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Factors affecting the variability of household water use in Melbourne, Australia

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ABSTRACT

This study investigates the variability of household water use in Melbourne with the aim of improving the current understanding of factors affecting residential water use. This understanding is critical to predicting household water demand, particularly at an appropriate spatial and temporal resolution to support Integrated Urban Water Management based planning and to improve the understanding on how different household water demands respond to demand management strategies. The study used two sets of data each collected from 837 households under significantly different water use conditions in the years 2003 and 2011. Data from each household consist of the household characteristics and quarterly metre readings. Ordinary Least Square regression analysis followed by detailed analysis of each factor was used to identify key factors affecting household water use. The variables studied are household size, typology of dwelling, appliance efficiency, presence of children under 12 years, presence of children aged between 12 and 18 years, tenancy, dwelling age, presence of swimming pool, evaporative cooler, and dishwasher. All of them except presence of children aged between 12 and 18 years, tenancy and dwelling age were identified as variables that contribute to the variability of household water use in Melbourne. The study also found that the explanatory capacity of these variables increases with decreasing water use. This paper also discusses the significance of the explanatory variables, their impact and how they vary over the seasons and years. The variables found in this study can be used to inform improved prediction and modelling of residential water demand. The paper also explores other possible drivers to explain residential water use in light of the moderate explanatory capacity of the variables selected for this study thus, provides useful insights into future research into water demand modelling.

1. Introduction

Water is a renewable resource; however, the availability of clean fresh water is gradually decreasing (Harris, 2012) while its demand is increasing due to urbanisation and population growth (Lee et al., 2012). Climate change is imposing additional pressure on the problem of water scarcity (Haddeland et al., 2014). Reducing water consumption through demand management and expanding conventional water supplies (i.e. surface water and groundwater) are the traditional strategies to deal with this problem. However, such strategies alone are no longer adequate to address the problem of water scarcity. This has increased the popularity of Integrated Urban Water Management as an approach to obtain sustainable solutions.

A key principle of Integrated Urban Water Management is the use of all available water sources in an efficient manner considering fit-for-purpose water use (Burn et al., 2012). This entails utilising all the water sources available at household and precinct scale (i.e. decentralised sources), as well as city scale (i.e. centralised sources) as efficiently as possible, consistent with the fit-for-purpose water use concept. In recent years, there has been an increased adoption of this principle to urban water management (Maheepala et al.,

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2010). One of the key challenges associated with the adoption of this principle, particularly at the planning stage, is the prediction of water demand at an appropriate spatial and temporal resolution.

Several studies have been conducted to understand residential water consumption (Beal and Stewart, 2011; Heinrich, 2007; Lee et al., 2012; Loh and Coghlan, 2003; Mayer and DeOreo, 1999; Roberts, 2005; Sivakumaran and Aramaki, 2010; Willis et al., 2009). These studies have shown that water use varies significantly across households. Capturing the variability of household water consumption for the prediction of water demand is essential to perform efficient and effective supply and demand balance assessment at any spatial scale, particularly at household and precinct scales. For example, Coultas et al. (2011), Maheepala et al. (2013) and Mitchell et al. (2008) have shown the importance of capturing the variability of household water use to quantify the yield from a cluster of rainwater tanks to inform supply and demand assessment at both precinct and city scales. Further, Maheepala et al. (2013) have shown that ignoring the variability of water demand across households alone, could introduce about 15% error to the expected yield from a cluster of domestic rainwater tanks. This shows the importance of understanding the variability of household water demand and its underlying factors especially at small scale when employing the Integrated Urban Water Management concept.

This paper presents an analysis undertaken to understand underlying factors of the variability of household water use in Melbourne. It considers a large number of variables in conjunction with their cross sectional variability, their validity over time and under different water use conditions. While there has been prior research in investigating factors affecting residential water use (Kenney et al., 2008; Kim et al., 2007; Maidment and Miaou, 1986), Willis et al. (2013) have shown the need for country and location specific research due to variations in cultural, behavioural and environmental conditions. The findings of this study can be used to improve the prediction and modelling of residential water demand, especially at multiple spatial scales as required for planning and management of urban water resources.

The following sections describe the methodology adopted to analyse household water consumption data followed by a discussion of the results in the context of findings in the literature. Finally, conclusions from the study are presented.

2. Methodology

2.1. Data

This study examined household water use data collected from Yarra Valley Water distribution area in Melbourne. Yarra Valley Water is the largest water retailer in Melbourne which provides service to over 1.6 million people in Melbourne's northern and eastern suburbs (Water-LiLi, 2012). The Melbourne region boundary and Yarra Valley Water's service area are illustrated in Fig. 1. Further, the average annual water usage per household of Yarra Valley Water area (i.e. 144 kL in 2011–12) is closely similar to that in other major water utilities (i.e. 139 kL for South East Water and 143 kL for City West Water) in Melbourne (National Water Commission, 2014) which indicates the representativeness of Yarra Valley Water data to Melbourne water residential customers.

The water consumption data used in this study are quarterly metre readings collected at household scale. Currently, water end-use data is a popular source of information due to its ability to provide detailed information on water consumption (Roberts et al., 2011; Beal and Stewart, 2011). However, this data is typically limited to small sample sizes (100–300 households in Melbourne) and collected for only two week periods (Athuraliya et al., 2012; Roberts, 2005; Roberts et al., 2011). Therefore, the quarterly water consumption data combined with large and detailed survey data used in this study are more representative and particularly useful to identify variables that are widely applicable for demand prediction.

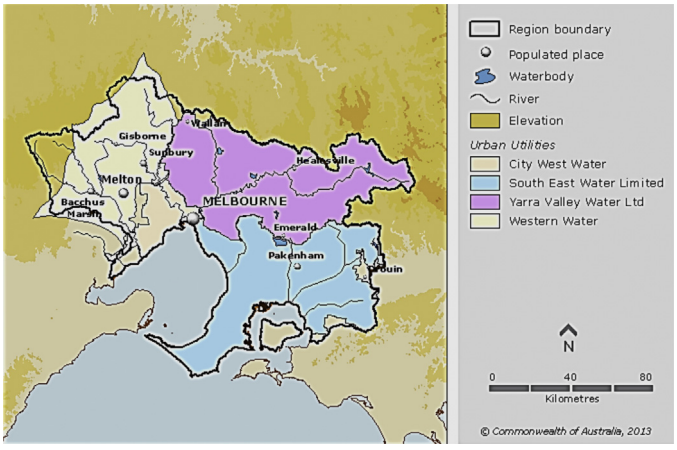

Fig. 1. The Melbourne region boundary and service areas of Melbourne's urban retail water authorities (Bureau of Meteorology, 2014a).

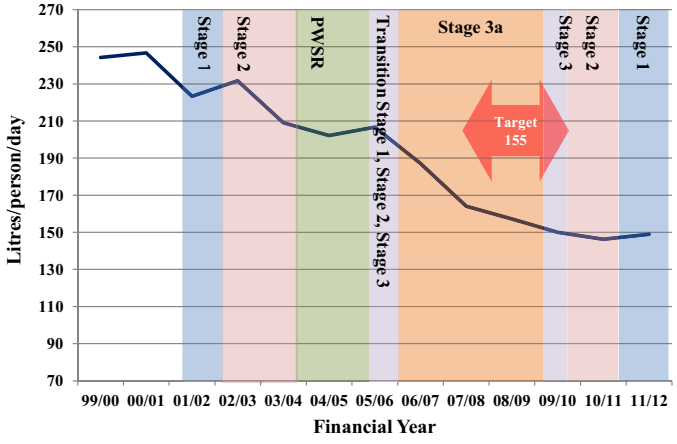

Fig. 2. Decline in residential daily per capita water use over the years and in different water demand management programmes (i.e. water restriction stages 1–3, Target 155 awareness programme) (Roberts, 2013).

This study is unique in that it is based on two different sets of household data each consisting of 837 households from two different periods: years 2003 and 2011. It should be noted that the city of Melbourne went through a series of water demand management programmes which include water restrictions and government rebates from November, 2002 to 2012 as a response to prolonged drought conditions and exhibited a considerable reduction in water use during this period (Melbourne Water, 2011; Roberts, 2013). Fig. 2 illustrates the reduction in water use during this period.

Roberts (2013) identified that the reduction in per capita residential water usage in Melbourne during the last 13 years from 2011/12 was 39% (Fig. 2). He also identifies change in user behaviour and appliances as the major drivers for this decline, especially in reducing indoor water use. As a result, it can be inferred that residential water use behaviour in Melbourne has changed significantly during the last decade and currently Melbournians exhibit more controlled water use behaviour. This behaviour can also change again if water restrictions are eased including the permanent water saving rules[1] that are currently in force. Therefore,

[1] Permanent water saving rules allow garden and lawn watering at any time, on any day using a hand held hose fitted with a trigger nozzle, but watering systems