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Procedure to derive parameters for stochastic modelling of outdoor water use in residential estates

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Abstract

The outdoor water use of residential properties is a major contributor to the seasonal fluctuation of the overall water use of these properties. The outdoor water use components were mathematically defined and combined to develop an outdoor water use model. The parameters that formed part of the mathematical outdoor water use model were formulated from data available for residential estates, where conditions such as types of vegetation, irrigated area and size of pool could be prescribed a home owners association or local authority. The data used to populate the model parameters was derived from aerial photography and contingent valuation methods.

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1. Introduction

Outdoor water use presents a combination of seasonal and behavioural aspects that are more difficult to predict than indoor end-use events [1]. These hurdles are likely to be addressed more often in future, as more detailed information and high resolution data becomes readily available.

Outdoor use, including irrigation and the evaporation from pools and other water features is the main contributor to seasonal fluctuation in water use. The seasonal fluctuation in water use is typically a function of the outdoor water use, where indoor water use is typically non-seasonal [2]. Roberts [3] recorded end-use data for two weeks in summer and two weeks in winter at 840 residential customers in the Yarra Valley, in Victoria, Australia. Roberts [3] reported that the seasonal end uses collectively made up 32% of the total use during the summer logging period. Seasonal end-uses were defined because the fluctuations in water use as a result of seasonal change in factors such as temperature, rainfall, snowfall and humidity. During the winter period, these seasonal end-uses could not be identified [3].

As part of the same study by Roberts [3] billing data was investigated. The results indicated that seasonal use could account for 25.4% of the total annual residential use, where garden irrigation was estimated to account for 87.3% of the total seasonal use [3]. In comparison Veck and Bill [4] reported in a contingent valuation study that outdoor use contributed 19% to the total use in the Alberton area in South Africa, of which 74% consisted of garden irrigation. The seasonal fluctuation in water use is typically a function of the outdoor water use, where indoor water use is typically non-seasonal [2].

This study quantifies the outdoor water use parameters that relates to properties located in residential estates, where vegetation areas, vegetation types and pool size often controlled by the estate regulations.

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2. Description of Parameters

For the purposes of conducting the analyses and comparison with the stochastic simulations, data had to be sourced from existing residential properties. The data was also generated by based on known parameter distributions. The data required in order to perform the analyses is summarised in Table 1.

Table 1 : Estate characteristics

Water use:	Behavioural aspects	Geometrical information	Climatological information:
Total water use data of existing properties recorded monthly	Irrigation methods	Property sizes of typical residential estates	Precipitation
Outdoor water use of the properties for comparison purposes	Irrigation efficiency	The area under irrigation	Evaporation
	Pool filter maintenance	The surface area of water features and pools	Evapotranspiratio n.
		Types of vegetation	

The data used in this study was collected from various sources using different methods which will be covered in the sub sections hereunder. Section 3 describes the proposed outdoor water use model; Section 4 describes a data collection methodology and Section 5 describes the typical parameter results that pertains a this study.

3. Proposed outdoor water use model

The model parameters are populated in a distribution format that enables the @Risk software to use the Monte Carlo method to sample various combinations of values for each parameter and then run multiple iterations of the mathematical model. The results of all the iterations could then be evaluated Monte Carlo simulation software to return the most likely solution for the mathematical model.

The proposed mathematical model and the parameters that were used in the development of this model are listed below and described in the subsections that follow [5].

$$Q_{outdoor} = A_i \frac{E_{to} \times K_{bc} - P_r \times F_{ep}}{I_e} + F_{po}\left(A_p \times (E_w - P_r) + D_d \times A_p \times O_m\right) \quad (1)$$

Where,

$Q_{outdoor}$ = Outdoor water use
A_i = The area of a property that is under irrigation.
E_{to} = Evapotranspiration
K_{bc} = Crop coefficient
P_r = Measured precipitation
F_{ep} = Effective precipitation factor
I_e = Irrigation efficiency
A_p = The surface area of a pool or water feature.
E_w = Evaporation rate of water in a specific location (Including pan factor)
P_r = Measured precipitation
D_d = The water level difference after performing a maintenance cycle
A_p = The surface area of a pool or water feature.
F_{po} = Pool ownership factor
O_m = The occurrence of pool maintenance per calendar month.

The various physical parameters were based on the analyses of geometrical measurements taken from Estate A's cadastral layout and aerial photographs taken of the estate in 2009 and supplemented by online lower resolution imagery photographs taken in 2012. Further analyses of these aerial photographs are being conducted to automate the process of disaggregating the surface area of the vegetation, pools, and buildings using remote sensing technology imbedded in GIS software [6].

The behavioural parameters such as irrigation efficiency, water level drawdown during backwash and monthly occurrence of backwash were determined from a contingent valuation survey and a questionnaire email. The climatic information was obtained from the SAPWAT and CLIMWAT data basis which contains more than 50 years of climatic data