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Determinants of household water conservation: The role of demographic, infrastructure, behavior, and psychosocial variables

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[1] Securing water supplies in urban areas is a major challenge for policy makers, both now and into the future. This study aimed to identify the key determinants of household water use, with a view to identifying those factors that could be targeted in water demand management campaigns. Objective water use data and surveys were collected from 1008 households in four local government areas of southeast Queensland, Australia. Results showed that demographic, psychosocial, behavioral, and infrastructure variables all have a role to play in determining household water use. Consistent with past research, household occupancy was the most important predictor of water use. Households in regions recently exposed to drought conditions and higher-level restrictions also used less water than those who had less experience with drought. The effect of water efficient technology was mixed: some water efficient appliances were associated with less water use, while others were associated with more water use. Results also demonstrated the importance of considering water use as a collective behavior that is influenced by household dynamics. Households who reported a stronger culture of water conservation used less water. These findings, along with evidence that good water-saving habits are linked to water conservation, highlight the value of policies that support long-term cultural shifts in the way people think about and use water.

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1. Introduction

[2] Water is fundamental to human life and for maintaining the planet's ecosystems, yet there is growing evidence that human activities are placing unsustainable demands on fresh water resources. Groundwater supplies are overextracted in many regions in the world [*Postel*, 1999], many major river systems do not have adequate water flows [*Postel*, 1996], and a large proportion of the world is currently experiencing water stress [*Vörösmarty et al.*, 2000]. Water resources will be placed under further pressure in coming decades by population growth and economic development [*United Nations*, 2009; *Vörösmarty et al.*, 2000] and climate change is likely to further exacerbate existing stressors on water supplies [*Intergovernmental Panel on Climate Change*, 2008]. Future water security therefore poses a serious challenge for policy makers, who need to meet increasing human demand for water while at the same time protecting fragile ecosystems. Although meeting this challenge will require sourcing alternative water supplies and increasing the productivity of existing water supplies [*Postel*, 2000], managing demand is also considered an essential element of future water security [*Arbués et al.*, 2003; *Brooks*, 2006; *Jeffrey and Gearey*, 2006]. Indeed, the Intergovernmental Panel on Climate Change has heralded demand management as a "no-regrets option" to cope with future vulnerability of water supplies in the face of climate change impacts [*Intergovernmental Panel on Climate Change*, 2008].

[3] Recent drought conditions across Australia provide evidence of the critical importance of demand-side approaches to water management. As examples, prolonged drought in Brisbane and Melbourne, two major metropolitan centers in Australia, resulted in policy makers introducing a range of demand management instruments including regulation (restrictions on residential and commercial water usage), incentives for installing water efficient appliances, information campaigns and per person water use targets [*Queensland Water Commission*, 2010; State Government Victoria, Using and saving water, http://www.water.vic.gov.au/saving/home]. The combination of these approaches and the salience of drought conditions resulted in significant decreases in household water use and significant shifts in the way residents use and think about water [*Fielding et al.*, 2011]. These anecdotal examples emphasize the importance of identifying the determinants of residential water conservation so that policy makers can gain an in-depth understanding of the ways in which they can positively influence urban water demand. To this end, there is a growing body of research that has investigated a range of factors associated with household water

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consumption. These factors include household and/or sociodemographic characteristics (e.g., number of adults and children, dwelling type, household income) [*Aitken et al.*, 1991, 1994; *Australian Research Centre for Water in Society*, 2002; *De Oliver*, 1999; *Gregory and Di Leo*, 2003; *Independent Pricing and Regulatory Tribunal* (*IPART*), 2004, 2007, 2008, 2010, 2011; *Kenney et al.*, 2008; *Syme et al.*, 2004; *Willis et al.*, 2011], water use behaviors [*Aitken et al.*, 1991, 1994; *Gregory and Di Leo*, 2003; *IPART*, 2004, 2007, 2008, 2010, 2011; *Richter and Stamminger*, 2012; *Water Corporation*, 2010], attitudes and values [*Aitken et al.*, 1994; *Australian Research Centre for Water in Society*, 2002; *Gregory and Di Leo*, 2003; *Syme et al.*, 2004; *Willis et al.*, 2011], water restrictions [*De Oliver*, 1999; *Kenney et al.*, 2004; *Renwick and Archibald*, 1998], water pricing [*IPART*, 2004; *Kenney et al.*, 2008; *Renwick and Archibald*, 1998], and installation of water efficient appliances [*Australian Research Centre for Water in Society*, 2002; *Kenney et al.*, 2008; *Willis et al.*, 2011].

[4] The current study goes beyond past research by assessing a broad range of determinants of household water conservation including sociodemographics, psychosocial variables, water conservation behaviors, and water efficient appliances. The study therefore represents the most comprehensive investigation of determinants of household water conservation to date and allows an assessment of the relative contribution of key predictors of household water consumption identified in past research. In their review of social models of household water use *Jorgensen et al.* [2009] call for research that incorporates a greater range of variables including water use habits, individual household water use data and variables reflecting exposure to restrictions and water shortages among others. The current research incorporates these variables and therefore goes some way to addressing the limitations identified by *Jorgensen et al.* [2009].

[5] To date, *Zhang and Brown* [2005] have conducted the most comprehensive assessment of determinants of residential water use in Beijing and Tianjin in China. They investigated differences in water use across these two cities and examined the extent to which dwelling type, sociodemographic factors, water using behaviors, and general environmental attitudes predicted average monthly water use. However, their study involved multioccupancy dwellings that were not individually metered and therefore water use was based on averaged data. Moreover, their attitudinal measures were limited to questions about the importance of a range of environmental problems. The current study focuses on separate individually metered dwellings to provide accurate household water use data and links this to survey data that assesses the range of water conserving habits in the household, the range of water efficient appliances installed, and psychosocial variables grounded in well-established theoretical models. In doing so, it provides critical information to policy makers seeking to manage urban water demand and implement demand-side management strategies. In sections 1.1–1.4 we review relevant literature on the determinants of household water use and then present the current study.

1.1. Demographic Determinants

[6] Research shows clear findings for the relationship between some demographic variables and household water use. Not surprisingly households with more residents use more water [*Aitken et al.*, 1991, 1994; *Gregory and Di Leo*, 2003; *Jeffrey and Gearey*, 2006]. In terms of education and income, research has shown that households with higher-education levels often have stronger intentions to conserve water [*Gilg and Barr*, 2006; *Lam*, 2006] and higher-income households have also demonstrated stronger intentions to install water efficient appliances [*Lam*, 1999]. In terms of actual household water use, however, households with lower education engage in more water conservation behaviors and use less water than higher-education households [*De Oliver*, 1999; *Gregory and Di Leo*, 2003] and households with higher incomes use more water than lower-income households [*Gregory and Di Leo*, 2003; *Jeffrey and Gearey*, 2006; *Renwick and Green*, 2000]. The findings relating to age are less clear; while some research has shown that older householders consume less water [*Gregory and Di Leo*, 2003], it may be stage of life rather than age that determines water use. For example, being retired or having teenage children may increase water use. The former because people are at home more often than when they are working and the latter because teenagers are high water users [*Makki et al.*, 2012]. In summary, the demographic profile of a low water using household tends to be one with fewer people who have lower education and income.

1.2. Efficiency Infrastructure

[7] An important part of the repertoire of demand management strategies is the installation of water efficient appliances. A review of studies from the U.S.A., Australia and United Kingdom concluded that retrofit programs that install devices such as toilet dams, faucet aerators, and low-flow shower heads resulted in water use reductions of between 9 and 12%. More comprehensive programs that replace existing appliances with highly water efficient appliances can result in savings of between 35 and 50% [*Inman and Jeffrey*, 2006]. As an example, a study of 30 homes in Tampa, Florida retrofitted water efficient toilets, clothes washers, showerheads and faucets and showed a decrease in per capita water use of 49.7% with the main savings coming from toilets, washers, and leaks [*Mayer et al.*, 2004]. The largest residential demand management study conducted in Australia, which involved a visit from a certified plumber, replacement of inefficient fixtures, and checking and repairing leaks, resulted in a 12% reduction in water use [*Turner et al.*, 2004].

[8] Despite the potential for water efficient infrastructure to result in substantial savings in household water use, there is also evidence that behavioral offsetting can undermine the effectiveness of efficient appliances. Offsetting occurs when potential savings are undermined because of a corresponding increase in water use behaviors. For example, in a study comparing the effectiveness of education, feedback, and low-cost water saving devices (e.g., toilet dam, aerator on shower head, flow restrictors on faucets), Geller and colleagues found that water saving devices were the only approach that resulted in significant water savings. However, they also noted that the savings achieved were much lower than would be expected given the estimates of manufacturers and laboratory data [*Geller et al.*, 1983]. They speculated that residents may have altered their water

consumption behavior in the knowledge that they had installed water saving devices. *Campbell et al.* [2004] also concluded that behavioral offsetting may have occurred in response to policies relating to the provision of water efficient appliances in Phoenix, Arizona. They evaluated four approaches including: legislation to ensure that new or retrofitted appliances were water efficient, doorstop delivery of devices, inviting community members to pick up efficient devices, and a program that had individuals work with households to install efficient devices. Their results suggest that offsetting behavior occurred frequently, with findings of an increase in water consumption or at best very small reductions in water use in response to these programs. Further evidence that engineering approaches do not always have the desired effects comes from a recent study by *Stewart et al.* [2012], in which shower display monitors were installed that beeped loudly at the end of a predetermined shower time. Results showed that although water use from showering initially reduced by 27%, shower use returned to original levels over a four month period. Taken together, these data suggest that engineering approaches may help to reduce water demand, but this reduction is not guaranteed and for maximum effectiveness, consideration must be given to how humans interface with the technology.

1.3. Psychosocial and Behavioral Determinants

[9] The results relating to efficiency devices highlight that demand management approaches are as much about human behavior as they are about technology. In addition to efficiency approaches, the environmental psychology literature also highlights curtailment approaches to conservation: that is, ongoing, everyday behaviors that help to conserve resources [*Gardner and Stern*, 1996]. In the context of water conservation, this could be actions like taking shorter showers, turning off the tap when brushing teeth, and only doing full loads of washing. A handful of studies have investigated the relationship between psychosocial variables and household water consumption. Although *Aitken et al.* [1994] did not find a relationship between values or water conservation attitudes and household water consumption, *Syme et al.* [2004] found that households with more positive attitudes to water conservation used less water in the garden [see also *Australian Research Centre for Water in Society*, 2002]. In addition, research by *Gregory and di Leo* [2003] showed that households who reported more engagement with and awareness of water conservation used less water and similarly, *Willis et al.* [2011] found that households who were more environmentally concerned and who reported more water conservation awareness and practices used significantly less water than those who were less concerned and aware.

[10] Theoretically, attitudes play a central role in the theory of planned behavior [*Ajzen*, 1991], one of the most widely used and well-supported social psychological theories of behavioral decision making. According to the theory of planned behavior, intentions, which reflect a motivation or plan to engage in an action, are the most immediate predictor of behavior. In turn, intentions are predicted by attitudes (positive or negative evaluation of the behavior), subjective norms (perceptions of social support for the behavior from important others) and perceived behavioral control (perception of the extent to which the behavior is under volitional control). A meta-analysis of 185 studies utilizing theory of planned behavior demonstrated that theory of planned behavior variables explained on average 39% of variance in behavioral intentions and 27% of the variance in behavior [*Armitage and Conner*, 2001]. *Russell and Fielding*'s [2010] review of the psychological literature on water demand management shows support for theory of planned behavior variables as predictors of water conservation intentions [*Clark and Finley*, 2007; *Kantola et al.*, 1983; *Lam*, 1999, 2006], although *Nancarrow et al.* [2008] showed only limited support for the theory in the context of intentions to use recycled water. In general there is limited evidence of whether water conservation intentions are translated into action. As a number of past researchers have noted, self-reports of water conservation behavior are often not strongly linked to actual household water consumption [*Beal et al.*, 2011; *De Oliver*, 1999; *Hamilton*, 1985].

[11] One of the key barriers that may prevent an individual's intentions being translated into outcomes is that household water use is a collective behavior, involving the water-using actions of multiple household members. If one person is committed to conserving water, unless other members of the household are similarly committed, that individual's attitudes are unlikely to result in reduced household water use. Thus, the dynamics of the household could play an important part in residential water demand. Consistent with this perspective, studies framed by the theory of planned behavior demonstrate that water conservation intentions are stronger when individuals perceive social support from important others [*Clark and Finley*, 2007; *Kantola et al.*, 1983; *Lam*, 1999, 2006; *Trumbo and O'Keefe*, 2005]. Similarly, past research integrating social identity theory with the theory of planned behavior has shown that the identity and norms of behaviorally relevant groups are important determinants of environmental decisions [*Fielding et al.*, 2005, 2008; *Terry et al.*, 1999]. In the context of household water conservation the most behaviorally relevant group is family or fellow household members. Consistent with this, *Grønhøj* [2006] found that a process of normative influence emerged through the relationships and interactions among household members, which either promoted or undermined household water conservation. Hence, research and theory suggests the importance of household dynamics as an influence on household water consumption.

[12] Another barrier that could inhibit the translation of intentions into actions is the water-using habits of household members. Within the psychological literature there is recognition that behavior is not always rational and reasoned, but is sometimes guided by automatic habits or routines [*Steg and Vlek*, 2009; *Stern*, 2000], which can be defined as automatic behavioral tendencies that arise as a result of repetition and practice of actions in similar situations [*Ouellette and Wood*, 1998]. Many water using behaviors are actions that are performed frequently and therefore may become habitual. Just as people can develop positive water use habits (e.g., turning off taps when brushing teeth) they may also be prone to negative habits (e.g., taking long showers), which, when repeated over time, impact on the amount of water used in the household. In the literature, habits are usually operationalized as past behavior. For example, *Aitken et al.* [1994] showed that the number of self-reported loads of clothes washing per week

was a significant predictor of actual water use. *Gregory and De Leo* [2003] also found that habits relating to clothes washing and showering were related to actual household water use, with lower water users taking fewer showers, doing fewer loads of washing and only doing full loads of washing. Thus, to the extent that past behavior indicates the entrenched nature of water using practices, these data suggest that water using habits can significantly influence levels of household water use.

1.4. Current Study

[13] The aim of the current study was to identify the key determinants of household water use with a view to understanding those factors that could be targeted in water demand management campaigns. The present research measures sociodemographic variables, water efficient appliances, water conservation behaviors, and psychosocial variables as determinants of objective household water use. In terms of the sociodemographic variables, we also explore the role of region as a predictor of household water use. Given the differences that existed across southeast Queensland regions in drought experience and associated restrictions, region can be a proxy for examining the effects of these variables. As noted previously, the current study represents the most comprehensive examination of a range of household water use determinants. Moreover, the current study goes beyond past research that has investigated the role of psychosocial variables as determinants of household water conservation by incorporating a range of individual and group-level psychological variables that are theoretically grounded. The current research is therefore a more robust exploration of the role of psychological variables and their relationship with an objective measure of household water use. By including sociodemographic, infrastructure, behavioral, and psychological variables, the research also allows an examination of the relative importance of these variables for residential water demand.

[14] Consistent with past research we expect that households with more residents, higher income, and higher education will use more water. Past research has not been clear about the relationship between age and water conservation and therefore we do not have specific expectations for this variable. We also expect the region that households are in will be related to water use. Residents of Brisbane and Ipswich had more pronounced experiences of drought and associated regulation than the Gold Coast or Sunshine Coast. The former regions experienced the highest-level water restrictions (level 6) from 2007 through to 2009, whereas water restrictions were not imposed on the Sunshine Coast until December 2009 and the Gold Coast had periods of exceptions from high level restrictions (see Figure 1). Past research has shown that environmental conditions and regulations influence water conservation [*Kenney et al.*, 2004; *Trumbo et al.*, 1999] and hence we expect households in the Brisbane and Ipswich regions to use less water than those in the Gold Coast and Sunshine Coast. In terms of psychosocial variables, although the theory of planned behavior posits that attitudes, subjective norms, and perceived behavioral control will predict intentions and behavior, we argue that it may be psychosocial variables that capture water conservation identity and norms at the household level rather than the individual level that better predict household water conservation.

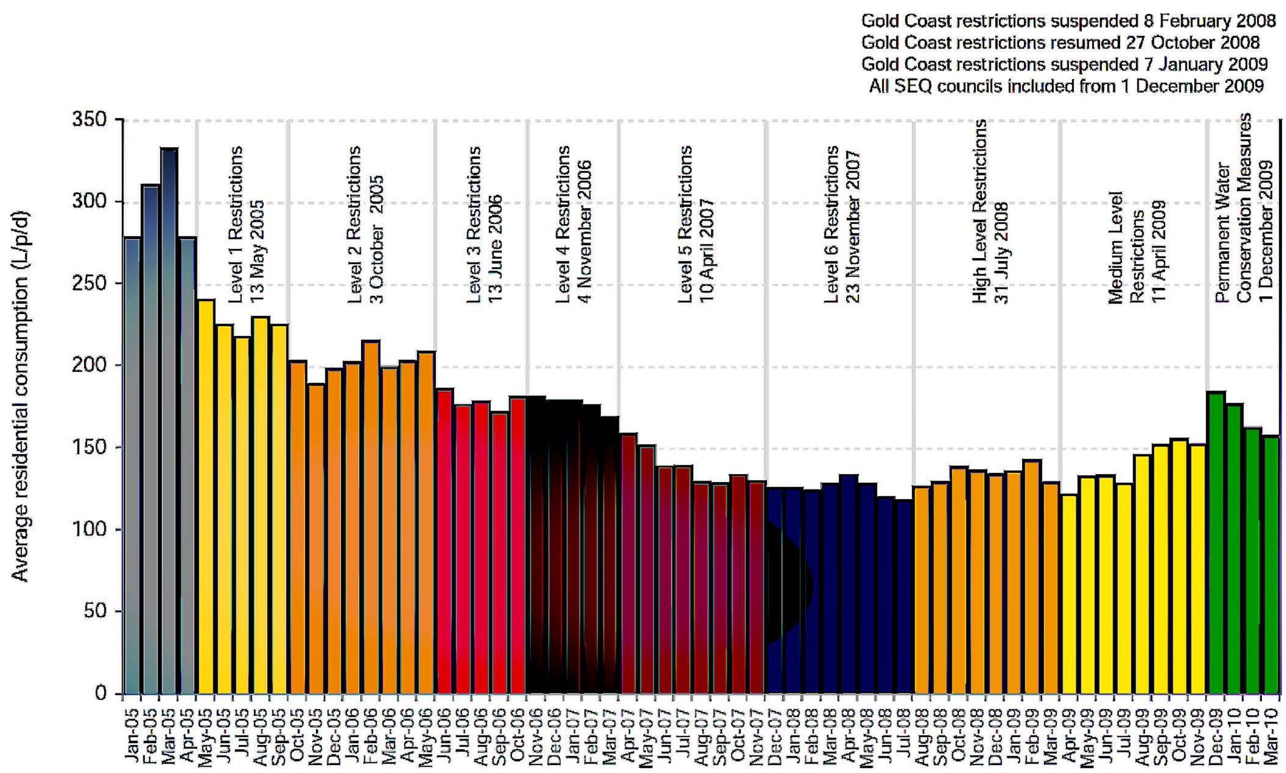

Figure 1. Average residential water consumption and water restrictions for southeast Queensland regions in 2005–2010 (source: *Queensland Water Commission* [2010]).

Hence, households with more of a culture of household water conservation should use less water. Moreover, to the extent that households have a water conservation identity and norms, they should be more likely to engage in a range of water conservation behaviors that will reduce their household water use. Finally, the installation of water efficient appliances should be related to lower household water use, although this effect may not be uniform across appliances. For example, the presence of some water efficient appliances (e.g., water efficient irrigation, pool covers) goes hand in hand with activities that are related to higher water use. That is, people with pools and gardens use more water than those without [e.g., *Syme et al.*, 2004].

2. Method

2.1. The Study Context

[15] The study involved a household water use survey of free-standing dwellings connected to mains water in four regions of southeast Queensland, Australia: Brisbane, Ipswich, Sunshine Coast, and Gold Coast. Survey data were linked to household water use data obtained from the appropriate utility. At the time of the research (September 2009 to March 2010) the region had emerged from the "Millenium Drought," the worst drought on record. During 2006–2007, the region recorded record low rainfall and the combined dam levels for the region fell to less than 20% of their combined capacity [*England*, 2009]. Residential water use accounts for 70% of the water used in the region and therefore a suite of strategies were implemented to promote residential water conservation to ensure the region did not run out of water. In addition to long-term structural changes (e.g., installing a water grid), short-term strategies that focused on promoting residential water conservation were also promoted. These included water restrictions, rebate programs for water efficient devices, and the Target 140 campaign that provided householders with the goal of using 140 L per person per day and accompanied the goal with information and feedback (for an overview, see *Walton and Hume* [2011]). These measures resulted in a 50% reduction of residential water consumption between 2004–2005 and 2008–2009 [*Queensland Water Commission*, 2010]. The drought broke in April 2008 and at the time of the survey the combined dam levels were above 60% (considered the point at which the drought was over), high-level water restrictions had been lifted and the per person water use target was increased. Despite relaxed restrictions and increased voluntary water use targets, residents in the southeast Queensland region continue to use water at lower levels than the voluntary target of 200 L per person per day [*Queensland Water Commission*, 2010].

[16] As noted in section 1.4, there were differences across the region in terms of the experience of drought and regulation. Figure 1 displays average residential water use across the region as well as the restriction regime from 2005 through to March 2010. Brisbane and Ipswich were most affected by drought and experienced increasing water restrictions from 2005 with the introduction of high-level restrictions from April 2007 through to April 2009. The Gold Coast was excluded from high-level restrictions for periods in 2008 and 2009. The Sunshine Coast was exempt from restrictions until December 2009 when permanent water conservation measure were introduced to all regions in southeast Queensland. Although there were differences in the application of water restrictions across regions, all areas had access to the government rebate and retrofit schemes.

2.2. Participants and Procedure

[17] The study was conducted within four local government areas (LGAs) in the southeast Queensland region: Brisbane, Gold Coast, Ipswich and the Sunshine Coast. The survey was conducted in September 2009 and household water use data was collected from all households across all regions for the period October 2009 to March 2010. This period represents spring and summer in Australia. To help overcome the inherent biases in any particular recruitment method, participants were recruited via two separate methods: either direct mail or through an online research panel. The criteria for inclusion in the study were that participants were homeowners (i.e., owned home outright or mortgage) of a free-standing dwelling, and were not intending to move residence in the next 12 months. The focus on this population enabled easier access to objective measures of household water use; renters cannot usually provide permission to access water use records and multidwelling residences are not usually individually metered. In addition to completing the survey, participants were asked to complete a consent form giving permission for the researchers to access their household water use data from the appropriate water utility. Only households who completed this form, and for whom water utility records were available, were included in the analysis for this study.

[18] Across both recruitment methods, the research was presented as a study of household water use in southeast Queensland. For the direct mail recruitment, names and addresses were purchased from commercial list suppliers. A three-stage mail-out process was used, consisting of (1) an initial postcard about the survey, (2) a survey pack, and (3) a reminder postcard. The purpose of the initial postcard was to notify people that they had been selected for participation in the study and to provide a brief rationale of the study's purpose prior to their receiving the survey itself. The survey pack consisted of an information sheet, a copy of the survey, a consent form, a reply-paid envelope and a small incentive to encourage participation: two teabags from an Australian-owned organic tea company (Koala Tea) and a pen from one of the institutions involved in the research. Participants were asked to sign the consent form and return it with their survey.

[19] A commercial online research company was subcontracted to administer an online version of the survey to members of their research panel. Panel members were individuals who had signed up to complete surveys on a wide array of research topics in return for a small financial incentive (AU$10) for each survey completed. An invitation was sent to 720 panel members who met the target criteria. These eligible participants were subsequently sent an online version of the survey. Reminder emails were sent to participants who either did not complete or only partially completed the survey to increase the response rate. All online survey participants were asked to provide postal contact details (name and address) so that a consent form could be mailed to them, along with a reply-paid envelope to allow for the return of the form. A reminder letter with a second

consent form was mailed to all participants who had not returned a completed form after three weeks.

[20] In total, 1179 surveys were returned via the direct mail recruitment method (27% response rate) while 570 households completed the online survey (79% response rate). However, water consumption data were not available for all households completing the survey, because a portion of surveys were completed by nontargeted households which had shared water meters (i.e., multidwelling complexes) or which were not connected to a central water supply. Additionally, not all participants returned a signed consent form to allow for the release of water consumption data by the water utility, and there were some households who were not able to be matched with the water utility records. The final sample of households for whom objective water use data was available was 1008: 868 households recruited via direct mail and 140 recruited via online panel.

[21] The demographic variables for the sample are shown in Table 1. As Table 1 shows, the average age was just over 54 years, however, age ranged from 18 to 95 years. There were more female than male respondents, and the average household size was 2.71, with a range of 1 to 10. The majority of households (61%) earned under $90,000 per annum and the respondents' education was relatively evenly spread across high school, trade or technical qualifications and tertiary education.

2.3. Measures

[22] The majority of questions asked in the survey used Likert Scale response formats. Consistent with *Gardner and Stern* [1996], a distinction was made between curtailment and efficiency approaches to water conservation. This distinction was described to respondents at the beginning of the questionnaire; for ease of understanding curtailment actions were called "everyday actions to save water" and efficiency actions were called "installing water efficient appliances." Unless otherwise indicated, responses to the questions were on seven-point scales. Theory of planned behavior variables were measured in accordance with recommendations [*Ajzen and Fishbein*, 1980]. All multiple item scales were computed by taking the mean of the scale items and in all cases higher values represented more of the construct. Table 2 shows that all scales had good reliability.

[23] Attitudes toward household water curtailment actions were measured with four semantic differential items. Respondents indicated whether engaging in everyday actions to save water around the house and garden was: extremely bad/extremely good, extremely harmful/extremely beneficial, extremely worthless/extremely valuable, and extremely unpleasant/extremely pleasant. Subjective norms were assessed with three items: (1) It is expected of me that I save water around the house and garden, (2) I feel like there is social pressure to save water around the house and garden, and (3) people who are important to me want me to save water around the house and garden (1 = strongly disagree, 7 = strongly agree). Perceived behavioral control was measured with three items: (1) I am confident that I could save water around the house and garden if I wanted to, (2) the decision to save water around the house and garden is beyond my control (reversed), and (3) whether I save water around the house and garden or not is entirely up to me (1 = strongly disagree, 7 = strongly agree). These items did not form a reliable scale and for this reason only one item (the first item listed above which was considered the clearest measure of the construct) was used in the analyses. Note that inclusion of the other items in the regression did not change the results. Intentions to engage in curtailment actions were assessed with three items: (1) I expect I will engage in everyday actions to save water around the house and garden in the next six months, (2) I intend to engage in everyday actions to save water around the house and garden in the next six months, and (3) I want to engage in everyday actions to save water around the house and garden in the next six months (1 = strongly disagree, 7 = strongly agree). The mean of the three items was used as the measure of water conservation intentions and had good reliability.

[24] Household water culture was assessed with six items similar to those used in previous research [*Fielding et al.*, 2011]. The items measure the level of approval of water conservation in the household (e.g., members of my household think that engaging in everyday actions to save water around the house and garden is a good thing), and whether it is normative for household members to engage in everyday water conservation (e.g., members of my household engage in everyday actions to save water around the house and garden). The items also asked about the level of consensus in the household about water conservation (e.g., there is agreement among the members of my household that engaging in everyday actions to save water around the house and garden is a good thing to do) and identity relating to water conservation (e.g., we think of ourselves as a water conserving household) (1 = strongly disagree, 7 = strongly agree).

[25] Water curtailment habits were measured by asking how often in the last six months the household had engaged in six curtailment actions (check and fix leaks, have shorter showers, use half flush or do not flush every time, only do full loads of washing, use minimal water in kitchen, turn

Table 1. Sample Demographics

Demographic	Value
Age	
Mean	54.58
Standard deviation	14.86
Range	18–95
Gender	
Males	43.2%
Females	56.6%
Male and female completed together	0.2%
Household size	
Mean	2.71
Standard deviation	1.31
Range	1–10
Household income	
Less than $30,000	17.5%
$30,000–$59,999	20.9%
$60,000–$89,999	22.5%
$90,000–$119,999	11.4%
$120,000–$149,999	6.6%
Greater than $150,000	5.7%
Did not respond	15.4%
Respondent's highest education	
Primary	3.7%
High School	34.4%
Trade/technical	26.3%
Tertiary/undergraduate	18.0%
Tertiary/postgraduate	17.6%

Table 2. Means, Standard Deviations, and Bivariate Correlations Among Continuous Variables[a]

Variable	Number for Each Question	Mean (SD)	Household Water Use	Number of People in House	Age of Respondent	Household Income	Intentions	Attitudes	Subjective Norms	Perceived Behavioral Control	Water Conservation Habits Index	Household Culture
Household water use	1008	429.59 (271.01)										
Number of people in house	996	2.75 (1.32)	0.51***									
Age of respondent	974	53.01(14.81)	−21***	−0.41***								
Household income	850	2.83[b] (1.42)	0.30***	0.34***	0.36***							
Intentions	1003	6.30 (0.74)	−0.04	0.02	0.05*	−0.03	**0.88**					
Attitudes	1002	6.25 (0.67)	−0.03	0.02	0.07**	−0.07**	0.65***	**0.75**				
Subjective norms	1000	5.70 (0.92)	0.01	0.01	0.11***	0.02	0.50***	0.39***	**0.63**			
Perceived behavioral control	1000	5.98 (1.05)	0.07	0.08***	−0.07**	0.03	0.47***	0.35***	0.30***			
Water conservation habits index	926	26.72[c] (3.15)	−20***	−0.07**	0.27***	−0.19***	0.52***	0.42***	0.36***	0.27***		
Household culture	881	5.82 (.90)	−16***	−0.11***	0.17***	−0.14***	0.59***	0.43***	0.44***	0.31***	0.54***	**0.96**

[a]Cronbach's alpha for computed scales are in bold on the diagonal. Asterisks indicate the following: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.
[b]Household income was based on a continuum where 1 = less than \$30,000, 2 = \$30,000–\$59,999, 3 = \$60,000–\$89,999, 4 = \$90,000–\$119,999, 5 = \$120,000–\$149,999, 6 = more than \$150,000.
[c]Water curtailment habits index could range from 6 to 30, with higher values representing more engagement in water conservation behaviors.

off taps when brushing teeth). Responses were measured on a five-point scale (1 = never, 5 = always) and a "not applicable" response option was provided. A water conservation habits index was created by adding participants' responses for each of the behaviors. The index could range from 6 to 30 with higher values representing greater reported engagement in water conservation habits.

[26] The installation of water efficient infrastructure was captured by asking respondents whether they had installed each of eleven water efficient appliances in their home: low-flow taps and/or shower heads on all fittings, pool cover, hose with trigger or a timed sprinkler (hereafter referred to as water efficient irrigation), water-wise plants and/or gardens, dual-flush or composting toilet, shower timer, gray water system, rainwater tank plumbed into the house, rainwater tank not plumbed into the house, water-wise washing machine, water efficient dishwasher. A "not applicable" option was also provided.

[27] Household water use was assessed by obtaining average daily water use for each household for the six months following the survey from the appropriate water utility.

[28] Demographic data included respondent age, level of education (dummy coded into primary/secondary, technical/trade with the reference category as tertiary education), household gross annual income (less than \$30,000 up to greater than \$150,000), and number of people in the household. The region in which respondents resided was also dummy coded into Brisbane, Ipswich, Gold Coast with the reference category as Sunshine Coast.

3. Results

3.1. Overview of Analyses

[29] Sequential regression analysis was used to test the hypotheses. The sociodemographic variables including region of residence were entered at the first step of the regression. The psychological variables (i.e., attitudes, subjective norms, control, household culture, intentions) were entered at the second step and water curtailment habits at the third step. At the final step, each of the eleven water efficient infrastructure measures was entered. We entered the water efficient appliances separately rather than creating an index as past research has suggested that efficient appliances are not always related to lower water use. The regression analysis allows an investigation of the individual effects of the efficient appliances while controlling for other variables such as whether the household has other efficient appliances installed. We expected that each block of variables, that is, demographics, psychosocial variables, water curtailment habits, and infrastructure would account for significant variance in household water use.

[30] Consistent with past research, household water use data was positively skewed and was therefore log transformed [*Campbell et al.*, 2004]. Seven outliers (i.e., >3 standard deviations above the mean) were identified on the log transformed household water use and they were excluded from subsequent analysis leaving 1001 households for final analysis. Note that including recruitment method as a dummy coded variable did not change the results and therefore it is not included in the analyses.

[31] Means, standard deviations and correlations among continuous variables are shown in Table 2. It is evident that

respondents had very positive sentiments toward everyday water conservation actions with intentions and attitudes displaying very high means, and subjective norms, perceived behavioral control and household culture also demonstrating means well above the midpoint of the scale. The mean for water conservation habits also shows that respondents tended to report high levels of water conservation behaviors in their household. Table 3 shows the number of households who had installed each of the water efficient appliances and the mean water use according to whether they had installed the appliance or not. Comparison of mean household water use for households who had installed or not installed the appliances revealed some statistically significant differences. The results revealed that relative to households who did not have the appliances, households with pool covers and rainwater tanks plumbed into the toilet and laundry used significantly less water whereas households with water efficient washing machine used significantly more water. Note that the comparison relating to pool covers only included those households who had a pool. Table 4 shows the number of households surveyed from each region and the mean household water use for each region. One way analysis of variance revealed a significant difference across regions, $F(3999) = 16.61$, $p < 0.001$ and posthoc tests showed that households in Ipswich and Brisbane used less water than those in the Sunshine Coast and Gold Coast.

3.2. Predicting Household Water Use

[32] As Table 5 shows, at the first step of the regression, sociodemographic variables including region accounted for significant variance in household water use. Consistent with expectations, households with more people and higher income used more water. It was also evident that households residing in Brisbane and Ipswich used less water than those in the Sunshine Coast and Gold Coast.

[33] The addition of the psychological variables significantly increased the amount of variance explained in household water use. Household culture emerged as the most important of the psychological predictors and, as expected, households who reported having a stronger culture of water conservation used less water. Unexpectedly, perceived behavioral control emerged as a positive predictor, that is, the more respondents felt confident that they could save water around the house and garden, the more water they used. This relationship is the opposite of what the theory of planned behavior would predict. It was also evident that, contrary to previous research using the theory of planned behavior, there was no link between intentions and behavior. The addition of water curtailment habits significantly increased the amount of variance explained in household water use and consistent with expectations, households that engaged in more water conservation habits used less water. The addition of this variable reduced the effect for household culture to nonsignificance, suggesting that the effect of household water conservation culture is mediated through water conservation habits. The Sobel test for mediation was significant ($z = -4.00$, $p < 0.001$), supporting this conclusion.

[34] Finally, the addition of the water infrastructure variables also increased the variance explained in water use. Households with a plumbed rainwater tank and those with a water efficient dishwasher used less water. The effect of low-flow taps and shower heads approached significance, and suggests that having these appliances is also associated with lower water use. It was also evident that households with a pool cover, water efficient irrigation, and a water efficient washing machine used more water. In total, the demographic, psychological, behavioral, and infrastructure variables accounted for 40% of the variance in household water use.

4. Discussion and Conclusions

[35] The current study aimed to test the importance of sociodemographic, psychosocial, behavioral, and water efficient infrastructure predictors of residential water conservation. Our results show that each set of variables explained significant variance in household water use, however, the demographic variables accounted for by far the largest amount of variance. Moreover, consistent with past findings [*Aitken et al.*, 1991, 1994; *Gregory and Di Leo*, 2003; *Jeffrey and Gearey*, 2006], the number of people in the household emerged as the strongest predictor of household water use. Indeed, the demographic variables and water conservation habits were the strongest predictors of household water conservation, a finding that is consistent with *Aitken et al.* [1994]. In summary, our results suggest that households who conserve more water were those in

Table 3. Mean Mains Water Use for Households With and Without Particular Water Efficient Appliances[a]

	Not Installed		Installed		
Water Efficient Infrastructure	Number	Mean Water Use (L d^{-1})	Number	Mean Water Use (L d^{-1})	t Value
Low-flow taps/shower heads	305	451.41	696	419.96	1.70
Pool cover	234	582.93	93	499.28	2.19*
Water efficient irrigation	225	429.95	679	445.24	−0.728
Water-wise plants	344	431.18	601	434.21	−0.164
Dual-flush toilet	148	429.40	855	429.62	−0.009
Shower timer	559	436.86	444	420.43	0.954
Gray water system	841	430.37	162	425.52	0.209
Plumbed rainwater tank[b]	873	439.39	130	363.76	2.98**
Nonplumbed rainwater tank	619	430.78	384	427.66	0.177
Water-wise washing machine	549	393.21	454	473.58	−4.72***
Water-wise dishwasher	369	425.06	634	432.23	−0.404

[a]Note that households that indicated that pool covers, irrigation, and plants were not applicable are not included. Asterisks indicate the following: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.
[b]Plumbed rainwater tanks are those that are plumbed into the toilet and laundry.

Table 4. Mean Water Use Shown Across Regions[a]

	Brisbane (N = 304)	Ipswich (N = 213)	Gold Coast (N = 231)	Sunshine Coast (N = 255)
Household water use (L d^{-1})				
Mean	400.74_a	341.12_a	490.64_b	482.58_b
Standard deviation	222.41	222.90	272.78	328.80

[a]Note that means with different subscripts are significantly different from each other.

Brisbane and Ipswich, with a smaller numbers of residents who were younger and on lower incomes. Water conserving households also had a culture of water conservation in their home and therefore engaged in more water saving habits. In terms of water efficient appliances, the findings varied according to the type of appliance. Rainwater tanks that were plumbed into the house, water efficient taps and showerheads and water efficient dishwashers were associated with lower water use and therefore greater water conservation. On the other hand, pool covers, water efficient irrigation, and water efficient washing machines were associated with higher water use and therefore less water conservation.

[36] Although our results largely accorded with past research and theory there were some unexpected findings. Some research has shown that households with higher education use more water; however, education level did not emerge as a significant predictor in the current study. The overlap between income and education may account for this finding. In addition, *Gregory and Di Leo* [2003] found that households with older residents consume less water whereas there was a positive relationship in our study between age and water use. It may be that it is life stage rather than age per se that determines water consumption [*Gregory and Di Leo*, 2003]. We did not have measures of life stage in our study; however, we can speculate that older age could be associated with two patterns that would account for higher water use: older householders may have teenage children who are higher water users [*Lyman*, 1992; *Mayer and DeOreo*, 1999; *Stewart et al.*, 2012] and older householders may be retired or working less, spending more time at home and therefore using more water in the home [*Mayer and DeOreo*, 1999].

[37] The finding that some water efficient appliances were related to higher water use is somewhat surprising although other studies have also suggested that installing water efficient appliances does not always have the expected effects [*Campbell et al.*, 2004; *Inman and Jeffrey*, 2006]. As past research has shown that households with pools and gardens use more water, it is perhaps not surprising that appliances related to these activities are also associated with higher water use [*Syme et al.*, 2004]. Similarly, people who are particularly concerned about clean clothes and linen may be more likely to invest in a water efficient washing machine.

Table 5. Sequential Regression Analysis Predicting Objective Household Water Use[a]

Predictor Variables	Step 1 Adjusted $R^2 = 0.33$, $F(8841) = 52.12$, $p < 0.001$	Step 2 R^2 Change = 0.02, $F(5836) = 3.79$, $p = 0.002$	Step 3 R^2 Change = 0.03, $F(1835) = 33.28$, $p < 0.001$	Step 4 R^2 Change = 0.05, $F(11{,}824) = 6.30$, $p < 0.001$
Region: Brisbane	−0.156***	−0.149***	−0.148***	−0.168***
Region: Gold Coast	−0.005	0.001	0.004	−0.008
Region: Ipswich	−0.224***	−0.219***	−0.223***	−0.237***
Number of people	0.471***	0.462***	0.473***	0.460***
Age	0.064	0.080*	0.118***	0.104**
Primary/secondary school	0.035	0.040	0.052	0.047
Trade/technical school	−0.008	−0.007	0.000	−0.011
Household income	0.187***	0.176***	0.166***	0.150***
Curtailment intentions		0.000	0.051	0.042
Attitudes		−0.029	−0.013	−0.001
Subjective norms		0.033	0.041	0.045
Perceived control		0.067*	0.073*	0.082**
Household culture		−0.125***	−0.063	−0.068
Water curtailment habits			−0.205***	−0.210***
Low-flow taps				−0.058[b]
Pool cover				0.055*
Water efficient irrigation				0.130***
Water-wise plants				0.023
Dual-flush toilet				−0.044
Shower timer				0.022
Gray water system				0.045
Plumbed rainwater tank				−0.138***
Nonplumbed rainwater tank				0.018
Water-wise washing machine				0.098***
Water-wise dishwasher				−0.064*

[a]Asterisks indicate the following: *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.
[b]Here $p = 0.059$.

Without the efficient appliances, these households may use even more water. Of course, it is also possible that these findings are evidence of rebound effects or offsetting behavior [*Midden et al.*, 2007] whereby people feel they can be less vigilant and even use more of a resource because they have efficient appliances. This explanation implies a causal relationship but we cannot establish causality with our correlational data. Longitudinal and experimental research is needed to disentangle these explanations. Taken together, these findings suggest that technology can only be part of the solution in addressing household water demand.

[38] One additional unexpected finding is that respondents who reported greater confidence in their ability to engage in everyday water conservation used more water in their households. This finding clearly reflects the attitude-action gap that is often found in the literature [*Kollmuss and Agyeman*, 2002] and, as noted above, highlights the importance of developing measures that assess the household context rather than individual's decision-making processes.

4.1. Implications

[39] The findings of the current study have implications for both policy makers and theory. Our results highlight the importance of both technological and behavioral approaches to demand management. Water efficient appliances can help to reduce water demand, although this may be more likely for appliances that are "invisible" such as plumbed rainwater tanks. There is a need for technological approaches to go hand in hand with water conservation behavior that can help to ameliorate the potential for offsetting behavior. One way of promoting water conservation behaviors may be through developing a culture of water conservation in the household. School-based education could help with this, as it facilitates two-way influence processes between parents and children. Publically committing to water conservation (e.g., stickers that assert "We are a water conserving household") could also help to develop a household identity around water conservation and foster conversations among household members that highlight the importance of water conservation. The extent to which demand management campaigns should focus their attention predominantly on indoor or outdoor water use (or both) will depend on the specific climatic context. The current study was conducted in a subtropical climate where rain is received in summer when it is most needed, reducing the requirement for outdoor irrigation. Recent end use analysis of southeast Queensland homes demonstrates that over 50% of household water is used in the bathroom [*Beal et al.* 2011] with very little water used for irrigation. Outdoor irrigation will form a greater proportion of water use in more temperate climates and programs in these climatic regions will therefore need to pay greater attention to influencing behavior and appliances that relate to outdoor use.

[40] Our findings also emphasize the role of the environmental context and regulation in fostering water conservation. Demand management policies have greater traction in regions that experience drought or water scarcity [*Nieswiadomy*, 1992]. Residents of southeast Queensland have continued to use water at lower than predrought levels and at lower levels than the target of 200 L per person per day, although there are differences across the regions depending on restriction experiences. These findings suggest that drought experience along with regulatory and voluntary policies can result in continued water conservation even when the environmental and regulatory context has changed.

[41] Theoretically, an important contribution of the current study was in testing the link between individual and collective-level psychosocial variables and objective measures of household water use. Household water use is a collective outcome and consistent with this we found that psychosocial variables that assess the household water context were more important in explaining household water conservation. This finding has important implications for theoretical models of environmental behavior: where behaviors have collective outcomes, as in the case of household water or energy use, theories that do not take into account the dynamics of the collective are unlikely to adequately capture the psychological antecedents of resource conservation.

4.2. Limitations

[42] One of the limitations of the current study is that our data are correlational and therefore we are unable to establish causal relationships between variables. For example, we cannot fully understand the interaction of householders with water efficient appliances unless we have longitudinal data that assesses water use before and after the installation of appliances. In a study investigating the effectiveness of shower alarms it was found that water use initially reduced in response to the shower alarm but over time, water use from showers returned to previous levels [*Stewart et al.*, 2012]. This type of research approach, coupled with household interviews, would provide the most detailed understanding of the interface of people with water efficient devices.

[43] Another limitation of the current study is that we only sampled from among owner-occupiers of free standing dwellings. Our reasons were practical—we could more easily access water records for these residents. In addition, residents of free standing houses still form the majority of households in Australia with 78% of households living in separate houses as at 2007–2008 [*Australian Bureau of Statistics*, 2010] and are therefore an important demographic. Nevertheless, *Randolph and Troy* [2008] argue that household water consumption is influenced by the types of homes people live in and whether they are owners or renters. Therefore it will be important to gain a better understanding of the water using profiles of other dwelling and tenure types if policy makers are to develop strategies that appeal to the broader community. It is also possible that households who took part in our study were more interested or concerned about water conservation than the general population, which would reduce the representativeness of the sample. However, there was a broad range of household water use in the sample (up to 2455 L per household per day) suggesting that the study did not sample only from committed water conservers. Furthermore, we think it unlikely that taking part in the questionnaire survey would have influenced subsequent water use as water use data were collected for the following six months from the water utilities and there were therefore no reminders that data collection was occurring. There is of course the possibility that people overstated their water conserving behaviors because water conservation is socially desirable. If this were the case though, it would likely reduce the match between water conservation habits and household water use

and therefore underestimate the strength of the relationship between these variables.

4.3. Conclusions

[44] In the current research we have shown that sociodemographic, psychosocial, behavioral, and infrastructure variables all have a role to play in determining household water use. Putting aside factors, such as household size and income, that are out of the control of policy makers, our findings suggest the importance of policy makers promoting a culture of water conservation that could persist even when the environmental context changes. This may be achieved through voluntary and mandatory approaches that encourage ongoing water conservation behaviors and the installation of efficient appliances. Ongoing low-level water restrictions, school-based education programs and widespread campaigns that emphasize the precious and finite nature of water are strategies that could help to achieve this end. Securing water supplies in urban areas is a major challenge for policy makers now and into the future. The current research provides valuable insights about the factors that are important to target in order to manage residential water demand. This information can inform future research testing interventions to promote household water conservation. Armed with the outcomes of this research, policy makers are in a better position to make judgments about the best ways to address future water scarcity.

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