially deliver an annual water consumption saving of  
480 A\$21 in 2009 increasing to A\$115 in 2033 equating to a A\$11451 cumulative saving per  
481 household over this 25 year period. Based on a A\$1200 capital cost for a 2000-4000L RWT a  
482 23 year payback period was determined. This payback period is high for the average  
483 homeowner and does not consider the ongoing maintenance requirements for a RWT,  
484 providing evidence to the argument that RWT installation that are not internally plumbed, is  
485 not low hanging fruit in the least cost planning framework. Understanding payback periods  
486 for the replacement of efficient water use devices provides important information to allow  
487 consumers to make economically informed decisions. These payback periods can also help  
488 support the introduction, or otherwise, of rebate schemes targeting the highest water savings  
489 at a reasonable price as part of a broader consideration of the social environmental and  
490 economic cost savings to the utility (through reduced pumping and treatment as well as lower  
491 infrastructure upgrade costs) as well as the consumer in a total resource cost approach to  
492 option evaluation (White et al., 2008).

493

#### 494 **4. Conclusion**

495

496 Smart metering has enabled the collection of a registry of end use water consumption  
497 data. The mixed method acquisition of this data in association with socio-demographic and  
498 stock survey information, allowed for the relationship between these factors and individual  
499 water end uses to be revealed. As discussed, socio-demographic factors such as household

500 income and makeup, lot size and RWT ownership, were examined in this study and had an  
501 influence on relevant end uses. End use data demonstrated that actual water savings  
502 associated with the installation of efficient water use devices was generally at the higher end  
503 of ranges reported in previous research investigations. This may be due to the extreme  
504 drought conditions experienced in SEQ in 2008 influencing water consumption habits or a  
505 range of other contributing factors. The payback period of showerheads occurs within half a  
506 year or less, while clothes washer and RWT payback periods were determined as 6.5 and 21  
507 years respectively. These findings support the continuation of rebates particularly for  
508 showerheads and clothes washers.

509 As a final note, savings achieved through water demand management programs have  
510 a flow-on benefit to the entire water and wastewater system (as well as the water heating and  
511 electricity supply system) that is not often considered, but can be substantial, such as:

- 512
- Enables the deferment of expensive supply expansion options such as desalination  
513 plants;
  - Reduces the peak hour potable water demand and thus can lead to deferred water  
515 supply pump and pipe infrastructure upgrade requirements;
  - Reduces average and peak effluent loading to the wastewater system; and
  - Lower overall requirement for heated water (i.e. lower shower volumes means  
518 less hot water from heating system) which is energy intensive and contributes  
519 significantly to GHG emissions.

520

521

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523

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528

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**Tables:**

**Table 1**

Comparison between national end use water consumption studies (Willis et al., 2009)

End use category	Perth (2003)		Previous studies		Present study		Gold Coast (2008)	
	L/p/d	Percent	L/p/d	Percent	L/p/d	Percent		
Clothes washer	42.0	13%	40.4	19%	39.9	24%	30.0	19%
Shower	51.0	15%	49.1	22%	44.9	27%	49.7	33%
Tap (faucet)	24.0	7%	27.0	12%	22.7	14%	27.0	17%
Dishwasher	NA	NA	2.7	1%	2.1	1%	2.2	1%
Bathtub	NA	NA	3.2	2%	5.5	3%	6.5	4%
Toilet	33.0	10%	30.4	13%	31.3	19%	21.1	13%
Irrigation	180 <sup>†</sup>	54%	57.4 <sup>†</sup>	25%	13.9	8%	18.6	12%
Leak	5.0	1%	15.9	6%	7.0	4%	2.1	1%
Other	NA	NA	0.0	0%	0.8	0%	0.0	0%
<b>Total Consumption</b>	<b>335.0</b>	<b>100%</b>	<b>226.2</b>	<b>100%</b>	<b>168.1</b>	<b>100%</b>	<b>157.2</b>	<b>100%</b>

<sup>†</sup>Note: Irrigation volume per person calculated from provided volumes per household and end use break downs

**Table 2**

Showerhead efficiency cluster comparisons

Description	Showerhead efficiency clusters		
	Low $w \leq 2$	Medium $2 < w < 4$	High $w \geq 4$
Efficiency category			
Weight range			
No. of households in cluster ( $n=151$ )	50	42	59
Proportion (%)	(33.1%)	(27.8%)	(39.1%)
No. of people in cluster ( $n=495$ )	190	124	181
Proportion (%)	(38.4%)	(25%)	(36.6%)
Per capita shower consumption per day (L/p/d)	64.7	46.8	33.6
Ratio increase on high efficiency cluster	(1.92)	(1.39)	(1)
Household shower consumption per day (L/hh/d)	245.7	138.1	103.1
Ratio increase on high efficiency cluster	(2.38)	(1.34)	(1)
Per capita shower consumption per annum (kL/p/a)	23.6	17.1	12.3
Ratio increase on high efficiency cluster	(1.92)	(1.39)	(1)
Household shower consumption per annum (kL/hh/a)	89.7	50.5	37.6
Ratio increase on high efficiency cluster	(2.38)	(1.34)	(1)

**Table 3**

Clothes washer efficiency cluster comparisons

Description	Clothes washer efficiency clusters		
	Low	Medium	High
Efficiency category			
Star rating range	1 – 2.5	3 – 3.5	4 – 6
Category (L/wash)	120 - 170	80 - 119	40 – 79
No. of households in cluster ( <i>n</i> =148)	38	40	70
Proportion (%)	(25.7%)	(27.0%)	(47.3%)
No. of people in cluster ( <i>n</i> =486)	148	119	219
Proportion (%)	(30.5%)	(24.5%)	(45.0%)
Per capita clothes washer consumption per day (L/p/d)	53.0	36.3	14.4
Ratio increase on high efficiency cluster	(3.67)	(2.51)	(1)
Household clothes washer consumption per day (L/hh/d)	206.4	108.0	45.2
Ratio increase on high efficiency cluster	(4.57)	(2.39)	(1)
Per capita clothes washer usage per annum (kL/p/a)	19.3	13.3	5.3
Ratio increase on high efficiency cluster	(3.67)	(2.51)	(1)
Household clothes washer usage per annum (kL/hh/a)	75.4	39.4	16.5
Ratio increase on high efficiency cluster	(4.57)	(2.39)	(1)

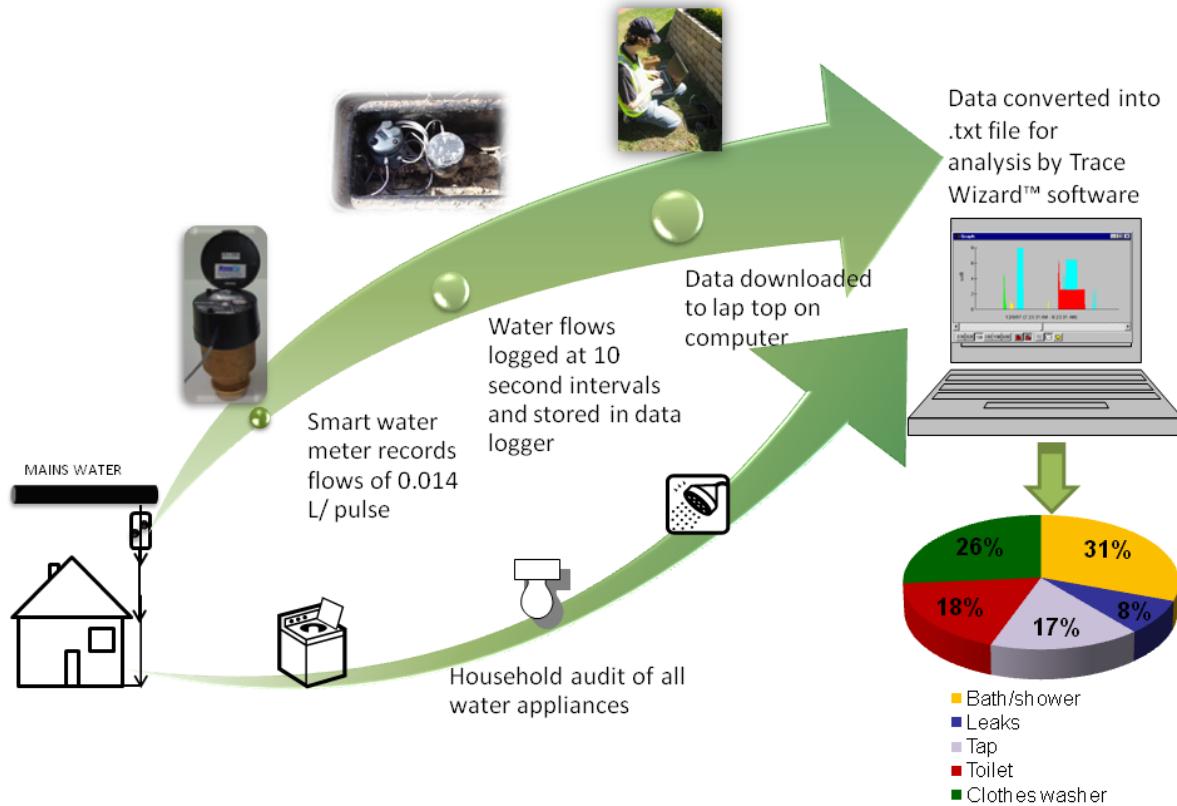
**Table 4**

Rainwater tank cluster comparison

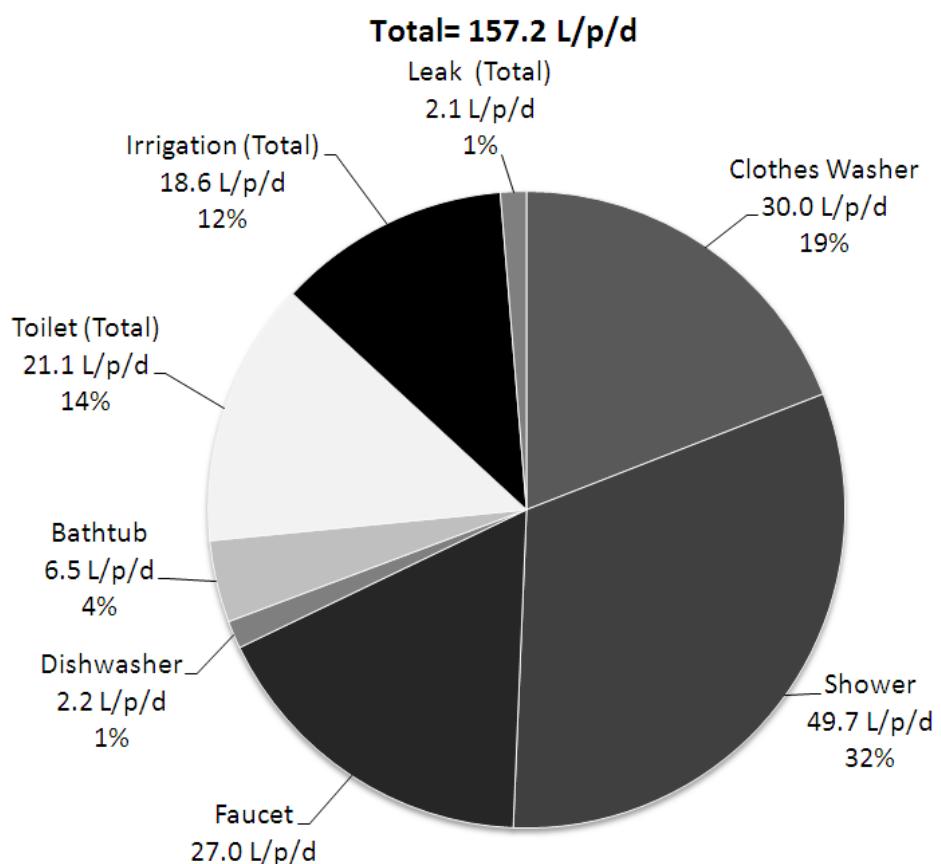
Description	Rainwater tank clusters	
	Households with RWT	Households without RWT
No. of households in cluster ( <i>n</i> =151)	39	112
Proportion (%)	(25.8%)	(74.2%)
No. of people in cluster ( <i>n</i> =495)	114	381
Proportion (%)	(23%)	(77%)
Per capita irrigation consumption per day (L/p/d)	10.1	19.6
Ratio increase on homes with RWT	(1)	(1.94)
Household irrigation consumption per day (L/hh/d)	29.6	66.6
Ratio increase on homes with RWT	(1)	(2.25)
Per capita irrigation consumption per annum (kL/p/a)	3.7	7.1
Ratio increase on homes with RWT	(1)	(1.94)
Household Irrigation consumption per annum (kL/hh/a)	10.8	24.3
Ratio increase on homes with RWT	(1)	(2.25)

**Figures:**

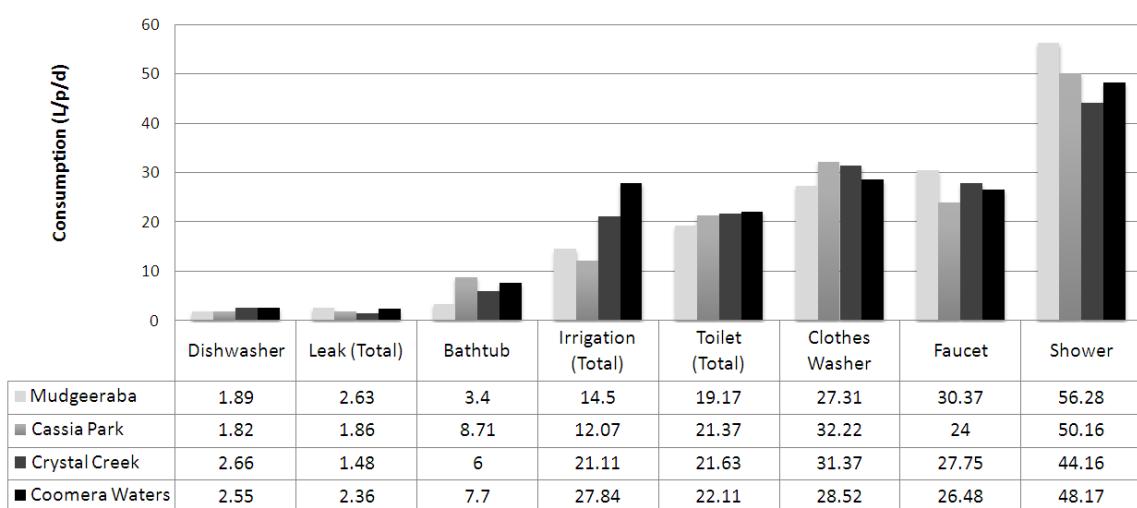
## HOW TO MEASURE END USES



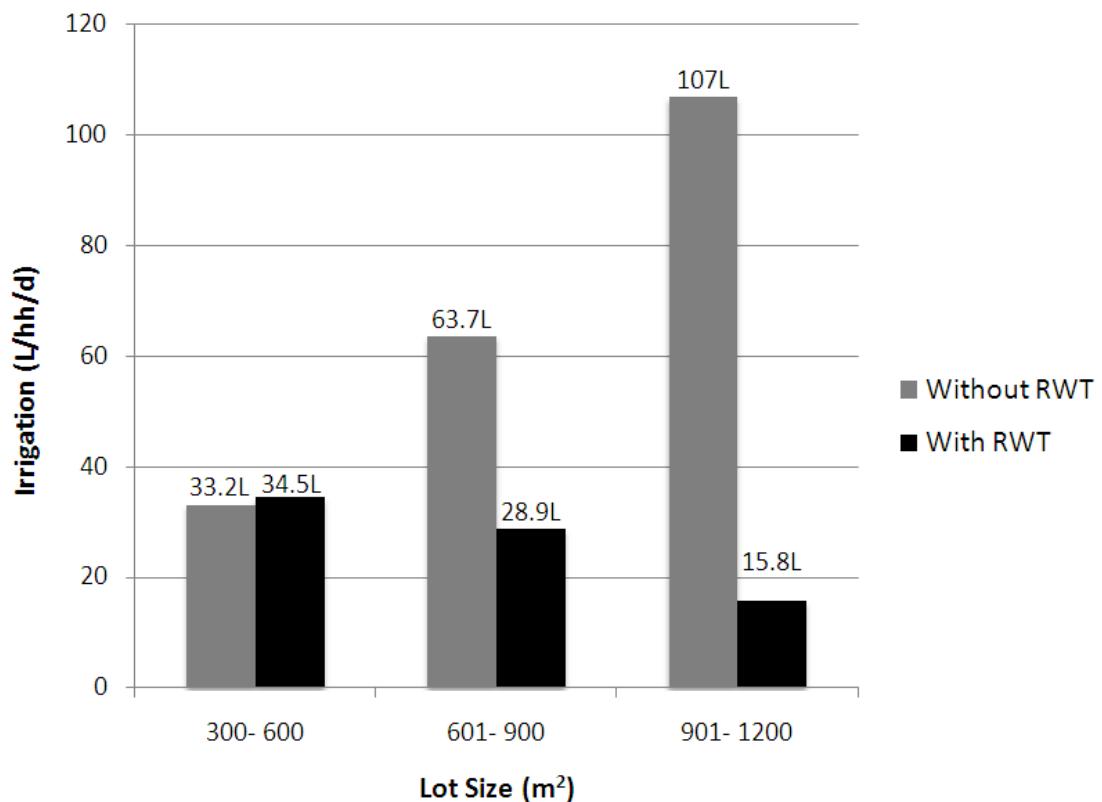
**Fig. 1.** Schematic illustrating water end use analysis process



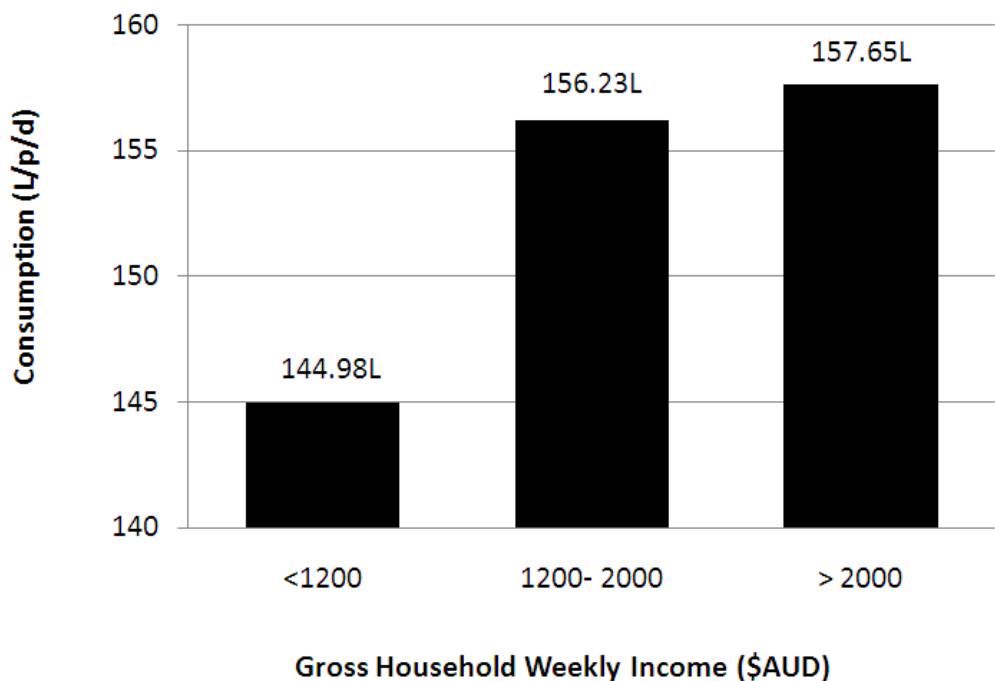
**Fig. 2.** Average daily per capita consumption (L/p/d): combined sample (n=151)



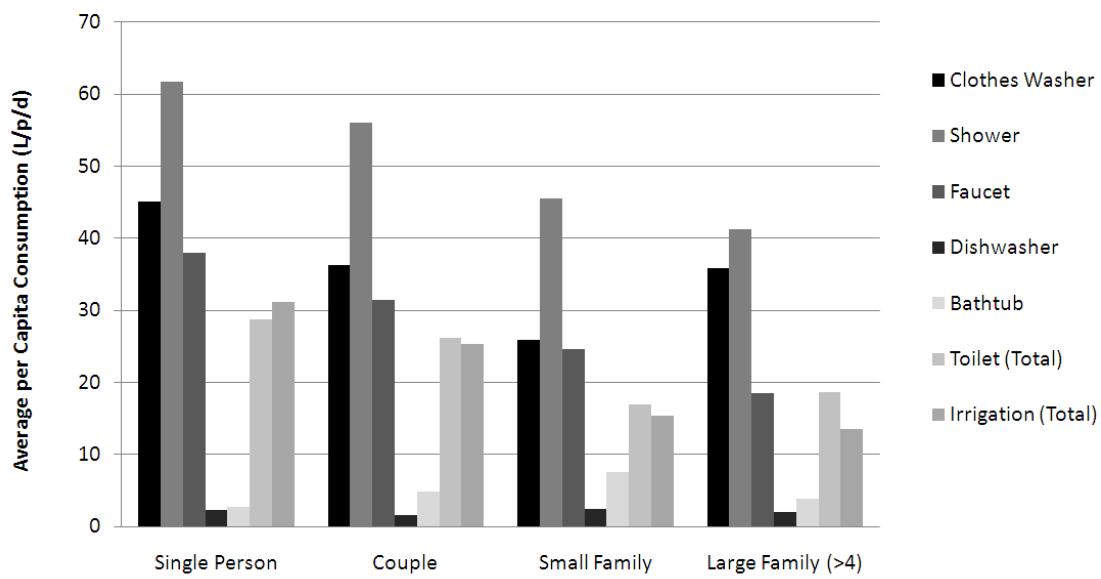
**Fig. 3.** Impact of socio-economic region on end use water consumption



**Fig. 4.** Impacts of lot size and RWT installation on irrigation end use



**Fig. 5.** Impact of gross household weekly income on total per capita water consumption



**Fig. 6.** Relationship between household resident makeup typologies and water end use consumption