Using Geographical Information Systems to explore the determinants of urban household water consumption

Using Geographical Information Systems to explore the determinants of urban household water consumption

Heather Shearer

PhD student

Urban Research Program, Griffith University

Contact Details:

Address: **Urban Research Program, Nathan campus, Nathan**
Griffith University, QLD 4111, Australia

Tel: **0407 338 942**

Email: Heather.Shearer@student.griffith.edu.au

Word Count – Excluding References, Table/figures insertion text; Tables and Figures: 4945

Key words: household water consumption, geodemographics, spatial, South-East Queensland**.**

Running Head: Spatial Dimensions of Household Water Consumption

Abstract

This paper reports on research using geodemographic approaches to examine the dimensions of household water use in South East Queensland. In 2005, a lengthy drought and high population growth was placing increasing pressure on urban water supplies. In response, the Queensland State Government implemented a suite of remarkably effective demand-side policy measures: from 2005 to 2008, average household water use dropped from 300 to 130 Litres Capita Day. The paper reports on Phase One of a research program, which used Geographic Information Systems, Principal Components Analysis, and other statistical methods to explore the spatial, socio-demographic and structural determinants of household water use. The most significant variables found to predict high water use at the Census Collection District scale were lot size, children at school and mortgages. This spatial analysis will inform Phase Two, which uses a behavioural science framework, based on an extended Theory of Planned Behaviour, to investigate individual householder attitudes and behavioural change in response to policy measures. Understanding how this behavioural change occurred on such a mass scale, and over such a short period, is potentially of great significance; the results of this research could enable finer targeting of demand-side policy, and help maintain lower levels of water use.

Introduction

One of the most critical resource management issues facing our society is the ongoing depletion of fresh water supplies (Gregory & De Leo; 2003; Pearce, 2006). This is particularly relevant for Australia; given predictions that climate change will likely increase existing climate variability, and lead to lengthier and stronger droughts (CSIRO, 2007). In Australia, the densely populated Eastern seaboard appears particularly vulnerable; for example, in South East Queensland (SEQ), the last decade has had historically low rainfall (BoM, 2007; CSIRO, 2007; NRW, 2007). This is of concern to governments and water managers, as a reduction in rainfall can lead to disproportionately greater reductions in water supply; for example, a 15% long-term reduction in WA rainfall manifested in a 40% reduction in dam inflows (Cai & Cowan; 2006).

However, SEQ has not only experienced a reduction in rainfall, but also rapid population growth; some areas have experienced growth rates in excess of 4% per annum (ABS a, 2006; Birrell, Rapson, & Smith, 2005; DLGP, 2007; OUM, 2008). In addition, the region is undergoing major demographic change, with increasing urbanisation, an ageing population, and a trend towards smaller households. This, together with population growth, has meant an increase in total numbers of households (ABSb, 2006; Birrell et al, 2005). This is relevant to household water use, because an increase in housing means, even if water consumption remains consistent, urban water demand is likely to keep rising—at the same time as more frequent droughts are lowering supply (Birrell et al, 2005; Clarke, Kashti, McDonald, & Williamson, 1997; Domene & Saurí, 2006; Hoffmann, Worthington & Higgs, 2006; QWCb, 2008; Stewart, Turner, Gardner & McMaster, 2005; Troy, Holloway & Randolph, 2005)

To counter this, policy makers often attempt to address existing or predicted water shortages with supply-side options such as dams. However, these can be economically, socially and politically costly; in addition to high financial costs, dams often disrupt and polarise communities, and engender community resentment against government (ABC, 2009). Further, supply-side options like dams depend on reliable rainfall and suitable sites, and have negative environmental effects, such as impacting natural flood cycles. Instead, governments often employ demand-side measures, as these are simpler to implement and monitor; relatively inexpensive and can effectively reduce water use (Birrell et al, 2005; Clarke et al, 1997; CSIRO, 2008; Hoffmann et al, 2006, Jackson, 2005; QWCb, 2008; Stewart et al, 2005; Troy et al, 2005).

In 2005, in response to the ongoing drought, the Queensland State Government implemented a suite of demand-side measures, including increasing levels of water restrictions, a water saving campaign (Target 140) and incentive programs, such as Home WaterWise (Table 1). Target 140 was a voluntary goal of 140 Litres Capita Day (LCD) and linked to the water restrictions; and Home WaterWise a program where, for a small fee, a licensed plumber would check for leaks, and fit a low flow showerhead and flow restrictors on taps (QWC a, 2008). Figure 2 shows how these measures were a notable success; average household water use dropped from approximately 300 to 130 Litres Capita Day (QWC a, 2008; Spearritt, 2008; Wallace, 2007). The efficacy of the measures was even more remarkable given that, until the 1990s, most Brisbane householders had no water meters, let alone water restrictions (Spearritt, 2008).

However, despite the success of these measures, there is little information available *why* they were so effective; which measures were most useful; what determinants of household water use were targeted; and what socio-demographic groups responded best. But answering these questions is potentially of great benefit, as this could provide vital information to more finely target future policy and maintain lower levels of household water use.

[Insert Figure 1 **(QWC GRAPH BY LGA)** here]

Aims

The primary aim of the larger study is to explain how the SEQ demand-side measures were so successful in changing household water use behaviour, and identify which were the most effective. Phase One of the study, reported in this paper, aims to identify the spatial variation of household water use in urban SEQ, and whether this pattern changed significantly as a result of the demand-side policies. Phase One also aims to identify which, if any, socio-demographic groups responded most favourably to the demand-side measures, by identifying any correlations between household water use and socio-demographic variables at Census Collection District (CCD) and State Suburb scales. It also aims to investigate the hypothesis that, of these measures, the major factor contributing to the lowered levels of household water use was the water restrictions.

Study Area

[Insert Figure 2 **(STUDY AREA)** here]

This study compares the urban household water use of Brisbane and the Sunshine Coast Local Government Areas (Figure 2). Brisbane is the capital and largest centre in Queensland and the Sunshine Coast lies approximately 100km north of Brisbane. Brisbane and the Sunshine Coast Local Government Areas (LGAs) form part of South East Queensland (SEQ), a region of 22,420km^2, with a population of approximately 2.6 million. SEQ is highly urbanised, and more than 90% of the population live in the coastal LGAs of Brisbane, Gold Coast and Sunshine Coast (ABS b, 2006). Annual average rainfall ranges from 600mm in the west to 1800mm on the coast (BoM, 2007; NRW, 2007).

Of note, the remaining 9 Local Government Areas (LGAs) in SEQ were excluded because of the 2008 Local Government amalgamations and their multiple data collection protocols, giving a lack of comparable water data for the entire period. However, this was not seen as a major limitation, as they had similar water restrictions to Brisbane, or are largely rural, thus outside the scope of this investigation. In addition, due to data limitations, only the consumption of detached houses was analysed; a departure from the work of Troy et al (2005), where differing urban forms were compared.

Determinants of Urban Household Water Use

At the broadest scale, total water use is a function of population, climate and price: more people use greater quantities of cheaper water on hotter days (Birrell et al, 2005; Clarke et al, 1997). However, at smaller spatial scales, patterns of household water consumption are highly heterogeneous, and influenced by a complex range of variables, such as legislation and policy, socio-demographics, structural factors and human behaviour (Birrell et al, 2005; Clarke et al, 1997; Durga Rao, 2005; Syme, Shao, Po & Campbell, 2003; Troy et al, 2005; Wentz & Gober, 2007).

In general, the large scale determinants of water use are beyond the reach of most short term policy measures, but at the smaller scale, are much more amenable to policy intervention (Brown, Tucker, Johnston & Leviston, 2007; Domene & Saurí, 2006; Hoffmann et al, 2006, Zhang & Brown, 2005). However, most studies on household water use have been relatively broad and at large spatial scales, with few using disaggregated data at the smaller scales such as individual households (Clarke et al, 1997; Stewart et al, 2005; Wentz & Gober, 2007). In addition, detailed research on how many of these smaller scale factors influence household water use is also lacking (Clark & Finley, 2007; Clarke et al, 1997; de Oliver, 1999; Domene & Saurí, 2006; Gilg & Barr, 2005; Hoffmann et al, 2006; Stewart et al, 2005; Troy et al, 2005).

Legislation and Policy

Legislation and policy are important determinants of, and means of reducing household water consumption. Whilst voluntary measures, such as Home WaterWise, can be effective; prescriptive legislation, such as water restrictions, is more often used in demand-side policy. Restrictions can be an effective tool to reduce water use; particularly when accompanied by pressure to conform to subjective norms, like "outing" high water users (Birrell et al, 2005; Brown et al, 2007; Hoffmann et al, 2006). Of note, increasing levels of water restrictions were possibly the major component of the SEQ demand-side measures; although not consistently implemented, as Brisbane had much stricter restrictions than the Sunshine Coast (Table 1). However, restrictions mostly target outdoor water use; restricting indoor water use poses privacy and enforcement problems, and significant community resistance to reducing levels of "essential" indoor use (Allon & Sofoulis, 2006; Brown et al, 2007; Syme et al, 2003; Troy et al, 2005).

[Insert Table 1 **(WATER RESTRICTIONS)** here]

Structural Factors

Other important smaller scale determinants are structural factors, such as dwelling type and urban form—for example, total household water use is often higher in the outer suburbs, because of greater numbers of detached houses and larger gardens (Birrell et al, 2005; Domene & Saurí, 2006; Syme et al, 2003; Troy et al, 2005; Wentz & Gober, 2007). However, it has been found that there is not necessarily a direct relationship between smaller lots and lower water use as, on a per capita basis, smaller households in the denser, inner-city suburbs can use more water (Troy et al, 2005). Further, indoor water use is generally consistent no matter what the urban form (Domene & Saurí, 2006, Hoffman et al, 2006; Troy et al, 2005).

Socio-demographic Factors

Socio-demographic factors such as household numbers, age, income and education, are important determinants of household water consumption; the most significant of these is household numbers—the larger the household, the greater the water use (Clarke et al, 1997; de Oliver, 1999; Troy et al, 2005; Zhang & Brown, 2005). However, due to economies of scale, once household numbers exceed a certain number, size is no longer as significant; and nor does it have any significant influence on outdoor water use (Troy et al, 2005).

The influence of other demographic determinants of water use, such as age, education and income, is less obvious. The influence of age is contested; a Sydney study found that householders frequently blamed children and teenagers for high water use (Domene & Saurí, 2006; Troy et al, 2005). But, a Mexican study found that younger residents were more environmentally aware, and used less water (Corral-Verdugo et al, 2003). This holds true for other environmental behaviours, such as recycling; in general, older people were less likely to recycle (Gilg & Barr, 2005; Gregory & De Leo, 2003).

Income tends to be linked with education, but like age, the direction of influence can be positive or negative. On one hand, higher income households often use more water because, as affluence increases, so do numbers of appliances, swimming pools and larger garden size (Birrell et al, 2005; Corral-Verdugo et al, 2003; Domene & Saurí, 2006, Gregory & De Leo, 2003; Randolph & Troy, 2008; Syme et al, 2003; Troy et al, 2005; Zhang & Brown, 2005). However, on the other hand, higher income residents sometimes use less water, because they are usually better educated, more environmentally aware, and can afford better quality, more water efficient appliances (Barr & Shaw, 2006; Hoffman et al, 2006; Jackson, 2005).

Spatial Factors

Spatial factors are also apparently significant for water use behaviour; households of similar socio-demographic characteristics can have markedly different water consumption profiles, with residents apparently using water at similar levels to their neighbours rather than those not in spatially contiguous areas (Aitken 1991). Another study found average annual water consumption was spatially distributed, with some urban areas having significantly higher water consumption than others (Wentz & Gober 2007). Whilst this apparently indicates the influence of socio-demographic variables, significant spatial variation was found both in the relationships between the variables, and how nearby properties responded to changes in significant independent variables (Wentz & Gober 2007).

Methodology

The aim of Phase One of this study was to investigate the influence of some smaller scale determinants on household water use, as well as to identify and understand some spatial variations in water consumption. To do this, known household water consumption data was compared to socio-demographic variables from the 2006 Census. Socio-demographic and structural variables were chosen with regard to research on household water consumption and more general socio-demographic analyses (inter alia, Baum, Van Gellecum, & Yigitcanlar, 2004; Gregory & De Leo, 2003; Syme et al, 2003; Troy et al, 2005). Once the chosen variables were statistically analysed, the results were mapped. Mapping enables the ready visualisation of data, can highlight observable patterns, such as areas with high water use, and can provide important insights into the relationship between the different datasets, such as Census data and structural variables (de Oliver, 1999; Hiller, 2007).

All analysis was performed with Microsoft Excel and Access 2007; SPSS Grad Pack V.17 and Esri ArcMap 9.3.

Rainfall

To begin, rainfall data from 2005 – 2009 from three Bureau of Meteorology stations in each LGA (Maroochy Aero, Caloundra STP and Brisbane Long Pocket) was graphed to establish if rainfall was related to household water consumption levels. In general, rainfall decreased southwards, with Maroochy registering the highest annual rainfall, and Brisbane the lowest.

[Insert Figure 3 (**ANNUAL RAINFALL BY LGA**) here]

Water Consumption Data

After some negotiations, detailed water consumption data was sourced from the Queensland Water Commission (QWC). This data was in Excel spreadsheet format, with average litres used per household per measurement period—quarterly for Brisbane, and biannually for the Sunshine Coast. Because this dataset included Lot and Plan information, it could be accurately georeferenced; although, for privacy reasons, individual data cannot be represented. To ensure comparability, all properties with zero water consumption readings were eliminated, as well as those without records for the entire period. Further, by using the codes in the Digital Cadastral Database (DCDB) and the Queensland State Valuations database, non-residential and non-urban properties were also eliminated.

After eliminating the majority of non-residential properties (it was impossible, without detailed ground-truthing, to eliminate all), separate spreadsheets with individual household consumption data for each measurement period, were created for each LGA. This was to enable spatial and temporal comparisons between LGAs. Thereafter, each spreadsheet was processed to be compatible with ArcMap. The DCDB layer was spatially joined to the ABS Census Collection District (CCD) layer, so each LotPlan of the DCDB was linked to a single CCD code. Then the spreadsheets were joined by LotPlan to the DCDB, to spatially georeference the water consumption data, and were added to ArcMap as layers. Mapping enabled further filtering, as visual identification revealed some anomalies, such as airports.

Results

The water data was then analysed at three levels; LGA per annum, LGA per measurement period, and CCD per annum. Statistical analyses were carried out between the LGA per annum and LGA per period data, to identify any significant temporal changes, to map household water use, and to compare the data with the demographic Census data.

[Insert Figure 4 **(GRAPH OF MEAN WATER USE)** here]

[Insert Table 2 **(MEAN WATER USE BY LGA PER ANNUM)** here]

Statistical Analysis – LGA per annum.

First, the water consumption records were summarized to give the aggregate annual average water consumption by LotPlan for each LGA. Mean water use was normally distributed, with some extreme outliers at both ends of the data. Extreme high values were most common in Caloundra, however these could indicate poorly coded non-residential uses or large water leaks. In general, the average water use was higher for Caloundra and Maroochydore than Brisbane; and whilst all three LGAs used less water with each successive year of the drought, the mean water use in 2008 for Caloundra was still greater than the highest mean water use for Brisbane in 2006 (Table 2)[1]. Mapping the water use by CCD enabled the immediate visualisation of the greater levels of water use of the Sunshine Coast (Figure 4).

[1] As the data was normally distributed, mean water use for each LGA was initially classified by Natural Breaks, using ArcMap's default, the Jenks algorithm. However, it was then manually adjusted so that the water use per CCD for all LGAs fell into the same categories.

[Insert Figure 5 (**MEAN WATER USE PER CCD (2007) BRISBANE AND SUNSHINE COAST)** here]

To verify this statistically, a repeated measures test was carried out on the water use for each of the three LGAs[2]. The change in water use over the three years for all LGAs was significant[3]. As a further analysis on this data, paired samples t-tests were also conducted between each year for each LGA. All were significant ($p<.05$) for each paired observation (Table 3).

[Insert Table 3 **(CORRELATIONS PER ANNUM PER LGA)** here]

Statistical Tests – Water Data per period, per State Suburb per LGA

Secondly, the water data was also summarized by State Suburb to test for significant change between periods (quarterly for Brisbane, and biannually for the Sunshine Coast), and to identify if reductions in water consumption coincided with increases in water restriction levels. The records for the State Suburbs of Murrarie, Wacol and Eagle Farm were removed from this analysis, as it was concluded that their very high mean water use indicated non domestic uses such as industry.

[Insert Table 4 (**MEAN WATER USE PER LGA PER PERIOD)** here]

[2] For Brisbane and Maroochy, Mauchley's test of sphericity was non significant, so the value of F-max assumed sphericity. For Caloundra, this test was significant, so the Greenhause-Geiser correction was used.

[3] Brisbane ($F=1041.279, p<.05$), Caloundra: ($F=51.676, p<.05$), and Maroochy ($F=107.209, p<.05$)

To statistically test this data, paired samples t-tests were performed between each period for each LGA (Table 4). Although the overall mean water use for Caloundra was significant; at a Suburb scale, only the changes between P2:2006 and P1:2007, and between P1:2007 and P2:2007 were significant; and in the first period (P2:2006 to P1:2007), the direction of the change was positive (i.e. mean water use increased). The situation was the same for Maroochy. For Brisbane, the change between Q2 and Q3 (April to June) 2006 was significant, as was the change between Q2 and Q3 (July to September) 2007, and between Q3 and Q4 (October to December) 2007. As indicated in Table 2, Level 3 water restrictions were imposed in June 2006, and Levels 5 & 6 water restrictions were imposed in April and November 2007.

Statistical Tests – water use and ABS data

The water data was then summarized and aggregated to CCD level scale, to enable comparison of water consumption data with Census data. The Australian Bureau of Statistics Census 2006 Basic Community Profile (BCP) was used for the geodemographic analysis (ABS, 2006). Selected independent variables were converted to percentages of measured populations, and then to z-scores (to ensure comparability between datasets). Some variables, such as income, mortgage payment and rent payment, were combined to give a smaller number of categories (as per the Socio-Economic Indexes for Areas (SEIFA) methodology), as well as the creation of combined variables, such as "Born in the EU" (ABS b, 2006).

[Insert Table 5 **(DEPENDENT VARIABLES: MEAN HOUSEHOLD WATER CONSUMPTION (2006 – 2008)** here]

A multiple regression analysis was performed against the ABS data to establish which variables were significant for water consumption at CCD level (Table 5). Significant variables to positively predict household water use were Average Household Size, Median Age, Married, Aged 15-19, Three Cars, Mortgaged and Average Lot Size. Together, these variables explained 28.7% of the variance which, although not particularly high, is in keeping with other studies on water consumption (Birrell et al, 2005; Clarke et al, 1997; de Oliver, 1999; Domene & Saurí, 2006; Hoffman et al, 2006; Troy et al, 2005; Wentz & Gober, 2007).

However, as the count of properties with water data in each CCD did not correspond to the Detached Dwelling count in the ABS Census BCP, it was impossible to calculate per capita water use. This was likely because the Census dataset is a cross-sectional study, whilst the water data was longitudinal; in addition, only properties with water records for the entire period were included in the analysis.

Of note, this study found water use to be higher for larger, family households on bigger properties. Therefore, whilst Troy et al (2005) found *per capita* water use was often higher for smaller households and units; this study only investigated aggregate water use, and did not include non-detached properties, thus is not directly comparable.

Interestingly, R^2 decreased over the three year period, possibly meaning that the influence of socio-demographic variables on water use lessened during the drought (Table 5). A possible explanation might be that the demand-side measures overrode the underlying socio-demographic influences on household water use. This will be further investigated in Phase Two of this study, a large scale questionnaire survey to investigate individual water use behaviour.

Statistical Tests – Principal Components Analysis

A series of Principal Components Analyses (PCA) was then calculated to identify a set of common components in the data. Variables included were those previously found significant for demographic profiling and household water use, such as the number of people per bedroom, income, children at school and industry of employment (*inter alia,* Baum et al, 2004; Clark & Finley, 2007; Troy et al, 2005). Unless relevant to previous studies on household water use, variables that were highly inter-correlated (over 0.9, positive or negative) were eliminated, for example, the correlation of Professionals with Persons holding Degree Qualifications. After a number of iterations, and varimax rotation, the set of variables was narrowed down to 41, which revealed a similar set of 7 common components with Eigenvalues over 1, and explained 74.387% of the variance (Table 6). However, only the first 3 components were readily identifiable, the remainder were too complex to name and had variables loading on to more than one component. A scree plot was also used to identify an appropriate cut-off point beyond which the components did not explain much extra variance[4].

According to the methodology of Baum et al (2004), the three major components were split into five (the third had mostly positive loadings, so two variables with small negative loadings were discarded). Using the methodology of McIntyre & Okorafor (2003), the standardised variables which loaded on the component were multiplied by their component score coefficients, summed and averaged to give to give a weighted mean variable. To calculate the second variable from each component, the signs were reversed to ensure comparability. Internal consistency tests indicated that the composite variables had good internal validity[5]. In addition, bivariate correlations were performed to ensure the composite variable was highly correlated with the original variables.

[Insert Table 6 (**ROTATED COMPONENT MATRIX)** here]

[4] These first three components explained 26.229%, 22.589% and 10.638% of the variance respectively, and the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were significant (*KMO =.896*) and Bartlett's test (*p<.05*).

[5] Cronbach Alpha results: (*Component 1a=.904; Component 1b=.875; Component 2a=.844; Component 2b=874; and Component 3=.883*).

Variable 1a was labelled “Traditional Family” because of high positive loadings on variables characteristic of families, such as Married, with Children 5-14 in Education. Significant housing related variables were Mortgaged, Median Mortgage Payment and Two Cars. As expected, this variable mapped to traditional family suburbs; the Sunshine Coast included Buderim, Peregian Springs and Mountain Creek; and Brisbane included Ferny Grove, Carindale and Kedron.

Variable 1b (comprising variables which loaded negatively on the first component) was labelled “Young and Mobile”, as it included variables such as People aged 20-24 who had Moved Less Than One Year, with relatively low incomes, One Resident and Journey to Work Public Transport. As expected, this mapped to different areas to the Traditional Family variable. In Brisbane, many inner urban suburbs scored highly, including Fortitude Valley, South Brisbane and Zillmere. On the Sunshine Coast; Bokarina, Maroochydore and Marcoola scored highly.

Variable 2a was labelled “High Income and Education” because of positive loadings on Degree Qualifications, Household Income Over $3,000 Per Week and Professionals. No suburbs on the Sunshine Coast scored in the top quartile, although Alexandra Headland, Peregian Beach and Coolum Beach had medium high scores. In Brisbane; Toowong, Indooroopilly, Paddington and St Lucia scored highly.

The negative loadings on the second component were related to traditional “Blue Collar” professions, as well as low socio-economic status, such as only completing Grade 10, with Certificate Qualifications and Employed in the Trades and as Labourers. Socio-economic variables included Single Parents and Median Unemployment. Therefore, the split Variable 2b was labelled, “Low Income Blue Collar”. In Brisbane; Coopers Plains, Acacia Ridge, and Carole Park scored highly; and on the Sunshine Coast; Nambour, Yandina and Landsborough scored highly.

The third composite variable had positive loadings on Non English Speaking, Born in China and Vietnam, and Buddhist. Because of this, Variable 3 was labelled “Asian Ethnic”. In Brisbane, suburbs scoring highly on this included Stretton, Inala, Forest Lake and Eight Mile Plains. No Sunshine Coast suburbs scored above the median.

[Insert Figure 6 **(MAPPED PCA)** here]

As a further test, the composite variables were compared with the SEIFA scores from the ABS, at a CCD level (ABS b, 2006). In particular, “Professional High Income Education” was highly correlated with the Index of Occupation and Education ($r=.904$). The Index of Economic Resources was also highly correlated with the “Traditional Family” variable ($r=.719$). The other variables were less significant, which leads to the conclusion that they are probably not measuring the same combination of variables as is the SEIFA index, which is specifically aimed at socio-economic variables.

Statistical Tests – PCA and Water Use

The composite variables were then used as independent variables against the dependent variable water use in a multiple Regression. Together, the composite variables significantly predicted household water use at the CCD level, but the effect was extremely weak. The most significant was “Traditional Family” and the least was “Asian Ethnic”. This result is expected, given that the individual variables found most significant in the initial analysis also all scored highly on Variable 1a in the PCA; namely Median Household Size, Mortgaged, Children in Education and Two Cars.

[Insert Table 7 **(COMPONENT SCORE CORRELATIONS)** here]

A bivariate correlation was also performed between Mean Water Use (2006, 2007 and 2008) and the composite variables (Table 7). Whilst the correlation of CCD Average Water Use with most variables, with the exception of Asian Ethnic, was significant, these correlations were not high. Of note, Young Mobile was strongly negatively correlated for all years, and Low Income Blue Collar was negatively correlated in 2006 and slightly positive in 2007 and 2008. However, as with the other statistical analyses, the strongest positive correlation was Traditional Family; and in keeping with the Regression analyses; the strength of all correlations decreased over time (2006 – 2008).

Conclusion

Mapping and statistically analysing household water consumption at a range of spatial scales showed that mean water use for all study areas decreased during the period 2006-2008. However, despite the overall reduction, the Sunshine Coast still had higher water use than Brisbane. These results appear to support the hypothesis that the demand-side measures had a greater impact on water use in Brisbane than the Sunshine Coast. However, apart from the water restrictions, most of the demand-side measures (such as rebates on water tanks) were available throughout SEQ, including the Sunshine Coast. Therefore, it is thought, of the demand-side measures, the different levels of water restrictions had the greatest impact on reducing household water use.

Another possible confounding variable was rainfall as, during the period, the Sunshine Coast had higher rainfall than Brisbane. It could be assumed that Sunshine Coast households would use less water on gardens, and thus less overall water; however, this was not the case. This also supports the hypothesis that the stronger water restrictions in Brisbane; in particular, the emphasis on restricting outdoor water uses, were more significant than rainfall (Table 2). This also accords with other research that found rainfall is not particularly significant for household water consumption (Troy et al, 2005). In addition, it is possible that the largely unpopular State Government decision to build the Traveston Dam, and impose on the Sunshine Coast, the same level of water restrictions as Brisbane, could have resulted in a community backlash, manifested by higher levels of water use.

However, despite the overall higher mean water use of the Sunshine Coast; over time, all areas showed statistically significant reductions in household water consumption. This suggests that other variables besides prescriptive legislation contributed, such as changes in water use behaviour due to non prescriptive demand-side measures; for example, the awareness-raising campaigns and the media branding the issue as a “crisis” (Clark & Finley, 2007; Syme, Nancarrow & Seligman, 2000). Other research findings largely support this; householder attitudes were equally as influential as socio-demographic characteristics for levels of outdoor water use (Kolokytha et al, 2002; Syme et al, 2000; Syme et al, 2003). This will be further studied in Phase Two.

The geodemographic analyses revealed a set of composite variables which were largely similar to other such analyses (Baum et al, 2004). Some, such as “Traditional Family”, were positively correlated with water use, whilst others, such as “Asian Ethnic” apparently had little influence, at least on water use. Mapping these largely supported the known spatial distribution of socio-demographic characteristics of Brisbane and the Sunshine Coast suburbs; although of course, such characteristics cannot be extended to individuals within suburbs. In addition, as previously noted, the water use data is a longitudinal dataset (2006-2008), the Census 2006 is a cross-sectional dataset. However, as the study compared aggregate water data to CCD and LGA level socio-demographics, it was considered unlikely that socio-demographics would change significantly over a relatively short time scale.

The results of this analysis largely support other research showing that household water use is influenced by socio-demographic variables, such as household size, income and education

(Aitken, Duncan & McMahon, 1991; Clark & Finley, 2007; Troy et al, 2005). However, these influences were weak, and decreased over time. This adds further support to the hypothesis that patterns of household water use are influenced by factors other than socio-demographic or structural variables, in particular, by individual behaviour responding to policy measures (Syme et al, 2000).

However, the question remains, how did individual behaviour change so dramatically in response to the demand-side policy measures? Phase Two will investigate this, by surveying householders on their beliefs, attitudes and individual water use behaviour. In addition, it will endeavour to answer an important question; now that the drought has broken, will the behavioural changes be maintained, or will householders revert to wasteful water using practices?

References

Aitken. C. K.; H. Duncan.; & McMahon, T.A. (1991). A cross-sectional regression analysis of residential water demand in Melbourne, Australia. *Applied Geography*, 11(2), 157-165

Allon, F. and Sofoulis, Z. (2006). Everyday Water: cultures in transition. *Australian Geographer*. 37(1), 45-55

Australian Bureau of Meteorology (BoM) (2007) *Climate Change* http://www.bom.gov.au/climate/change/

Australian Broadcasting Association (ABC) (2009*), Traveston Dam notice 'cold, heartless'* http://www.abc.net.au/news/stories/2009/09/13/2684376.htm?site=news Internet Website Accessed September 2009.

Australian Bureau of Statistics (ABS a) (2006). *3235.0 - Population by Age and Sex, Australia, 2006*. http://www.abs.gov.au/ Internet Website Accessed March 2008.

Australian Bureau of Statistics (ABS b) (2006) *2039.0.55.001 - Socio-Economic Indexes for Areas (SEIFA) - Technical Paper, 2006* http://www.abs.gov.au/ Downloaded November 2007.

Barr, S. & Shaw, G. (2006). Understanding and Promoting Behaviour Change Using Lifestyle Groups. *Proceedings, RRF conference - Can we change a rubbish habit*. Winchester, Hampshire, UK. June 29, 2006

Baum, S.; Van Gellecum, Y. & Yigitcanlar, T. (2004). Wired Communities in the City: Sydney, Australia. *Australian Geographical Studies*, 42(2), 175–192

Birrell, B.; Rapson, V.; and Smith, T.F. (2005). *Impact of Demographic Change and Urban Consolidation on Domestic Water Use.* Water Services Association of Australia. Occasional Paper No. 15, June 2005.

Brown, A.L.; Tucker, D.I.; Johnston, C.S.; and Leviston, Z. (2007). *Sustainable Water Use at the Household Level: A Scoping Report.* CSIRO Water for a Healthy Country National Research Flagship, Perth.

Cai, W., and T. Cowan (2006), SAM and regional rainfall in IPCC AR4 models: Can anthropogenic forcing account for southwest Western Australian winter rainfall reduction?, *Geophys. Res. Lett.*, 33, L24708

Clark, W.A.; & Finley, J.C. (2007) Determinants of Water Conservation Intention in Balgoevgrad, Bulgaria. *Society & Natural Resources*. 20(7), 613-627

Clarke, G.P.; Kashti, A.; McDonald, A.; and Williamson, P. (1997). Estimating Small Area Demand for Water: A New Methodology. *Water and Environment Journal.* 11, 185-192

Corrall-Verdugo, Victor.; Bechtel, Robert, B.; & Fraijo-Sing, Blanca. (2003). Environmental beliefs and water conservation: An empirical study. *Journal of Environmental Psychology.* 23(3), 247-254

CSIRO (2007). *How the West has Dried*. Website accessed May 2007. http://www.csiro.au/news/newsletters/0509_water/story3.htm

CSIRO (2008). *Water for a Healthy Country Flagship*. http://www.csiro.au/org/WfHC.html Internet website accessed 1 April 2008.

Davis, D. & Morgan, A. (2008). Using the Theory of Planned Behaviour to determine recycling and waste minimisation behaviours: A case study of Bristol City, UK. *The Australian Community Psychologist.* 20(1), 105-117

De Oliver, M. (1999). Attitudes and Inaction: A Case Study of the Manifest Demographics of Urban Water Conservation. *Environment and Behaviour*. 31(3), 372-394

Domene, E.; and Saurí, D. (2006). Urbanisation and Water Consumption: Influencing Factors in the Metropolitan Region of Barcelona. *Urban Studies*. 43(9), 1605-1623

Durga Rao, K.H.V. (2005). Multi-criteria spatial decision analysis for forecasting urban water requirements: a case study of Dehradun city, India. *Landscape and Urban Planning.* 84(3-4), 301-311

Gilg, A. and Barr, S. (2005). Behavioural Attitudes towards water saving? Evidence from a study of environmental actions. *Ecological Economics.* 57(3), 400-414

Gregory, G. D., & De Leo, M. (2003). Repeated behavior and environmental psychology: The role of personal involvement and habit formation in explaining water consumption. *Journal of Applied Social Psychology.* 33(6), 1261–1296

Hiller, A. (2007). Why Social Work Needs Mapping. *Journal of Social Work Education.* 43(2), 205-221

Hoffmann, M.; Worthington, A.; and Higgs, H. (2006). Urban water demand with fixed volumetric charging in a large municipality: the case of Brisbane, Australia. *The Australian Journal of Agricultural and Resource Economics.* 50(3), 347-359

Kolokytha, E.G.; Mylopoulos, Y.A.; and Mentes, A.K. (2002). Evaluating demand management aspects of urban water policy—A field survey in the city of Thessaloniki, Greece. *Urban Water*. 4(4), 391-400

McIntyre, D. & Okorafor, O. (2003). *Deprivation in South Africa and its potential relevance to resource allocation issues: An analysis of 2001 Census data.* Health Economics Unit, University of Cape Town, October 2003

Pearce, F. (2006). *When the Rivers Run Dry: Water, the Defining Crisis of the Twenty-first Century.* Beacon Press, Boston, 367 pp.

Randolph, B. & Troy, P. (2008). Attitudes to conservation and water consumption. *Environmental Science and Policy*. 11(5), 441-455

Spearritt, P. (2008). The water crisis in Southeast Queensland: How desalination turned the region into carbon emission heaven. In *Troubled Waters: Confronting the Water Crisis in Australia's Cities*, ed Patrick Troy, ANU E-Press, Australian National University, Canberra

Stewart, J.; Turner, T.; Gardner, T. and McMaster, J. (2005). *Draft Urban Water Use Study of South Eastern Queensland.* The State of Queensland: Department of Natural Resources and Water (NRW)

Syme, G.J.; Shao, Q.; Po, M.; and Campbell, E. (2004). Predicting and understanding home garden water use. *Landscape and Urban Planning.* 68, 121-128

Syme, G.; Nancarrow, B.; & Seligman, C. (2000). The Evaluation of Information Campaigns to Promote Voluntary Household Water Conservation. *Evaluation Review* 2000. 24(6), 539-578

The State of Queensland: Department of Local Government and Planning (DLGP) (2007). *Queensland population update including regional population trends. No. 8*, March 2007. Website Accessed May 2007. http://www.lgp.qld.gov.au/docs/planning/information_and_forecasting/QPU-mar-2007/full-report.pdf

The State of Queensland: Department of Natural Resources and Water (NRW) (2007). *The South East Queensland Drought to 2007.* http://www.climatechange.qld.gov.au/forecasts/pdfs/seq_drought_2007.pdf

The State of Queensland: Office of Urban Management (OUM) (2008). *South East Queensland Regional Plan*. http://www.dip.qld.gov.au/seq Internet website accessed 31 March 2008.

The State of Queensland: Queensland Water Commission (QWC a) (2008). *Community beats Target 140*. Media Release. 25 Mar 2008. http://www.qwc.qld.gov.au/tiki-read_article.php?articleId=225. Internet website accessed 28 March 2008.

The State of Queensland: Queensland Water Commission (QWC b) (2008). *Water for today, water for tomorrow: South East Queensland Water Strategy* – Draft. March 2008.

Troy, P.; Holloway, D.; and Randolph, B. (2005). *Water Use and the Built Environment: Patterns of Water Consumption in Sydney*. City Futures Research Centre, Research Paper No. 1, December 2005.

Wallace, C. (2007). *Fine-tuning for State Government Water wise Services*. Department of Natural Resources and Water Media Release, 12 December 2007. http://statements.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=55662 Internet website accessed 27 March 2008.

Wentz, E. & Gober, P. (2007). Determinants of Small-Area Water Consumption for the City of Phoenix, Arizona. *Water Resource Management.* 21(11), 1849-1863

Zhang, H.J. and Brown, D.F. (2005). Understanding urban residential water use in Beijing and Tianjin, China. *Habitat International.* 29(3), 469-491.

TABLES

	Date	Watering	Pools	Other
Level 1	13/05/05	3 days a week; 4-8am; 4-8pm	3 days a week with hose	Boat, car, etc - yes driveways - no
Level 2	03/10/05	3 days a week; >7am & <7pm	Same	Same
Level 3	13/06/06	Hosing established gardens banned; bucket permitted	Topping up established 3 days; >7am & <7pm	Only with a bucket; hard surfaces forbidden
Level 4	01/11/06	Bucket only; 3 days a week; 4-8am; 4-8pm	If 3/4 water saving devices + tank, then can top up	Car/boat with bucket; others forbidden
Level 5	10/04/07	Bucket 4-7pm, 3 days. high volume users (>800LCD) all forbidden	3 days topping up permitted; 4-7pm; only if tank and 3 /4 saving devices	Only allowed to clean glass and flush boat engines, with bucket
Level 6	23/11/07	No lawns, gardens only with bucket, 3 days 4-7pm. More for high users.	3 days topping up permitted; 4-7pm; only if tank and 3 /4 saving devices	Only allowed to clean glass and flush boat engines, with bucket
High Level	31/07/08	Bucket only; 3 days a week; no lawns	If 3 out of 4 water saving devices, then can top up	Car/boat with bucket; others forbidden

Table 1. Increasing Level of Water Restrictions, South East Queensland, 2005 - 2008

LGA	Mean Water Use 2006	Mean Water Use 2007	Mean Water Use 2008
Brisbane	547.3302808	440.3359936	408.9326422
Caloundra	666.6177834	658.2698986	561.5508463
Maroochy	632.4825558	588.0220449	530.4630230

Table 2. Mean Water Use by LGA (2006-2008)

LGA	**Correlation**	**T**	**Significance**
Brisbane: 2006 – 2007	.739	35.203	.000**
Brisbane: 2007 – 2008	.611	10.040	.000**
Caloundra: 2006 – 2007	.851	1.116	.266
Caloundra: 2007 – 2008	.620	7.758	.000**
Maroochy: 2006 – 2007	.694	6.447	.000**
Maroochy: 2007 – 2008	.637	8.446	000**

Table 3: Correlations between years per LGA (** $p<.05$)

Month	LGA	Mean Water Use	LGA	Mean Water Use	LGA	Mean Water Use
Jan – Mar 2006	Brisbane Q1	No data				
Apr – Jun 2006	Brisbane Q2	726.82	Caloundra P1	1127.31	Maroochy P1	773.97
Jul – Sep 2006	Brisbane Q3	625.31				
Oct –Dec 2007	Brisbane Q4	596.09	Caloundra P2	996.89	Maroochy P2	836.67
Jan – Mar 2007	Brisbane Q1	601.25				
Apr – Jun 2007	Brisbane Q2	600.94	Caloundra P1	1085.44	Maroochy P1	984.68
Jul – Sep 2007	Brisbane Q3	501.84				
Oct –Dec 2008	Brisbane Q4	450.73	Caloundra P2	910.08	Maroochy P2	599.82
Jan – Mar 2008	Brisbane Q1	448.97				
Apr – Jun 2008	Brisbane Q2	524.88	Caloundra P1	2548.08	Maroochy P1	560.21
Jul – Sep 2008	Brisbane Q3	495.61				
Oct –Dec 2008	Brisbane Q4	500.72	Caloundra P2	828.60	Maroochy P2	568.15

Table 4 – Mean water use per LGA per period.

	R	R Square	Adjusted R Square	SE. of the Estimate
2006	.536[a]	.287	.284	.84628277
2007	.452[a]	.204	.201	.89407188
2008	.406[a]	.165	.161	.91609018

	Sum of Squares			Df	Mean Square			F		Sig
	2006	2007	2008		2006	2007	2008			
Regression	571.502	406.660	327.664	9	63.500	45.184	36.407	**2006**	88.663	.000**
Residual	1419.498	1584.340	1663.336		.716	.799	.839	**2007**	56.525	.000**
Total	1991.00							**2008**	43.382	000**

Table 5. Dependent Variables: Mean household water consumption: 2006 – 2008 (** *p<.05*)

	Component		
	1	2	3
% Two Car	.905		
%Married	.858		
% Lone Person	-.852		
%four people living in house	.850		
% No Car	-.829		
% Total Mortgage	.825		

% In Education 5 - 14	.820		
% Detached houses	.813		
% total rented	-.801		
% Three Car	.762		
% Dependent Student 15 - 24	.753		
%five people living in house	.739		
% One Car	-.727		
% JTW Public Transport one method	-.677	.482	
% Never married	-.627	.340	
% JTW vehicle one method	.582	-.563	
% Professionals		.928	
% Bachelor Degree		.928	
%Grade12		.872	
% Postgraduate Degree		.846	
% Professional and Scientific		.843	
%Grade10 – 11	.336	-.812	
% Technical and Trades		-.783	
%Certificate		-.769	
% Income 3000 or more	.345	.761	
% Labourers		-.695	
% MachineOperators		-.634	
% Single Parents		-.558	
% mortgage 3000 Plus	.337	.550	
% Financial Sector		.408	
%Non English Speaking			.924
% Chinese born			.846
%born in UK			-.827
% Buddhist			.780
% Indian			.701
% Anglican			-.581
% Vietnamese			.404
% Aged 15 – 19	.341		
% Unemployment_Male	-.307		
% moved less than one year	-.489		
% Education and Training		.526	

Table 6. Rotated Component Matrix – Component Analysis

		CCD_Average2006	CCD_Average2007	CCD_Average2008
TRADITIONAL FAMILY	Pearson Correlation	.215**	.154**	.118**
	Sig. (2-tailed)	.000	.000	.000
	N	1992	1992	1992
YOUNG MOBILE	Pearson Correlation	-.234**	-.186**	-.141**
	Sig. (2-tailed)	.000	.000	.000
	N	1992	1992	1992
PROFESSIONAL HIGH INCOME	Pearson Correlation	.074**	-.080**	-.081**
	Sig. (2-tailed)	.001	.000	.000
	N	1992	1992	1992
LOW INCOME BLUE COLLAR	Pearson Correlation	-.076**	.092**	.066**
	Sig. (2-tailed)	.001	.000	.003
	N	1992	1992	1992
ASIAN ETHNIC	Pearson Correlation	.078**	-.011	.019
	Sig. (2-tailed)	.000	.629	.390
	N	1992	1992	1992

Table 7: Correlations Between Component Score Variables and Mean Water Use per CCD per annum (** $p<.05$)

FIGURES

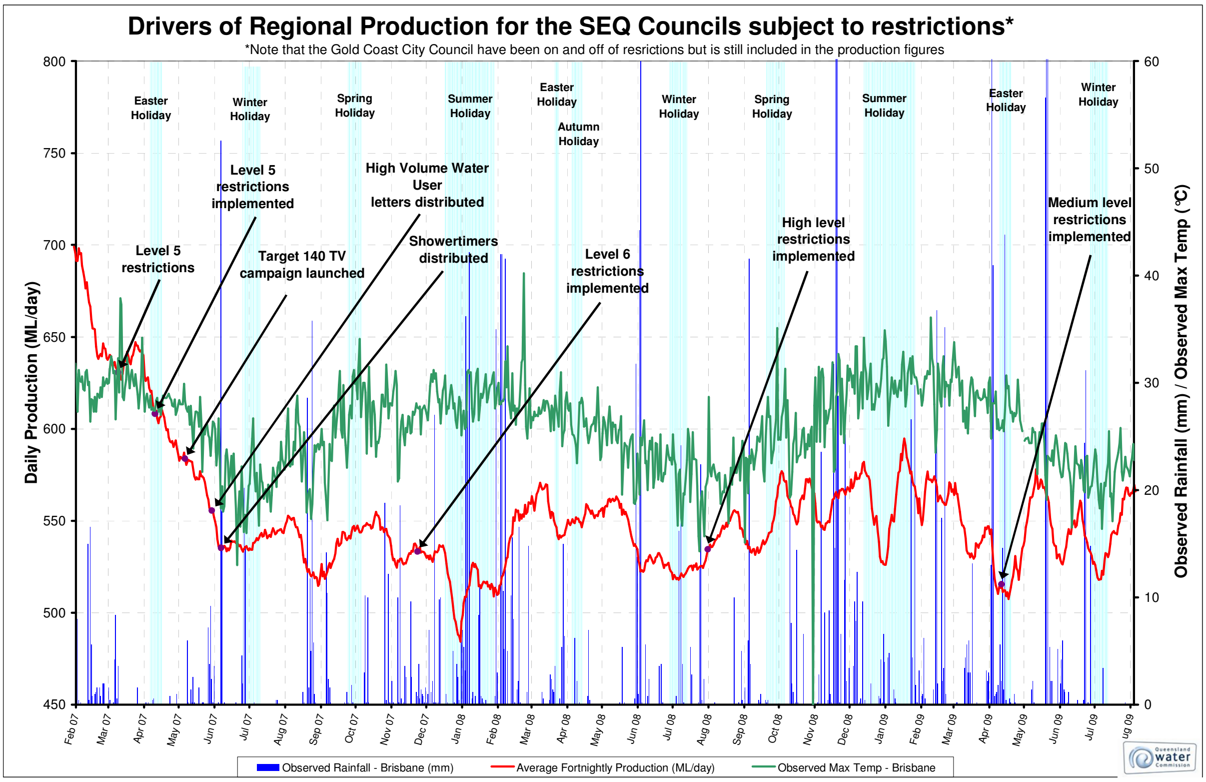

Figure 1: Drivers of Regional Production for the 12 Councils subject to restrictions. Reproduced by permission of the Queensland Water Commission (2009)

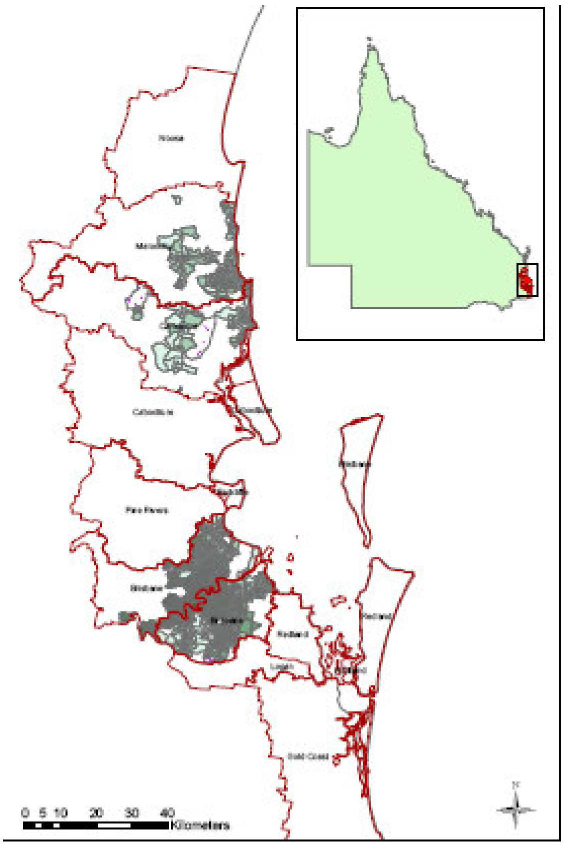

Fig 2. Study Area

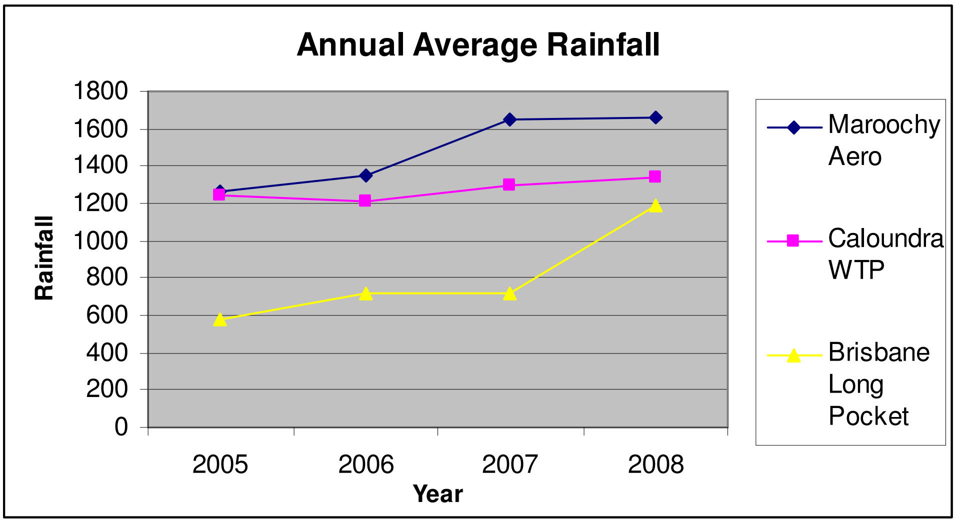

Figure 3: Annual Average Rainfall per LGA per Annum

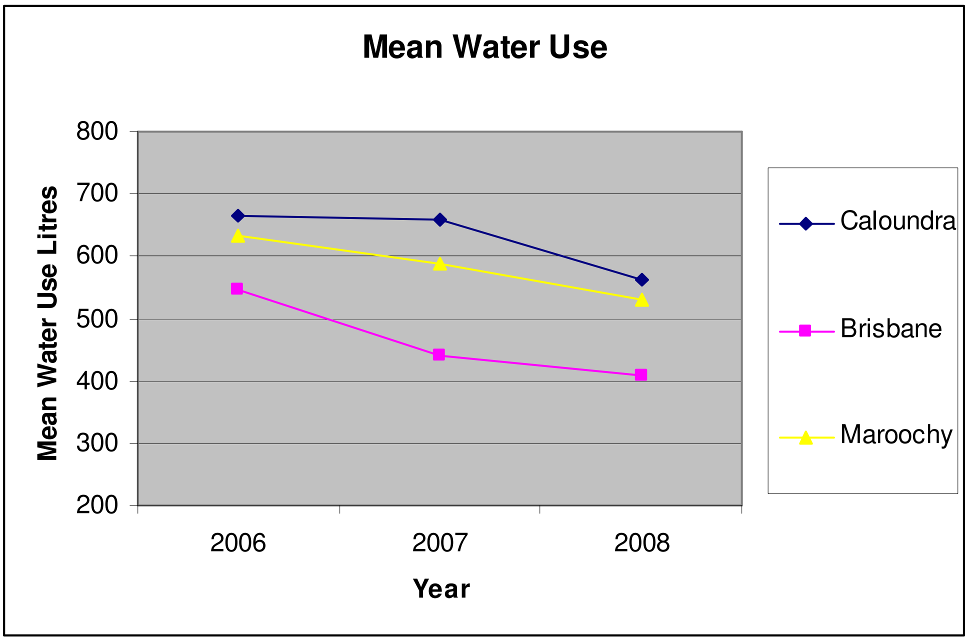

Figure 4. Mean Water Use Per LGA per Annum

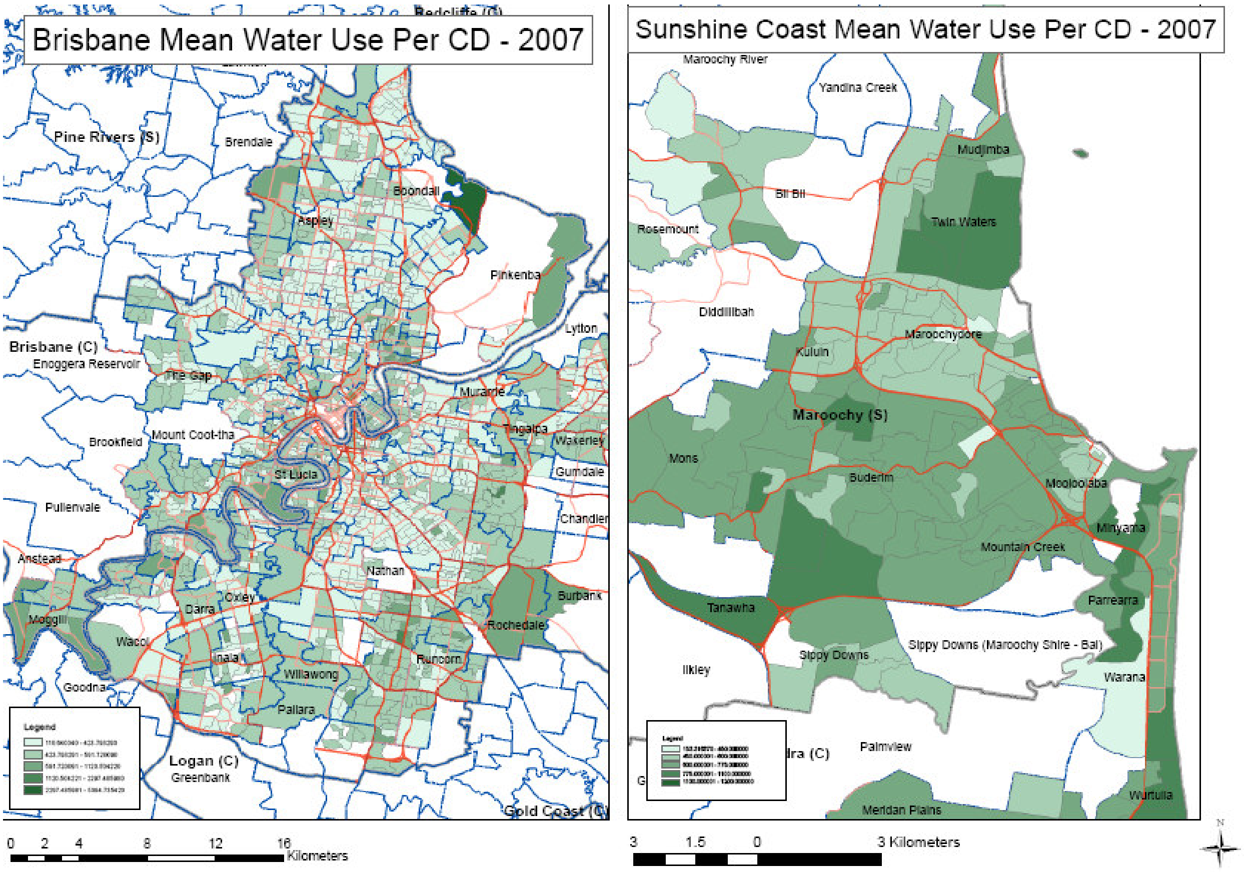

Figure 5. Mean Water Use per CCD (2007) Brisbane and Sunshine Coast

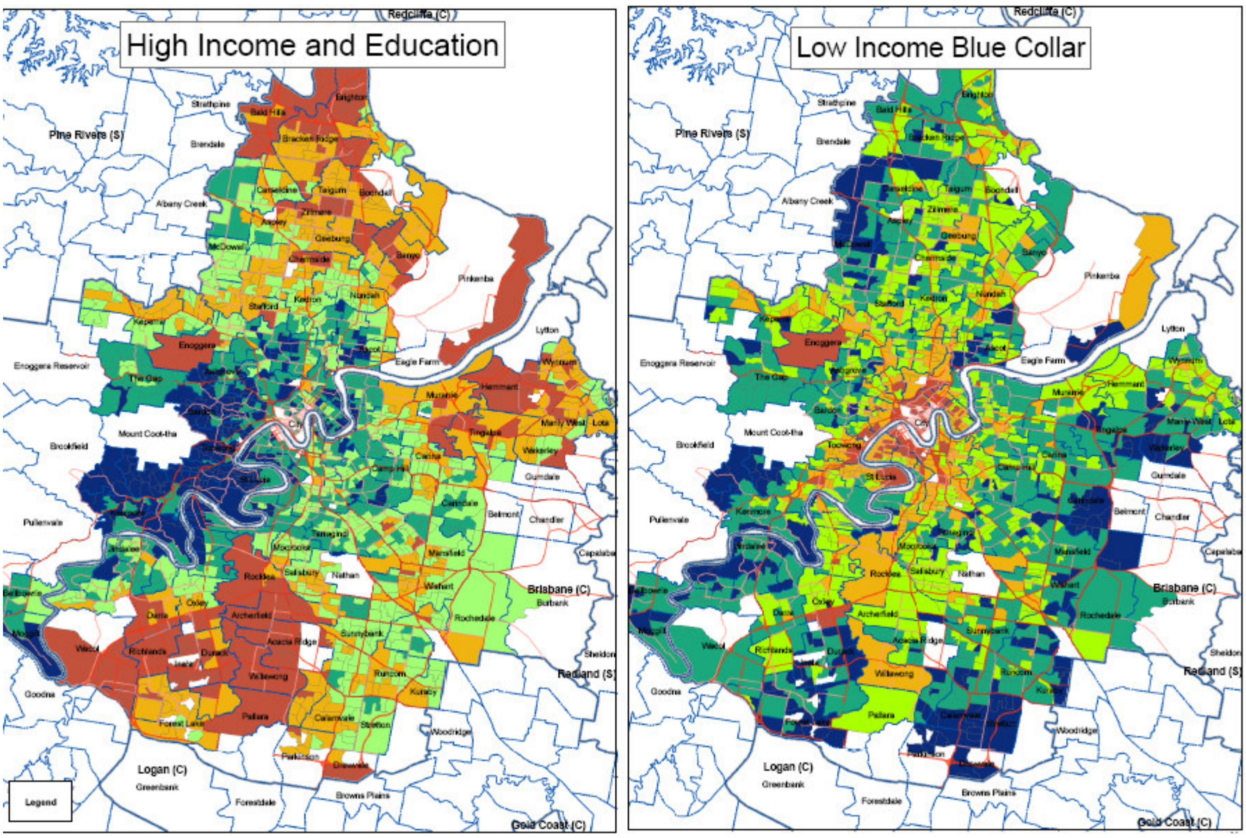

Figure 6. Results of Principal Component Analysis