USING GEOGRAPHIC INFORMATION SYSTEMS TO EXPLORE THE DETERMINANTS OF HOUSEHOLD WATER CONSUMPTION AND RESPONSE TO THE QUEENSLAND GOVERNMENT DEMAND-SIDE POLICY MEASURES IMPOSED DURING THE DROUGHT OF 2006-2008.

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ABSTRACT

Something hitherto unheard of happened in South East Queensland, Australia between 2005 and 2008. During a recent drought, a suite of demand-side measures was remarkably successful in reducing household water consumption. Over this relatively short period, residential water use plummeted from approximately 300 Litres Capita Day (LCD) to a low of 122 LCD. Average household water use dropped over 50%, unprecedented for a demand-side program, most of which only result in water use reductions of 10% or less. There is great interest in understanding how and why the policy measures were so effective so rapidly and on such a scale. Understanding how this behavioural change happened so rapidly and on such a large scale, is potentially of great significance for the future management of household water demand.

This paper reports on research using geodemographic approaches to examine key dimensions of household water use during the SEQ drought. The research first used Geographic Information Systems, Principal Components Analysis, and other statistical methods to explore the spatial, socio-demographic and structural determinants of household water use in the period. The most significant variables found to predict high water use at the Census Collection District scale were swimming pools, land value, and income. This information informed surveys of householder attitudes and behavioural change in response to policy measures. Householders largely supported the measures and showed a distinct preference for those, such as water tanks, that allowed them control over how water was used. As with similar studies, intention to practise conservation behaviour was not significant for actual behaviour. In conclusion, the results of this research could enable finer targeting of demand-side policy, and help maintain lower levels of water use into the future.

INTRODUCTION AND BACKGROUND

Prior to 2005, few legislative barriers to consumption existed in South East Queensland, and per capita water consumption was one of the highest in Australia (Hoffmann et al 2006; Spearritt, 2008). However, by late 2005, the region was experiencing an extended drought, and rapidly falling water storage levels. In response, the Queensland Government argued that, if rain did not fall, "…*SEQ will be in the grip of the worst drought in recorded history*" and for the first time it was mooted that SEQ might have to restrict domestic water consumption, to a relatively "low" 300 LCD (SEQRWWS *Interim Report*, November 2005: 1).

In June 2006, the Queensland Water Commission (QWC) initiated a combination of supply and demand-side policy measures. New supply-side infrastructure included; desalination and recycling plants, a series of interconnected pipelines to link up existing (and new) water storages across the region (the Water Grid), and a major new bulk water source on the Mary River, the Traveston Dam (NRW, 2007). The demand-side measures included an awareness campaign (Target 140); water restrictions, home retrofits, and a range of incentive mechanisms, including subsidies on water tanks (QWC, 2008a; QWC, 2008b). These were remarkably successful in reducing household water consumption; from 2005 – 2008, residential water use plummeted from approximately 300 Litres Capita Day (LCD) to a low of 122 LCD.

Demand-side Policies

Demand-side policies generally have fewer environmental and social impacts and lower costs than supply-side polices, and if well planned, and implemented as part of a targeted suite of measures, can effectively reduce household water use (Kolokytha et al, 2002, p391; Turner et al, 2005). However, responses to policy can differ markedly depending on the type of policy, and the individual concerned (Kenney et al., 2008, p194). For example, affluent householders typically respond poorly to voluntary measures; in part because such policies may impact property values (De Oliver, 1999; Harlan et al., 2009). Thus policy measures should be carefully developed; to strategically target those groups that use the most water and those with the greatest capacity to change (Allon & Sofoulis, 2006; Jorgensen et al, 2009).

Demand-side policies can generally be differentiated into Mandatory (i.e. Pricing, Water Restrictions and Penalties) and Voluntary (Awareness Raising, Subsidies and Incentives). For example, water restrictions are mostly used to reduce outdoor and not indoor water use, as the community is resistant to reducing "essential" uses, such as toilet flushing. In addition, maintaining strict, permanent restrictions leaves fewer options for short term crises (Birrell et al., 2005; Harlan et al., 2009; Jackson, 2005; Kenney et al., 2008; Troy & Randolph, 2005; WSAA, 2010). Fines and penalties are commonly used to support restrictions and pricing, but can be inequitable, and difficult to monitor and enforce (Barr et al, 2003; Chong, 2009; Syme et al., 2000; Troy & Randolph, 2005). Other mandatory policies include planning policy and construction standards, such as water tanks for new houses.

Voluntary policies include awareness raising and education campaigns. Awareness-raising campaigns are common, but it is difficult to isolate specific effects. Further, these are subject to the attitude-behaviour gap, and dependent on education (Allon & Sofoulis, 2006, p43; Gilg & Barr, 2006; Gregory & Di Leo, 2003, p1282; Jackson, 2005; Mankoff et al., 2007, p1; Shove, 2003; Syme et al., 2000; Troy & Randolph, 2005). Other voluntary policies such as subsidies, incentives and technology refits can also be dependent on education, income and tenure (Aitken et al., 1991; Domene & Sauri, 2006; Gilg & Barr, 2006; Gregory & Di Leo, 2003; Harlan et al., 2009; Randolph & Troy, 2008; Troy & Randolph, 2005; Turner et al., 2005, p6)

Target 140

The Target 140 awareness-raising Campaign (which ran from March 2007 to July 2008) aimed to reduce average household water use to a voluntary 140LCD (later mandated as part of Level 6 Restrictions). It was supported in the media, by advertising, as well as a website, with daily reports of total water consumption; reports on dam levels; and tools to compare personal water use with the average use of other Brisbane suburbs. Target 104 included communications material on how to reduce indoor water consumption, as well as how to apply for subsidies. The QWC also issued regular press releases, with headings such as "Target 140 beaten again". Unusually, the Campaign also targeted indoor water use.

Water Restrictions

From May 2005, the region (excluding the Sunshine Coast) was subject to increasingly strict levels of water restrictions, each succeeding stage of which further limited outdoor use. Level 6 restrictions completely banned lawn watering, washing vehicles and filling new pools, and also set per capita quotas for indoor use.

Fines and Penalties

The "Excessive water user program" targeted households that used greater than a specified per capita quota (depending on level of restrictions in place). Such households with legitimate reasons for using excessively high amounts of water were exempted; but if non-exempt, were subject to penalties, such as a complete ban on outdoor watering. The household was also given communications material on reducing use.

Subsidies, Incentives and Rebates

Home WaterWise paid a licensed plumber to carry out a range of water saving initiatives, such as water savings advice, identification of leaks and provision of a "low flow" showerhead. A paid rebate of $1500 was also offered on water tanks; and subsequently increased for tanks plumbed into the main water supply. Some LGAs, such as Brisbane, matched this with additional funding. The Queensland Government paid a total of $261 million in subsidies for approximately 508,000 water tanks, toilets, washing machines and water efficient toilets. Nearly 21% of existing households took up the water tank rebate (Spiller, 2010).

Aim

The outstanding success of the Queensland Government's policy measures could potentially have far-reaching consequences for the future management of household water demand in other urban areas, but it is unclear what drivers of household water use were most influenced by these measures. However, to plan, monitor and adapt demand-side policies, water managers need the ability to predict small area variations in water use—why some areas consistently use greater quantities of water, and respond differently to various policy measures (Aitken et al, 1991; Clarke et al., 1997; Durga Rao, 2005; Hillier, 2007; Wentz & Gober, 2007). Therefore, a comprehensive, academically rigorous evaluation into which determining factors are influenced by a policy can potentially be of great benefit for future policy iterations, and to the accountability of water managers (Syme et al, 2000; Turner et al., 2005).

To do so, this study aimed to identify some of the determinants of household water use and the types of households that responded most favourably to the demand-side measures. This richer understanding of the determinants of household water use could support future policy iterations in SEQ, and other urban areas. Therefore, the study aimed to answer the questions:

- How did household water use vary spatially and temporally in response to the SEQ demand-side policies, and what structural, socio-demographic and behavioural factors contributed to this variance?
- Which of the policy measures were the most effective, and why?

Drivers of Household Water Use

At the broadest scale, the determinants of total water use are 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, urban water use is driven by a complex combination of structural (property level), socio-demographic and psychological factors (Birrell et al., 2005; Clarke et al., 1997; Durga Rao, 2005; Eardley et al, 2005; Po et al., 2005; Troy & Randolph, 2005; Wentz & Gober, 2007).

Although not discrete, household water use can generally be differentiated into outdoor and indoor use. The determinants of outdoor water use are generally structural factors, such as lot size and water using equipment (Birrell et al., 1999; Clarke et al., 1997; Domene & Sauri, 2006; Hoffmann et al., 2006; Troy & Randolph, 2005; Wentz & Gober, 2007; Zhang & Brown, 2005). On the other hand, determinants of indoor use are generally socio-demographic, and include household size, income and education (Eardley et al, 2005;Harlan et al., 2009; Troy & Randolph, 2005; Wentz & Gober, 2007). Structural factors are generally better predictors of water use than socio-demographic factors, but both are better predictors than psychological factors (Domene & Sauri, 2006; Gilg & Barr, 2006; Grove et al., 2006; Jackson, 2005 Jorgensen et al., 2009; Kenney et al., 2008). The major structural, socio-demographic and psychological drivers of household water use are summarised in Table 1:

Table 1: Summary of the Major Drivers of Household Water Use

Determinant	Details	References
Structural • Climate • Lot area • Garden Type • Dwelling Type • Swimming pools & other water features	Generally drivers of outdoor water use, mostly related to lot size. Larger, older houses generally use more water, mostly because of numbers and age of appliances. Garden type can have a major impact on outdoor water use, depending on size of lawns and water features. Structural factors are interrelated with each other, and with socio-demographic factors (i.e. higher income households tend to have larger gardens with more water features). Can be managed with water-efficient technology. Higher water use generally best predicted by climate; lot size; and swimming pools.	Askew & McGuirk 2004 Birrell et al., 1999; Browne et al., 2007; Clarke et al., 1997; Domene & Sauri, 2006; De Oliver, 1999, p389; Domene & Sauri, 2006; Harlan et al., 2009 Syme et al., 2004, Troy & Randolph, 2005; Wentz & Gober, 2007, Zhang & Brown, 2005
Socio-Demographics • Age • Gender • Income • Education • Household Size • Household Makeup	Generally drivers of indoor water use, but can also influence outdoor water use. Household size is often the major socio-demographic influence on total water use; but per capita water use is inversely proportional to household size because smaller households can easily reduce personal use (i.e. showering and flushing toilets) but not general use (i.e. washing clothes and dishes). Income can be negative or positive: higher income households tend to have larger houses and gardens, but have a better capacity to reduce water use. Often respond better to mandatory rather than voluntary policies. Tenure is also interrelated with income, as lower income households tend to rent; and owner occupied houses tend to use more water. Age, gender and ethnicity are less significant for water use.	Birrell et al., 2005; Clark & Finley, 2007b; Corral-Verdugo et al, 2008; Domene & Sauri, 2006; Eardley et al, 2005 Gregory & Di Leo, 2003; Harlan et al., 2009 Syme et al., 2000; Troy & Randolph, 2005; Turner et al., 2005 Wentz & Gober, 2007; Zhang & Brown, 2005.
(Psychology) Behaviour • Awareness • Attitude • Subjective norms • Perceived Behavioural Control • Values and Morals • Affect • Past Behaviour	Psychological factors can interact with structural and socio-demographic factors to influence water use behaviour. Attitudes can influence intention to conserve water, although not necessarily behaviour. Awareness-raising is commonly used. Other factors include influence of social norms; (perceived) level of control; affect (emotional response); habit (water use is often habitual) and past behaviour (history of water saving behaviour). Conceptual psychological frameworks include Rational Choice (i.e. Theory of Planned Behaviour), Values-based (i.e. Norm Activation Theory), Social and Combination theories. Many subject to Attitude-Behaviour Gap and Fundamental Attribution Errors and generally have low explanatory power for actual behaviour.	Allon & Sofoulis, 2006, Armitage & Conner, 2001; Clark & Finley, 2007b; Corral-Verdugo et al., 2008; Gatersleben et al, 2002; Gilg & Barr, 2006; Hinds & Sparks, 2008; Jackson, 2005; McKenzie-Mohr & Smith, 1999; Tonglet et al., 2004; Trumbo & O'Keefe, 2005; Zhang & Brown, 2005.

Research into the small scale drivers of household water demand has mostly focussed on two major dimensions; structural and socio-demographic drivers; and psychological constructs—i.e. attitudes, beliefs and values (Clark & Finley, 2007b). A substantial literature exists on structural and socio-demographic factors, but less has been conducted on the combined influences of structural, socio-demographic and psychological factors on water use behaviour, particularly using disaggregate data at the household level (Birrell et al., 2005; Clark & Finley, 2007a; Domene et al, 2005; Domene & Sauri, 2006; Syme et al, 2004, p122; Troy & Randolph, 2005; Turner et al., 2005; Wentz & Gober, 2007). Another gap is the differing response of socio-demographic groups to demand-side policies, as well as the response to policy of households with different structural characteristics, such as lot area (Mankoff et al., 2007, p5). For example, in Arizona, detached households on larger lots maintained their decreases in water use after mandatory restrictions ended, and after a drought ended (De Oliver, 1999, p386).

Study Area

The study was set in the Local Government Areas (LGAs) of Brisbane and the Sunshine Coast (Figure 1). Both form part of South East Queensland (SEQ); a region which totals 22,420km2, and comprises 10 LGAs. SEQ is highly urbanised, with a population of approximately 2.6 million (72% of Queensland). SEQ had population growth rates in excess of 3%; but this has recently slowed (ABS, 2010b). Brisbane is the capital of Queensland, with a population of approximately 1.95 million; and the Sunshine Coast is approximately 100km north of Brisbane, and has a population of approximately 313,000 (ABS, 2010b). The Sunshine Coast formerly comprised three separate LGAs (Caloundra, Maroochy and Noosa); but these were merged on 15 March 2008. Due to data limitations, only Brisbane, Caloundra and Maroochy were analysed.

SEQ has a humid sub-tropical climate, and is generally free from temperature extremes. Brisbane generally has a lower rainfall than the Sunshine Coast; with an average rainfall of approximately 1,200mm pa, in comparison with the Sunshine Coast average of 1,650mm pa (BOM, 2007). In SEQ, residential households are the largest water users, using 76% of total urban water supplies, and detached houses use 59% of total supply (ABS, 2010c; QWC, 2008b).

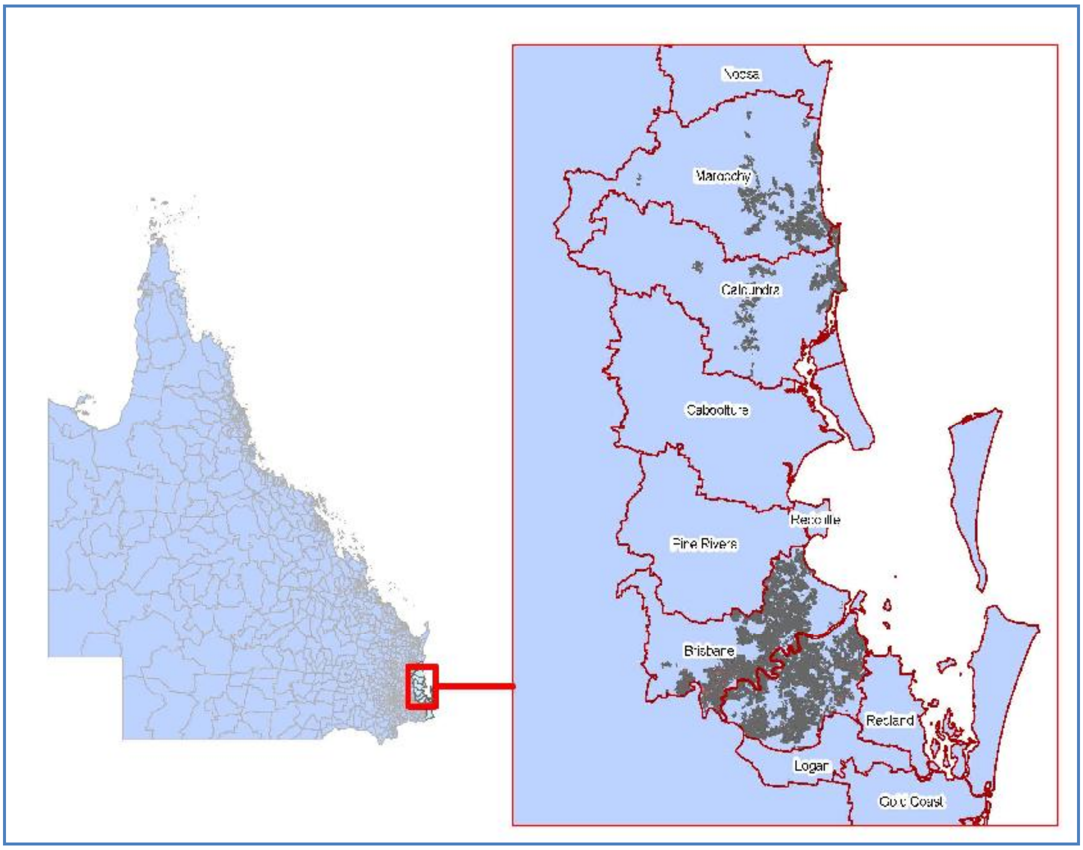

Figure 1 Study Area

METHOD(S)

Geographic Information Systems

The first phase of the study used Geographic Information Systems (GIS) for spatial analysis and mapping. By combining spatial analysis with geodemographics, mapping can give a broad indication of water use at a variety of spatial scales, and provide important insights into the relationship between various datasets, such as aggregate socio-demographic Census data and structural variables (Clarke et al., 1997; Domene & Sauri, 2006; Durga Rao, 2005; Hillier, 2007). Maps quickly and graphically indicate areas of high water use (Troy & Randolph, 2005). In addition, by using geo-statistical techniques, a GIS can analyse changes in water use in response to time-dependent policy measures, like water restrictions.

Phase One of the study used a GIS to determine the area of interest and the spatial resolution, and to select a smaller stratified subset for further investigation. The dependent variable, household water use, and independent structural and socio-demographic variables, were mapped at the household, Census Collector District (CCD), and Local Government Authority (LGA) scale. This GIS mapping was combined with descriptive and exploratory statistical analysis, including simple Bivariate Correlations, Ordinary Least Squares Regression Analyses, Analysis of Variance (ANOVA) variants such as Generalized Linear Models (GLM) and Linear Mixed Models (LMM); Principal Components Analyses (PCA); and Structural Equation Modelling.

Questionnaire Survey

The spatial analysis was supported by a large scale Questionnaire Survey, which included quantitative and qualitative questions on household water use and behaviour. The survey responses were linked with water use records, to match stated with actual behaviour. General descriptive analysis was used to identify socio-demographics of the sample, indoor and outdoor water use, and attitudes to policy and water conservation. The sampling frame for the survey was the total dataset consisting of all detached residential properties in Maroochy, Caloundra and Brisbane with four years of water data. All households identified in the initial GIS mapping exercise had an equal chance of selection. The sampling method used multistage cluster sampling, with Probability Proportionate to Size Sampling (PPS) (CDC, 2009). By including participants from all socio-demographic sectors, this enabled inferences to the wider population of South East Queensland (SEQ). Analysis of the Questionnaire data used simple descriptive statistics, as well as using the SPSS module, AMOS, to create a model of household water use, using a combination of regression, factor analysis and Structural Equation Modelling.

Qualitative Analysis

The final phase of the study was a qualitative analysis of the final open-ended question on the survey, which sought to clarify some in-depth beliefs of householders about water use, conservation and demand-side policies. This component was relatively minor, so basic text coding was used to organise comments into themes, which were identified both inductively, and from the literature; and then described in the text.

TECHNIQUE AND ANALYSIS

Dependent Variable: Household Water Use

The study used a large scale dataset consisting of four years of water consumption data, from April 2006 to December 2009. It included actual meter readings and dates of meter readings from all Single Family Residential (detached and semi-detached households) in Brisbane, Maroochy and Caloundra. As Sunshine Coast water meters are read twice yearly, the Brisbane quarterly water data was aggregated to annual and biannual periods, to ensure temporal data correspondence.

Brisbane had consistently lower water use than both Sunshine Coast LGAs, for every year (Fig 2). However, historical data (circa 2004) showed, prior to the drought, Brisbane households had similar water use levels to the Sunshine Coast. However, since approximately 2004/2005, most Brisbane suburbs had reduced their water use by around 50%, and to an even greater degree by 2007 and 2008 (Fig 3).

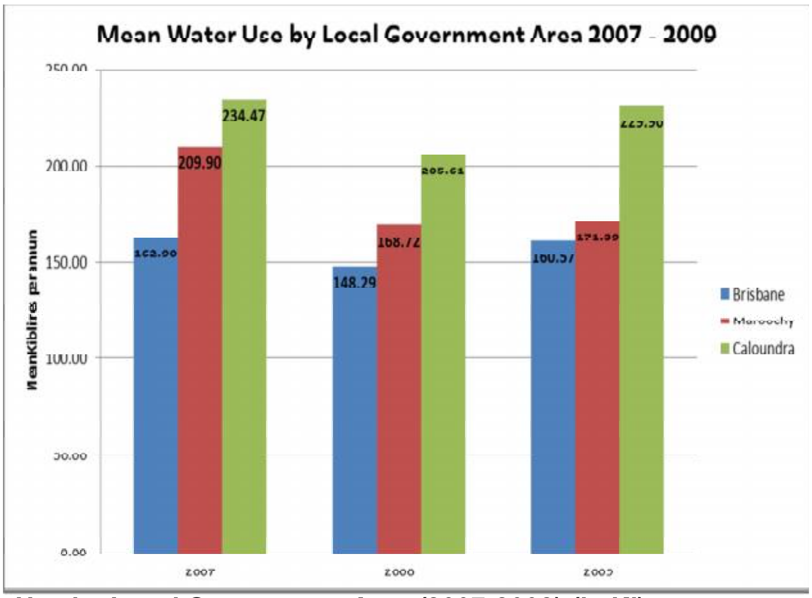

Figure 2 Mean Water Use by Local Government Area (2007-2008) (in Kl)

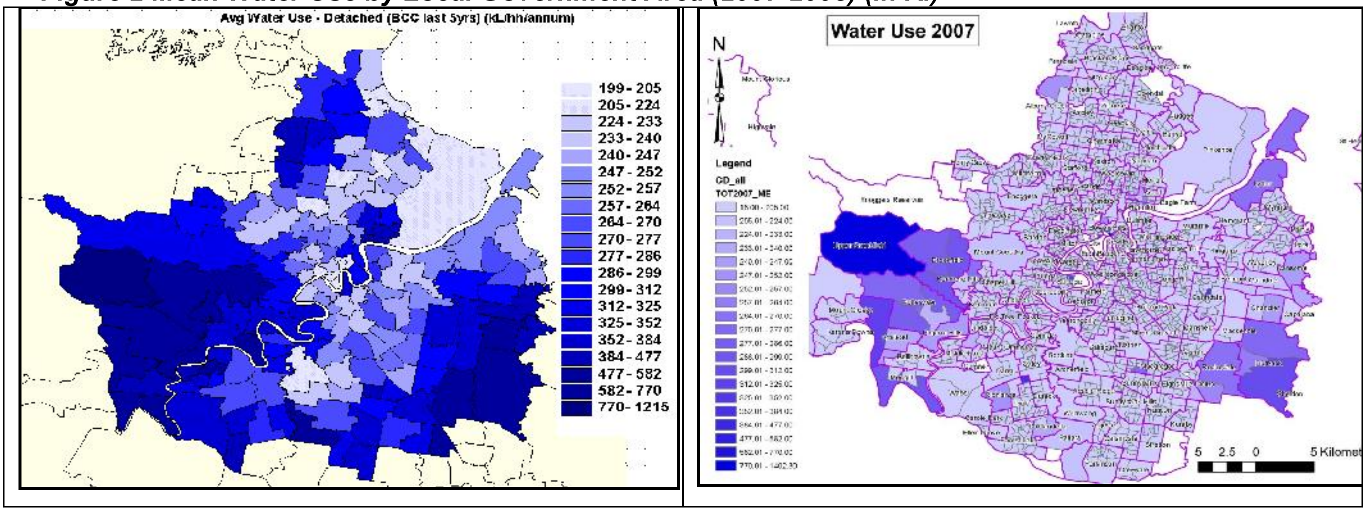

Fig 3. Comparison between Average Water Use Brisbane (<2005) (J. Stewart et al., 2005) & 2007

A Generalised Linear Model (GLM) Within Subjects Repeated Measures test was used to analyse the water data. The differences in mean water use were statistically significant between groups (LGAs) and within subjects (biannual time periods). Between groups, mean water use was higher for Caloundra and Maroochydore than for Brisbane. Within subjects (time periods); for Brisbane, the change in water use between all the periods was significant. For Caloundra, the change in water use for all periods was significant except for 2009; and for Maroochy, the change in water use for all periods was significant, except between the latter half of 2007 and the first half of 2008 (Table 2).

Table 2 Tukey Post Hoc Tests Water Use per LGA

(I) LGACode	(J) LGACode	Mean Diff (I-J)	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Brisbane	**Caloundra**	**-19.60***	1.03	-22.01	-17.19
	Maroochy	**-9.37***	0.87	-11.40	-7.34
Caloundra	**Brisbane**	**19.60***	1.03	17.19	22.01
	Maroochy	**10.23***	1.28	7.23	13.23
Maroochy	**Brisbane**	**9.37***	0.87	7.34	11.40
	Caloundra	**-10.23***	1.28	-13.23	-7.23

Based on observed means. The error term is Mean Square (Error) = 146.473

**. The mean difference is significant at the .05 level*

To visually highlight changes in household water use, the water data was aggregated to Census Collector District (CCD), and mapped for each year using equal intervals, and also Standard Deviations. To enable comparison over time; average water use per household per day for 2006 was used as baseline data. ArcGIS default, Jenks Algorithm was used to symbolise the data, Brisbane water consumption noticeably “flattened” during the period 2006 – 2008. By 2008, the water use of the majority of CCDs fell in the lowest 2 classes. This was particularly apparent for the smaller, more central CCDs, and larger CCDs (generally those with larger lots) had higher water use, with less variation. By 2009, water consumption displayed more variance, similar to 2006. In addition, despite the overall water use for the Sunshine Coast being higher than Brisbane (the majority of CCDs mapped in the highest 2 classes); the same trends were also apparent.

Independent Variables:

Structural Factors

Structural variables were also analysed using a GLM Repeated Measures ANOVA. As expected, for every LGA, the average water use of households with pools for all areas was significantly higher than for households without pools. However, the influence of the other variables differed by LGA (Table 3). For Brisbane, swimming pools, mean sale price and land area were significant; and in Maroochy, all independent variables were significant, with swimming pools and mean sale price, accounting for the most variance. For Caloundra, only swimming pools were significant. Current land value was not significant for Brisbane, and weak for Caloundra. All independent variables, with the exception of Rainfall (omitted in this model because previous analysis found it non-significant), contributed significantly to the model.

Table 3. GLM Repeated Measures on Split Dataset – Test of Between Subject Effects

LGA_first	Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Brisbane	Intercept	3343431.679	1	3343431.679	2646.172	**.000**	.925
	Lot Area (mean)	5676.713	1	5676.713	4.493	**.035***	.021
	Sale Price (mean)	20023.619	1	20023.619	15.848	**.000***	.069
	Land Value (mean)	3751.889	1	3751.889	2.969	.086	.014
	Pool	88723.410	1	88723.410	70.220	**.000***	.247
	Error	270388.458	214	1263.497			
Caloundra	Intercept	2820926.016	1	2820926.016	692.040	**.000**	.861
	Lot Area (mean)	10981.402	1	10981.402	2.694	.104	.023
	Sale Price (mean)	2530.413	1	2530.413	.621	.432	.006
	Land Value (mean)	5662.272	1	5662.272	1.389	.241	.012
	Pool	999746.897	1	999746.897	245.261	**.000***	.687
	Error	456539.919	112	4076.249			
Maroochy	Intercept	3883920.113	1	3883920.113	1497.944	**.000**	.892
	Lot Area (mean)	20061.433	1	20061.433	7.737	**.006***	.041
	Sale Price (mean)	62262.025	1	62262.025	24.013	**.000***	.117
	Land Value (mean)	18151.598	1	18151.598	7.001	**.009***	.037
	Pool	429020.120	1	429020.120	165.464	**.000***	.478
	Error	469303.053	181	2592.835			

a. Post hoc tests were conducted using Bonferroni adjusted alpha levels of P<.05 per test.
b. Mauchley's test of sphericity was significant, so df were corrected using the Greenhause-Geiser estimates

Water Restrictions

To investigate whether the water restrictions had a statistical significance on household water use, a fixed effects Linear Mixed Models (LMM) procedure was conducted. First, a LMM was run on the Brisbane dataset using Restriction Code as a Fixed Factor, and Mean Rainfall as a Covariate. Rainfall was not significant and was removed for future analyses. For each level of water restrictions, the influence on household water use was significant. The most significant reduction in water use occurred after the imposition of Levels 4 and 5 water restrictions. When including the water restrictions in an analysis with the structural variables, the most significant predictors of water use were the presence of a swimming pool, then the water restrictions. Lot Area was the least significant independent predictor.

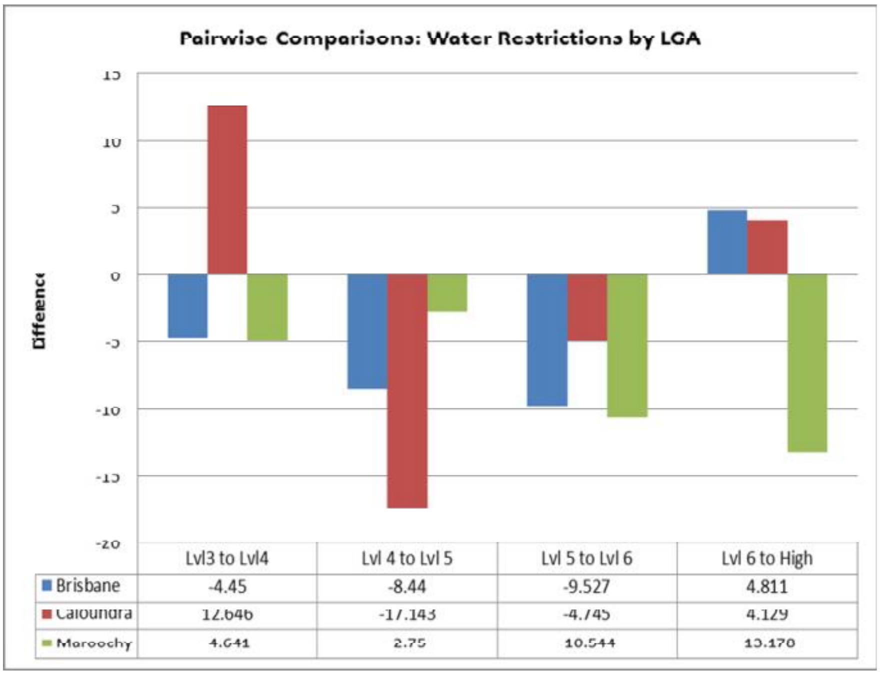

Figure 3 Mean Water Use per LGA at Restriction Periods (interpolated from LMM)

Socio-demographic Variables

This analysis was conducted using proportionate variables calculated at CCD level from the Basic Community Pack (BCP). First, a multiple regression analysis was performed to establish variables significant for water consumption at the CCD level. When VIF was over 4, variables initially entered into the regression analysis were removed, to ensure against collinearity. For the final model, the variables explained 42.8% of the variance in water use, similar to other studies of water consumption (Birrell et al., 2005; Clarke et al., 1997; De Oliver, 1999; Domene & Sauri, 2006; Hoffmann et al., 2006; P. H. Troy, D. & Randolph, B, 2005; Wentz & Gober, 2007). At the CCD level, the variables found to predict the greatest change in water use between 2006 and 2008 were Household Income Over $3,000; Average Household Size; Mean Land Value; Employed in Professional and Scientific Occupations; Mean Sale Price and Mean Land Area. These variables explained 32.4% of the variance in change in household water consumption 2006 – 2008 ($R2 = .324$, $F(6, 159.072) = 47.898$, $p < .05$).

Questionnaire Survey

The Questionnaire survey was sent to a random sample of 1680 residents in detached houses in Brisbane and the Sunshine Coast. The initial response rate was low, around 17%, but another round of reminder letters was sent, resulting in an eventual 351 useable responses; a response rate of 20.8%. Although this is relatively low, 47.72% of respondents provided useful qualitative responses.

The majority of respondents lived in two person households, and owned their own homes. The returned sample was strongly biased to older residents, with over 90% of respondents over 35, and 29.4% over 65. Of these, 50% owned their homes outright; and 42% of households had only two members. Per capita water use was highest for two and then one-person households.

A Spearman correlation analysis was conducted between the demographic variables and the annual log transformed water use. Household size contributed the most to the variance; it was significantly correlated with water use for every year *($p<0.1$)*. Income was also positively correlated (*$p<0.01$*) with water use, and was significant for every year; as were children (of all ages). Age was negatively correlated with water use (*$p<0.01$*). Employment was also negatively correlated with water use, with those in full time employment and self-employed more likely to use more water. Neither Education level nor Gender was significant.

Unsurprisingly, the larger the lot, the larger the house; and the larger the lot, the greater the mean water use. Mean annual water use was significantly correlated with Lot Area for 2006 and 2007 (*$p<.01$*) and for 2008 and 2009 (*$p<.05$*). On the split dataset, Lot Area was highly significant for Caloundra (*$n=37$*) in every year, but it was only significant for Brisbane ($n=160$) in 2006, and not for any year in Maroochy (*$n=61$*). For Brisbane, house size was correlated with water use in 2006 and 2007, but not for 2008 or 2009. 2006 and 2007 were the years in which more stringent levels of water restrictions were imposed (only imposed in Brisbane). For Maroochy, all years, with the exception of 2008, were correlated with water use. For Caloundra, house size was not correlated with water use.

There were no significant correlations between house age and mean water use for Brisbane and Maroochy. However, house age was significantly correlated with water use for every year in Caloundra. In general, houses built from 1991-2000 had the highest range and highest mean water use; and those built after 2001 had similar water use to those built from 1970-1990. Tenure was significantly correlated with water use for every year in Brisbane and Caloundra, but not at any time for Maroochy. Unlike house and lot area, the strength of the correlation *increased* over the period 2006-2008, and began decreasing again in 2009.

Table 4. Spearman Rho Correlations between water use and Questionnaire variables

LGA		LnAv06	LnAv07	LnAv08	LnAv09
Brisbane	Size house	**.246****	**.225****	.124	.139
	Age house	-.007	.008	.032	.037
	Tenure	**.254****	**.306****	**.400****	**.384****
Caloundra	Size house	.270	.264	.231	.315
	Age house	**.448****	**.435****	**.381***	**.325***
	Tenure	**.416***	**.414***	**.462****	**.369***
Maroochy	Size house	**.345****	**.340****	.219	**.263***
	Age house	.198	.192	**.270***	.189
	Tenure	.160	.115	.154	.099

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Outdoor Water Use

As with the previous analysis, the most significant variable for household water use was the presence of a swimming pool (Fig. 4). Most never watered lawns, particularly in Brisbane, where 73.3% of respondents (n=240) never watered their lawns. However, these results differed according to area; 90% of Brisbane residents never watered their lawns, in comparison to 53% of Sunshine Coast residents. The frequency and type of outdoor water use was highly significant for outdoor water use. Residents washing cars, watering lawns and filling pools with town water used significantly more water (p<.0.01).

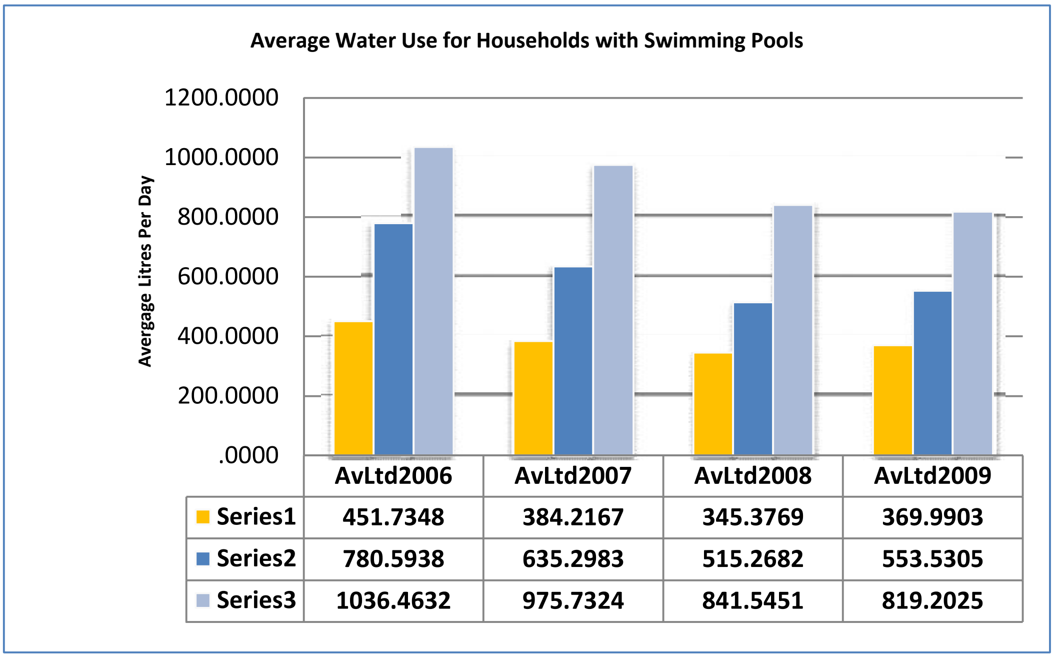

Figure 4. Water Use for Households with Pools

Responses to government policy were generally positive, but some responses displayed a strong geographical bias, with opposition to the now defunct Traveston Dam proposal more apparent on the Sunshine Coast (Fig 6). There was little opposition to recycled water or desalination plants, although many respondents only approved of recycled water for non-potable use. The strongest approval ratings were for the water tank rebate (88%) and Home WaterWise (82%). Over 60% of respondents had installed water tanks, and most of these had installed these in 2007, at the height of the drought. Several had more than one tank, and one person had five. A noted difference was that Brisbane householders used tank water for car washing and watering gardens, but even if they had tanks, most Sunshine Coast residents still used reticulated supplies. The majority of respondents approved of restricting water use. However, many respondents had no idea of the current level of water restrictions; 43.3% "*didn't know*" the level of water restrictions at the time of the survey.

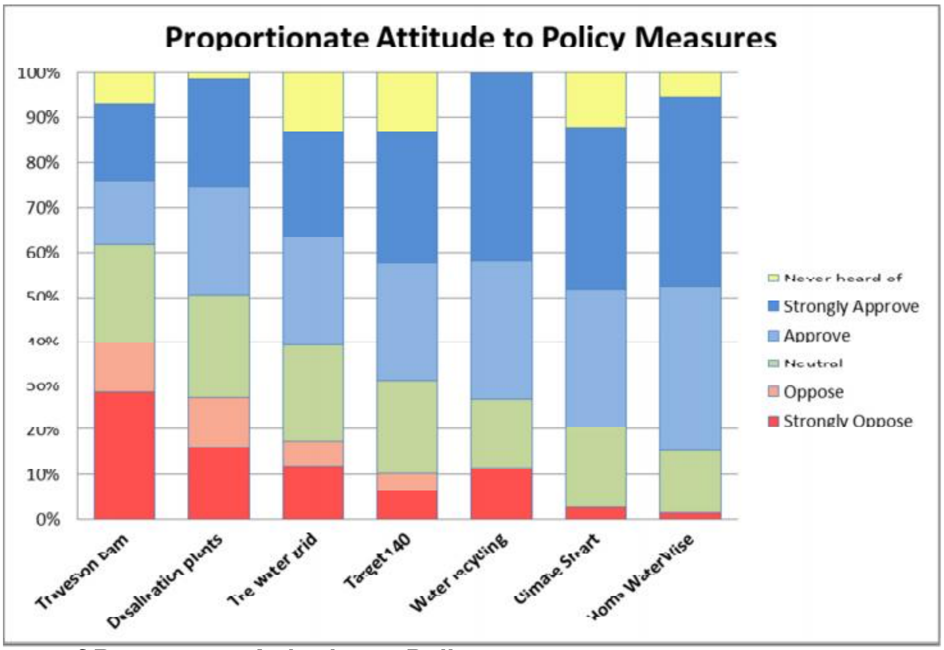

Figure 5. Summary of Responses, Attitudes to Policy

Attitudes to Water Conservation

Structural Equation Modelling (SEM) was used to analyse the relationship between water use and psychological and socio-demographic variables (Corral-Verdugo et al., 2008). Because of missing data, the SEM was run using Maximum Likelihood analysis, with the estimation of means and intercepts. A correlation analysis and a Factor Analysis, with principal axis factoring and Varimax rotation were performed. The PFA excluded the socio-demographic and structural variables, because the initial correlation analysis indicated these had high individual explanatory power over the dependent variable (particularly swimming pools and household size). After investigation of the scree plot, and variable loadings, extraction was limited to 6 factors. These combined variables were used to create a basic path diagram in Amos v17. Average Litres per Day for 2008 (the year in which the survey was conducted) was the dependent variable. For the final analysis, the model with the lowest Chi Square ($\chi 2$) was chosen.

Table 5. Regression Weights Structural Equation Model - All

Variable		Variable	Estimate.	S.E	C.R	P
Water Cons_Behaviour	<---	Policy	.05	.04	1.54	.125
Water Cons_Behaviour	<---	TPBComb	.41	.13	3.16	.002
Attitude_a	<---	TPBComb	1.29	.15	8.37	***
Climate Smart	<---	Policy	1.00			
Home WWise	<---	Policy	.85	.10	9.03	***
HH uses less	<---	Water Cons_Behaviour	1.00			
Water Tank	<---	Policy	.29	.05	5.83	***
Water Grid	<---	Policy	.32	.09	3.48	***
Attitude-Green	<---	Garden	1.00			
SN-Green	<---	Garden	1.19	.20	5.99	***
Sad Garden Died	<---	Garden	2.12	.44	4.78	***
BehaviourIntent	<---	Water Cons_Behaviour	1.56	.34	4.53	***
BehaviourDuring	<---	Water Cons_Behaviour	.80	.21	3.86	***
Changed Behaviour	<---	Water Cons_Behaviour	1.26	.24	5.26	***
Future Concern	<---	TPBComb	1.67	.20	8.25	***
SocialNorm	<---	TPBComb	1.00			
AvLtd2008	<---	HH Size	102.67	11.40	9.00	***
AvLtd2008	<---	Pool	239.68	38.78	6.18	***
AvLtd2008	<---	Garden	81.28	35.52	2.29	.022
AvLtd2008	<---	Water Cons_Behaviour	-165.81	49.08	-3.38	***

The final model explained 45% of the variance in water use (Fig 6). Most variance was explained by the structural variables: household size and swimming pool. Despite previous analysis that found lot area was significant; removing this variable considerably improved the final model fit. The two combined variables, Attitude Composite and Social Norm Composite, and the variable Future (concern about not enough water for the future) explained 35% of Water Conservation Behaviour (the latent endogenous variable).

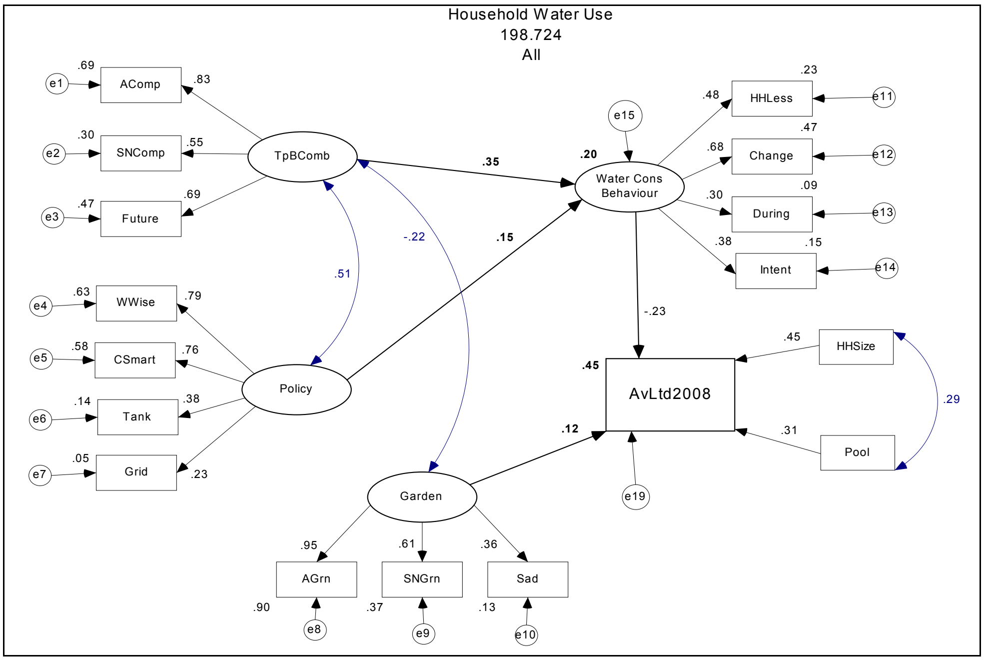

Figure 6 SEM, Average Water Use 2008 All Areas

However, this model only satisfactorily explained “Medium” water users; so another model was created to explain “High” and “Low” water users. This new model explained 51% of the variance in high water use, but not Low water use. For high water users, neither behavioural nor attitudinal variables were significant, and the most significant predictors were the structural variables, land value, swimming pools and tenure (fully owned or mortgaged). Outdoor water use and support for infrastructure based policies were also significant.

Attitudes to Water Policy

The most noticeable theme in the final, open-ended question was a general mistrust of the Government, especially the State Government. A common perception was of failure to plan for the future, and wasting taxpayer’s money on “*knee-jerk and reactive schemes*”. The State was perceived to be largely incompetent; but this criticism was mostly aimed in generic terms at “*the Government*”. Respondents generally confused levels of Government, and responsibility for water policy, and levelled criticism at the State for cancelling the popular water tank rebates.

Major themes were: a desire for self-sufficiency and personal control over water allocations. Instead of building large infrastructure, many felt local solutions, such as water tanks for every house (paid for by the Government) was more cost effective, and better for the environment. “*Instead of spending billions on dams, give every house a tank*”. Permanent water restrictions, per capita limits on water use, and the need to conserve water, were all acceptable

DISCUSSION

Household water use exhibited significant spatial variation. The most significant drivers for higher water use were the structural characteristics; swimming pools, lot size and land value. This largely accords with research showing that structural property factors are the most significant predictors of increased levels of household water use (Campbell et al., 2004; Cavanagh et al., 2002; Lyman, 1992; Olmstead et al., 2003; Renwick and Archibald, 1998; Renwick and Green, 2000; Syme et al., 2004).

However, household water use was also influenced by socio-demographic factors, particularly household size. However, per capita, smaller households used more water. Socio-economic variables (income and employment) were also significant for higher levels of water use. These results largely support other research showing that household water use is influenced by socio-demographic factors, such as household size, income and education (Aitken et al., 1991; Clark & Finley, 2007a; P. H. Troy, D. & Randolph, B, 2005).

Household water use also exhibited significant temporal variation. Prior to 2005, Brisbane water use was of similar levels to the Sunshine Coast, but by 2006, it had already reduced nearly 50%. All areas had significant reductions in water use during the period, largely corresponding with the imposition of water restrictions, particularly Levels 4 and 5 (April and November 2007); and rises in water use occurred when restrictions were eased. However, the water use of the Sunshine Coast (which had no restrictions), also declined sharply; over a longer period, but at similar times to Brisbane. This suggests that demand-side measures additional to the water restrictions contributed to changes in water use behaviour; such as the Target 140 awareness-raising campaign, and the media branding the issue as a “crisis” (Clark & Finley, 2007a; Syme et al., 2000).

In the temporal analysis, the most significant drivers for reductions in water use were the water restrictions, and socio-demographic factors (high income and high education households). Larger, high income households initially had greater water use, but these households reduced their water use to a proportionately greater extent than smaller, lower income households. Finally, households on larger lots reduced their water use to a greater extent than those on smaller lots.

However, no psychological factors were significant for high or low water use; although these did contribute to positive attitudes towards water conservation and the demand-side policies. Notably, the influence of structural and socio-demographic factors decreased over the period, with the least influence in 2008. Household water use also showed less variance; by 2008, there was relatively little variance in household water use across Brisbane, and to a lesser extent, in the Sunshine Coast.

In general, the demand-side policy measures were strongly supported, particularly the water tank rebates and the Home WaterWise program. Many felt that some degree of water restrictions should remain permanently in place; and that the drought and the restrictions had permanently changed behaviour. There was strong support for personal control; householders generally supported limits on water use, but wanted personal control over the water allocation. Finally, many distrusted the State Government; accusing it of being reactive and poorly prepared for droughts because of not building past infrastructure.

CONCLUSION

The results of this study provided further information on the determinants of water use, which may benefit policy makers in SEQ, and other similar areas. It was also possible to identify socio-demographic communities that were most likely to make meaningful behavioural changes (Mankoff et al., 2007). Higher income households, with pools, and higher levels of education, tended to use more water; but also reduced water use to a greater extent. Therefore, demand-side policy could be specifically targeted at such households. Further, providing financial assistance or subsidised water saving technology to households less able to change, such as smaller, lower income households, may achieve lasting benefits. Further, the lower water use of newer houses also supports further strengthening of building codes, and more efficient appliance standards.

The consistently higher water use by the Sunshine Coast also supports the hypothesis that the demand-side measures, in particular, the water restrictions, were the strongest factor in reducing household water use. However, although a community might willingly accept stringent restrictions during a “crisis”, once the drought breaks, and the media is not publicising water shortages to the same extent, will these behavioural changes be maintained? Continuing high level water restrictions when “normal” rainfall resumes and dams refill can lead to community backlash (Chong, 2009). Given the strong influence of lot size, income and swimming pools, these are all areas which could be targeted relatively simply. Therefore, for maintaining long term reductions in household water use, an integrated strategy of longer-term land use changes, together with demand-side policy, could provide a major component in planning for a sustainable urban environment.

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