ESTABLISHING A HOUSEHOLD WATER CONSUMPTION BENCHMARK FOR SOUTH AFRICA

Report

to the Water Research Commission

by

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on behalf of

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EXECUTIVE SUMMARY

Per capita water use is commonly employed as a baseline for the estimation of water demand, and is utilised in many countries. Per capita household water use benchmark studies based on South African data are limited and outdated. International studies do not cater for typical South African levels of service or dwelling types. The planning and management of water supply and distribution institutions would benefit from this study that collates and reports on per capita water use, consistent for South African conditions.

This study was commissioned to research the available household benchmark literature and data, and to establish a per-capita water use guideline. Various South African and international studies were reviewed to formulate a standardised approach that would satisfy local conditions and global trends. Studies reviewed included domestic water use, categories of water use and level of service (LOS), water loss and leakage, factors affecting water use, water end-uses and activities, minimum water use, household size, water price, household income and property value, geography and climate.

Five main parameters were identified for inclusion in the methodology of this research: level of service, usage scenario, the number of people per household, geographic region and property value. The available parameter data was further analysed to express its effect on water use in households. A model was then formulated to integrate the relationship that the parameters would have on overall water use in households.

A Microsoft (MS) Excel-based tool was subsequently developed to ease the implementation of the model for practitioners. The tool allows the user to change parameters and arrive at an estimated water use per capita for a specific use scenario, as a function of selected inputs. As more data is analysed and further research is conducted on the topic, further development of the tool would improve its accuracy. However, the current version of the tool compares well with the available data and other sources of research that depict water use in South Africa.

Experts from industry, government and academia were consulted in workshop format to source potential information and test whether the available information was relevant to the outcomes of the study. Workshops were held in Cape Town, Midrand and Durban, and the outcomes of the workshops were recorded in the form of meeting records. The model was adjusted and verified, based on inputs obtained from experts at the three workshops.

The tool is able to determine the low, intermediate and high water use for five LOS categories (standpipes, communal ablution blocks, yard connections, low-cost housing, house connections with indoor use only and full house connections), five climate regions (varying from arid to humid), a varying number of persons per household (one to seven) and three property value levels. Table 0.1 illustrates the typical variability of the outputs, showing a range of results obtained from the model for six different levels of service and four different household sizes. The results in Table 0.1 should be used as an indication of expected model results. However, the tool should be used to determine specific outputs for specific scenarios.

Table 0.1: Typical results for per-capita water use from the litre per capita per day (ℓ/c/d) model

		Estimated water use (ℓ/c/d)			
		Number of persons per household			
Level of service		**1**	**2**	**3**	**4**
LOS 1	Standpipes	22	22	22	22
LOS 2	Communal ablution blocks	54	42	37	34
LOS 3	Yard connections	85	62	52	46
LOS 4	Low-cost housing – limited fixtures	163	111	89	76
LOS 5	Full house connections (indoor)	275	198	163	143
LOS 6	Full house connections (including outdoor)	407	300	251	221

Based on the analyses and scenario testing of the model and tool, the following findings were derived:

- A multiparameter tool was developed that can be used to estimate household water use based on five key input parameters.
- The model is most sensitive to the number of persons per household, with a notable decline in per-capita consumption from a single-person household to three persons per household. The reduction in per-capita demand then flattens off from four to seven persons per household.
- Based on input obtained from the workshops, the climate regions in the model were linked to the regions defined in the modified Köppen-Geiger climate classifications (CSIR, 2015).
- Property value was used as a proxy for household income, in line with earlier studies (e.g., Van Zyl et al., 2008) and the effect of property value was included for LOS 3, LOS 4, LOS 5 and LOS 6.
- Considering the proposed input parameters, the tool produces a set of 270 different values (six levels of service for three usage scenarios, five regions and three property value categories) for each household size option. If one were to consider one to seven persons per household, the tool would produce 1,890 different answers of per-capita water use, depending on the selected inputs. The values presented in Table 0.1 show a small selection of only 24 results from the full result set.
- The model outputs compared well with other studies, such as the Department of Human Settlements (DHS) (2019), although the range of per-capita consumption is larger, as could be expected since additional parameters such as climate region and number of persons per household were incorporated in this study.

ABBREVIATIONS

AADD	Annual average daily demand
CABs	Communal ablution blocks
CSFWUES	California Single Family Water Use Efficiency Study
CSIR	Council for Scientific and Industrial Research
DHS	Department of Human Settlements
DWA	Department of Water Affairs
FBW	Free Basic Water
HDLI	High-density, low-income
HENH	High Efficiency New Home
JAWARA	Journal of the American Water Resources Association
ℓ/c/d	Litre per capita per day
LCD Tool	Litre per Capita per Day Tool
LOS	Level of Service
MS	Microsoft
NSFHS	National Survey of Functional Health Status
PPH	Persons per household
REUWS	Residential End Uses of Water Study
SNHG	Standard New Home Group
USEPA	United States Environmental Protection Agency
VB	Visual Basic
WHO	World Health Organisation
WRC	Water Research Commission

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Limited benchmarking information exists that relates to per-capita water use in South Africa. Other countries rely on per-capita water use as a baseline for water use estimation, but in South Africa, the available per-capita water use information is not readily available and is outdated. This information and data are not available, and related information has not been collated in a standardised format that pertains to South African conditions. This has an impact on planning and managing water supply in the face of extreme weather events and against growing water scarcity. Growing settlement pressure and the dichotomy faced by municipalities further adds to the complexity. Thus, there is a need to consolidate and verify the information and provide water use estimation and benchmarks based in South Africa.

Sustainable development solutions for water services provision can only be achieved if water use estimation is relevant to South African conditions (level of service, socio-economic conditions, demographics, regional climate, etc.). An international norm is often applied to a South African application, which could be inappropriate for a largely hot and dry country. Policy and decision making can be informed at local authority level by developing a South African benchmark of per-capita water usage.

It would be necessary to consider per-capita water use for different levels of service and from an availability-of-water point of view. Once the information has been compiled, an up-to-date central platform should be available from where estimators could access the per-capita water use.

1.2 OBJECTIVES

Benchmarking of per-capita water use in South Africa under South African conditions (climate, etc.) does not exist. An international norm is continuously used to determine what would be appropriate for a largely hot and dry country. The objective of this study is to determine a South African benchmark of per-capita usage. The intent of the study is to provide benchmarking criteria of per-capita water use in South Africa under South African conditions and an improved presentation of per-capita water use data.

1.3 OUTPUT

In support of the benchmarking exercise, a per-capita water use estimation tool was developed, called the Litres per Capita per Day Tool (LCD Tool). It is available online at www.wrc.org.za/software/lcdtool. The tool will assist municipalities, designers and regulators to estimate water use for existing and proposed settlements. The LCD Tool will ultimately be a way for designers, planners and researchers to compare conventional water use estimates with the tool's estimates.

1.4 METHODOLOGY

The study involved applying research techniques to address the research problem, employing well-known and accepted theories and principles, with immediate potential application. Several methods were used to address the research objectives.

Formerly published per-capita water consumption was collected by means of a comprehensive desktop review and targeted email requests from local experts. Where household water consumption is available in combination with the corresponding household size, the per-capita consumption will be calculated from the former values. The intention is not to collect new data, but rather to collate information that is already available.

The desktop review focused primarily on formerly published journal articles, conference papers and WRC research reports that were identified by the project team and key role players. Earlier studies were identified, collated and classified as being either micro scale, where consumption is reported for household use downstream of a consumer meter (e.g. Jacobs, 2007; Du Plessis and Jacobs, 2018), or macro scale, where consumption is reported on a city-wide scale, also including all water loss in the system and non-residential use. With macro-scale studies, the total consumption is typically divided by the total population (e.g. Du Plessis, 2007) to provide a crude estimate of per-capita water use. Guidelines for water use in South Africa have focused primarily on stand (plot) size as the independent variable (Jacobs et al., 2004).

As part of this study, a few selected key factors that influence per-capita consumption were incorporated into the LCD Tool. The following key input parameters were incorporated:

- **Level of service:** Six different levels of service were considered: standpipes, yard connections, communal ablution blocks, low-cost housing with limited in-house connections (e.g. government-subsidised housing; formerly RDP housing), full house connections: indoor only (including flats and townhouses) and full house connections: including outdoor use (full title home on plot with garden). The level of service will be used as a proxy for socio-economic factors such as income and property value.

- **Usage scenario:** Three usage levels were incorporated, to allow for the average unrestricted use, relatively comfortable unrestricted use and low-use scenarios that could be deemed a realistic target during water restrictions. It would make sense to encourage water infrastructure planners to provide for the comfortable unrestricted usage level to ensure adequate infrastructure capacity. On the other hand, water usage targets during restrictions would consider the low-use scenario, for example.

- **Number of people per household:** Various previous studies have confirmed a reduction in the per-capita consumption with increased household size, both locally and abroad. The tool proposed in this study allowed for this reduction by fitting a mathematical curve to all the available data, thus allowing for the said reduction to be incorporated in the result.

- **Geographic region:** The regional mapping is likely to be more subjective and boundary setting would rely on inputs from stakeholders and academic experts, and would be based on available socio-economic, political, geophysical and vegetation maps of South Africa. For this study, five water use regions were identified and mapped to describe water use in the different regions relative to the other regions.

- **Property value:** Property value was incorporated as a proxy for income level, which is often proportionate to willingness and ability to pay a specific price for water.

Considering the proposed input parameters, the tool produces a set of 270 different values (six levels of service for three usage scenarios, five regions and three property value categories) for each household size option. If one were to consider 10 options, for one to 10 persons per household, the tool would produce 2,700 different answers of per-capita water use, depending on the selected inputs.

CHAPTER 2: LITERATURE REVIEW

2.1 DOMESTIC WATER USE

Water is required for many everyday activities. It is required for consumption, such as for drinking and indirectly for cooking, and also for essential hygiene purposes, such as washing hands, preparing food, showering or bathing. In some cases, water required for hygiene may also be linked to religious activities. Water is also needed by those who aspire for more than just survival, in order to sustain a certain desired lifestyle. For example, outdoor residential environments have been found to be extremely important to homeowners (Blaine et al., 2012), also affecting residents' sense of social status and mental health. Gardening and outdoor water use have important positive effects on individuals, as well as on the urban ecosystem. A poorly maintained garden has also been found to lower the potential monetary value, not only of that property, but also neighbouring ones (Clayton, 2007). A lack of clean water often leads to a lack of hygiene, which can lead to diseases such as diarrhoea or other faecal-oral diseases, typhoid, and skin and eye diseases such as louse (Bradley, 1997). Esrey et al. (1985) determined many years ago that the quantity of water used in a neighbourhood has a greater effect on the frequency of diarrhoea events than the quality of the water.

Van Zyl et al. (2008) defined domestic water as water that is used for any household activity, both indoor and outdoor, including water for drinking, cooking, laundry, cleaning, flushing toilets, garden use, pool use, pet care, car cleaning, etc. Thompson et al. (2001) specifies four categories of domestic water use: hygiene (including personal and household cleaning), consumption (including drinking and food preparation), amenity use (including car washing, and garden and lawn irrigation) and productive use (including water for livestock, small-scale horticulture and other household productions). The latter category refers to developing countries or regions where people may cultivate backyard crops and keep livestock, or run bartering or trading businesses from home.

Several water requirements are essential for living, with regard to health and hygiene. These include water that is required for consumption, such as drinking and cooking water, as well as water needed for hygiene purposes, such as cleaning the body, clothes and the household. Conversely, other water use may not be vital to health and hygiene, but may be considered necessary for maintaining a relatively higher standard of living. These include irrigation and water for car washing or pools. The Department of Water Affairs (DWA) (2009) and later also the DHS (2019) provided guidelines for per-capita water consumption for different settlement categories in South Africa. Consumption values range from 25 to 400 ℓ/c/d for a residential household. The DHS (2019) presented a useful table with per-capita water use for different types of water supply, as per Table 2.1.

Table 2.1: Residential annual average daily demand (per-capita water consumption guidelines for South Africa) (DHS, 2019)

Land use		**Persons per unit**	**Typical annual average daily demand* (ℓ/c/d)**	**Annual average daily demand range* (ℓ/c/d)**
Standpipe		5	25	10-40
Yard connection	With dry sanitation	5	50	40-60
	With low-flow sanitation	5	60	50-70
	With full-flush sanitation	5	70	60-80
House connection	Low-income housing	5	90	60-120
	Residential	5	230	120-400
	Group/cluster housing	3-5	120	130-120
	Flats	1-4	150	250-110

* Per-capita calculated on persons per unit

2.2 CATEGORIES OF WATER USE AND LEVELS OF SERVICE

Table 2.1, as presented by the DHS (2019), outlines various levels of service from the South African perspective. These levels of service could be linked to different categories of use described by others. Two categories of water use were suggested by Willis et al. (2011) from an Australian perspective to describe the essential versus non-essential requirements. A third category could be considered to describe basic survival in line with the WHO (2003) and DHS (2019), which is equal to 20-25 ℓ/c/d. The three categories of use considered for the purpose of this study include the following:

- Basic survival (minimum for survival, typically provided from communal standpipes)
- Non-discretionary (essential for sustainable urban living, which could be viewed in this study as supply from yard taps provided on-site at each home)
- Discretionary (linked to improved standard of living), which could be further segregated to describe indoor use only, versus indoor and outdoor water use

These categories link to the level of service. In recent years, the line between non-discretionary and discretionary water use has become blurred as people tend to use non-discretionary end-uses as discretionary end-uses. For example, a shower, which is typically a non-discretionary end-use, with the purpose of cleaning the body for hygiene purposes, has become a discretionary end-use as people no longer use showers simply for sanitation, but rather as a leisurely activity. Thus, Willis et al. (2011) argue that there should be a set amount of water of approximately 40 to 70 ℓ/c/d that is a set requirement for basic human needs. The value presented by Willis et al. (2011) is in line with the recent publication of the DHS (2019) for yard tap supply, with a range of 40 to 80 ℓ/c/d. This level of use could be viewed as non-discretionary water use and any water use above this value should be considered discretionary water use, irrespective of what it is used for. The same approach is used in South Africa with supply of Free Basic Water (FBW), where consumers in low-cost houses would qualify as indigents based on their relatively low household income. The South African government initiated the FBW concept in 2001 (Smith, 2010). An indigent FBW allocation, normally set at 6 kℓ per month per household, is unique to South African disadvantaged communities. The quantity of FBW would be provided each month, regardless of what the FBW was used for.

In recent years, communal ablution blocks (CABs) have been introduced in areas where service providers improved the level of service for communities that were previously not serviced or were dependent on yard taps. Although the arrangement of CABs varies from different suppliers and projects, they often consist of containerised showers, wash basins, laundry facilities, urinals and toilets (Crous et al., 2013). Roma et al. (2010) reported that CABs have a water use of 35 to 40 ℓ/c/d.

2.3 WATER LOSS AND LEAKAGE

Water loss and leakage is common in residential homes. Leakages are neither non-discretionary nor discretionary as they are not influenced by behaviour. Leakage and water losses are normally excluded when reporting per-capita consumption. Water leakage and water losses were not defined as a water use category in this study, because water leakage or loss would be estimated separately and would then be added to the per-capita use.

2.4 FACTORS AFFECTING WATER USE

Water use is dependent on a variety of factors. As part of this study, a few selected key factors that influence per-capita consumption were incorporated into the estimation tool. The following four key input parameters were found to be notable: level of service, usage scenario (e.g. unrestricted versus water restrictions), household size or number of people per household, and the geographic region, which would mainly impact on outdoor use.

Per-household and per-capita consumption are affected by household size, (Beal et al., 2011; Gato et al., 2011; Lee et al., 2012), the age of the occupants (Kenny et al., 2008; Makki et al., 2011; Willis et al., 2009), household income (Beal et al., 2011; Kenny et al., 2008; Loh and Coghlan, 2003), the efficiency of water use appliances (Beal et al., 2011; Gato et al., 2011; Heinrich, 2009) and the presence of a pool and/or garden (Ferrara, 2008).

Per-capita water consumption can only be determined accurately if the number of occupants in the household is known. Once the household size (people per household) is known, the daily household consumption can be divided by the number of occupants to determine the per-capita consumption. Logically, not all members of the household will use exactly the same amount of water, as each member will have varying water use habits. However, this method provides a fairly accurate average per-capita consumption for a household and is commonly employed in research studies (Willis et al., 2013; Rathnayaka et al., 2015). A summary of earlier studies that reported on per-capita water consumption is provided in Appendix A.

2.5 WATER END-USES AND ACTIVITIES

The following international studies were used in the development of the LCD Tool: Roberts (2005), Blokker et al. (2010), Hussien et al. (2016) and Gleick (2003). Other less notable studies include Richter (2010), Richter (2011), Hand et al. (2005), Rosenberg (2007) and Vinogradova et al. (2012). Some notable South African studies include Jacobs and Haarhoff (2004), Van Zyl et al. (2008), Du Plessis (2007) and Jacobs (2007).

An Australian residential end-use study conducted by Roberts (2005) placed high-resolution water meters in 100 homes in the Yarra Valley. Water meter readings were recorded every five seconds for a two-week period – repeated in winter and summer. Water end-uses were disaggregated from the water meter readings using Trace Wizard software. Results from surveys conducted at the measured households were compared to the measured water use data. This technology allows for disaggregation accurate enough for the purpose of determining average water uses for different water end-uses.

Blokker et al. (2010) developed a stochastic end-use model to determine water demand patterns at residential level for a one-second time scale. Statistical parameters found for frequency, intensity and duration, as well as the penetration rate of different water end-uses, based on census data, were used in the development of the model. Measured data was compared to the simulated results of the model, which were found to be comparable. Hussien et al. (2016) conducted a survey of 407 households in Duhok City, Kurdistan, Iraq, to help determine the water use consumption patterns of developing countries. The survey consisted of 40 questions that covered household characteristics such as household size, number of adults and children, and garden area, as well as questions pertaining to water end-use behaviours. The results provided insight into household water use in low-, medium- and high-income households in Duhok. Furthermore, information about the characteristics of different end-uses was gathered. Per-capita water consumption of 241, 272 and 290 ℓ/c/d was determined for low-, medium- and high-income houses, respectively.

Gleick (2003) provided insight into the possible effects of implementing water-reduction measures in a Californian household. The conservation technologies that were investigated included low-flow toilets, flow-reducing faucets and showerheads, efficient residential dishwashers and washing machines, and drip- and precision irrigation sprinklers. The conservation policies investigated included water pricing schemes, subsidy, rebate and financial incentive programmes, the implementation of new state and national efficiency standards for appliances, education and public awareness programmes and water-metering programmes. The results showed that a 30% reduction in water use could be achieved from California’s water use in 2000.

Van Zyl et al. (2008) found that the guidelines published by the Council for Scientific and Industrial Research (CSIR) (2005) prior to their revision in 2019 (DHS, 2019) only accounted for 53% of suburbs. The study database of Van Zyl et al. (2008) comprised ~1.1 million consumption records from 48 municipalities, located in five water regions in South Africa. The proposed guidelines used only stand area to give different confidence intervals of annual average daily demand (AADD). The study found that households in coastal areas consume less water compared to their equally sized and valued counterparts inland, which is consistent with the per-capita water needs suggested by the DWA (2009).

Du Plessis (2007) investigated the per-capita consumption of 57 communities in nine different municipalities in the Western Cape. Du Plessis (2007) used bulk water usage, after treatment, divided by the population size of the communities to provide the daily per-capita consumption. The bulk usage gives an indication of the overall water required for everyday living, including domestic use, non-domestic use and water leakage. The study found 10 communities with unexplainably high or low water consumption. Removing these communities, the average water consumption was 201 ℓ/c/d, with about 15% being non-revenue water.

Jacobs (2007) conducted a study that investigated the water usage of high-density, low-income (HDLI) households in the Western Cape. Since most HDLI properties do not contain garden areas, the water demand from these households is considered to represent indoor water demand. The study, which was conducted with 113 respondents, found a range of 66 to 156 ℓ/c/d, depending on household size (five to two persons per household, respectively).

2.6 MINIMUM WATER USE

The World Health Organisation (WHO) (2003) conducted a study to determine the minimum amount of water needed to meet basic health-related needs. The study determined the water requirement for food preparation, hydration and basic hygiene. The study found that people who had to collect water from a communal facility used, on average, 20 ℓ/c/d, while those who had a single tap at their dwelling used, on average, 50 ℓ/c/d. However, for the case where multiple taps are available in a household, a value of greater than 100 ℓ/c/d was determined.

Gleick (1996) set out to determine an absolute minimum water requirement that should be provided to all human beings in order to meet their basic human needs (Gleick, 1996). A minimum value of 50 ℓ/c/d was recommended, with 5 ℓ/c/d for drinking water, 20 ℓ/c/d for sanitation, 15 ℓ/c/d for bathing and 10 ℓ/c/d for cooking and kitchen use. Gleick (1996) noted that different levels of water use are expected for different levels of service, as well as different climatic conditions, with higher water consumption expected for dry regions and fully connected houses with gardens.

The amount of water needed for human health, as well as the social and economic development of a country, was researched by Chenoweth (2007). The water requirements considered both domestic and commercial water use. However, agricultural water was excluded. The minimum water requirement for development was determined, firstly, by investigating water use by developed countries, allowing for the interconnected nature of industries to be taken into consideration, and later verifying this by using a first-principles approach. The first-principles approach included investigating the hypothetical minimum water requirements for each economic sector. A minimum water requirement for social and economic development was determined to be 135 ℓ/c/d. Some 10 to 15 ℓ/c/d of this water is attributed to a ±10% water loss in the system, and the remaining 120 ℓ/c/d is for domestic and commercial use. Chenoweth (2007) noted that even though it may be theoretically feasible to meet domestic and commercial development needs with a water use of 135 ℓ/c/d, of all the currently developed countries, only the United Arab Emirates and Kuwait have water use less than 135 ℓ/c/d, while most “low water use” countries reported consumption values of between 270 and 430 ℓ/c/d.

The international space station could be considered to represent the lowest water consumption possible, given current technology. Consumption of a mere 1 ℓ/c/d for crew and 0.45 ℓ/d for payloads is maintained aboard the space station (Tobias et al., 2011). Such a low consumption value is possible through an almost closed-loop system of recycling and producing water. Water is recycled from urine and condensation from sweat and other sources of evaporated water by collecting and treating all moisture and returning the fluid to a potable state. In a separate closed system, water is used to produce oxygen and hydrogen. The remaining hydrogen is then combined with CO_2 to produce water and methane gas. A summary of the water inputs and outputs for a single crew member is given in Figure 2.1.

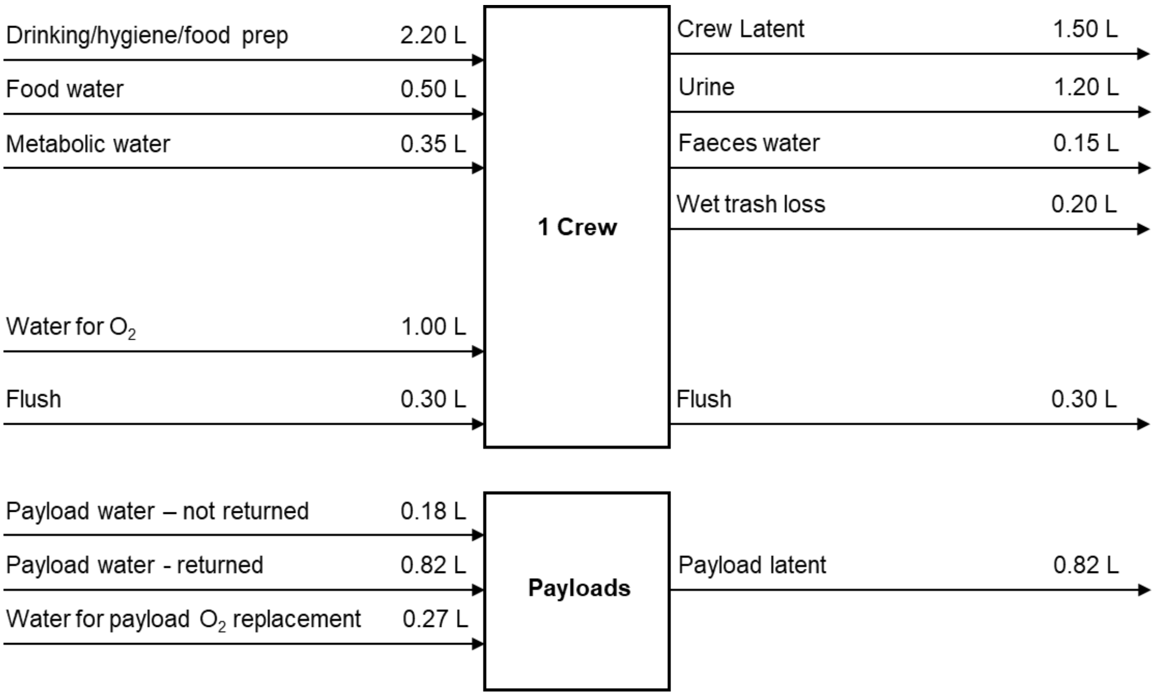

Figure 2.1: Water inputs and outputs of the international space station (Tobias et al., 2011)

2.7 HOUSEHOLD SIZE

Household size varies notably and contributes significantly to domestic water consumption, having been found to be the most significant factor affecting household water consumption (Rathnayaka et al., 2014). As household size increases, its water consumption increases due to the increased occupants in the household each requiring water. Conversely, the per-capita water consumption of a household decreases as the household size increases. The decrease in per-capita consumption is due to many household water uses, such as washing machines, dishwashers, cooking and irrigation, being shared among the occupants of the household. Domestic water consumption is also affected by the age and occupation of the members of a household. The age of the occupants has an effect on water consumption as the activities of individuals change with age and the associated lifestyle (Browne et al., 2014). When showers are used, children and teenagers have been found to shower for longer than adults, thus increasing household water consumption (Mayer and DeOreo, 1999). In Germany, household water consumption has also been found to increase with age, often because the elderly, who are retired, spend more time in the house, which implies an increased likelihood to use water (Schleich and Hillenbrand, 2009).

Attempts have been made to study and model the effect of an increase in household size on per-capita consumption. Schleich and Hillenbrand (2009) determined, in a study in Germany, that with a 50% increase in the average number of household occupants, per-capita consumption will decrease by 22%.

Cavanagh et al. (2002) found comparable results, while Höglund (1999) found, in a Swedish study, that the per-capita consumption decreases as much as 27-35% with a 50% increase in household size. Jacobs (2004) determined an equation (Equation 1.1) to model the decrease in per-capita water demand with an increase in household size, based on studies by Edwards and Martin (1995) and Morgan (1973). A number of international empirical studies have been conducted that have measured water consumption for households of varying sizes (Arbués et al., 2010; Lee et al., 2012; Sadr et al., 2016; Koketso and Emmanuel, 2017; Smith, 2010). DeOreo and Mayer (2012) compiled a review of five different end-use studies conducted in North America, specifically, the Residential End Uses of Water Study (REUWS) (Mayer and DeOreo, 1999), the United States Environmental Protection Agency (USEPA) combined retrofit report (Aquacraft, 2005), the California Single Family Water Use Efficiency Study (CSFWUES) (DeOreo, 2011), the National Survey of Functional Health Status (NSFHS), which was split into the Standard New Home Group (SNHG) and the High Efficiency New Home (HENH) Group (DeOreo, 2011). A graphical representation of the decrease in per-capita water demand with an increase in household size for each study is shown in Figure 2.2.

$$\boldsymbol{Per\ Caita\ Water\ Demand} = -\mathbf{60} \times \boldsymbol{ln}(\boldsymbol{d}) + \mathbf{210} \qquad \text{Equation 1.1}$$

where d = household size

Typical household size for Western countries generally ranges between two and three persons per household (PPH) (House-Peters et al., 2010; Rathnayaka et al., 2017), while the household size in urban areas in less-developed countries ranges between two and five PPH (Jacobs and Haarhoff, 2004). Townships or communal living areas in less-developed countries, such as South Africa, have household sizes ranging between five and 10 PPH (Emenike et al., 2017; Jacobs and Haarhoff, 2004; Mazvimavi and Mmopelwa, 2006). Caution should be taken with studies conducted in countries that have a mix of townships and urban areas, as data on the household size might be skewed by studies that include both development types.

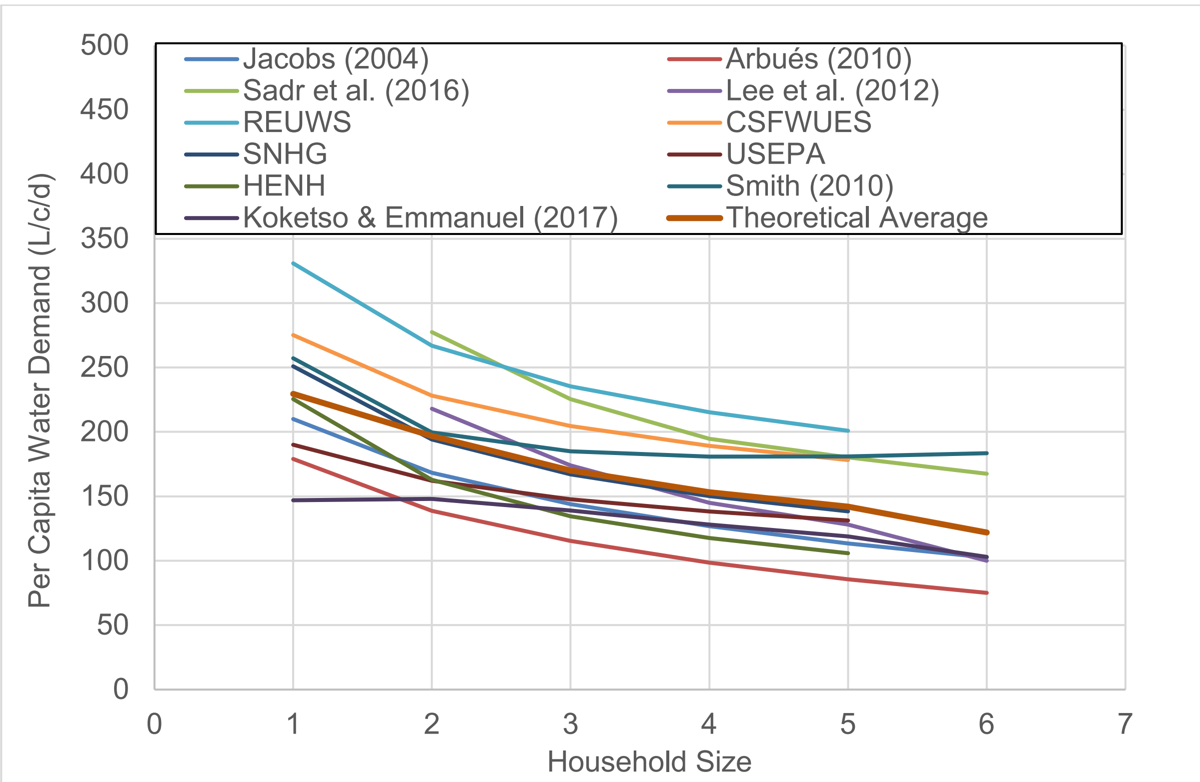

Figure 2.2: Summary of studies showing the effect of persons per household on per capita water demand

2.8 WATER PRICE, HOUSEHOLD INCOME AND PROPERTY VALUE

Price of water influences the volume consumed and is arguably one of the first demand-related variables to be investigated. Hanke and Davis (1971) first recognised price of water as a demand management measure, although the first price elasticity value for water demand was published much earlier by Metcalf (1926). Howe and Linaweaver (1967) presented the first detailed account of price elasticity for water demand that could be traced in the literature. Price elasticity of water is relatively inelastic (the absolute value is smaller than 1), implying that an increase in price would decrease water demand and at the same time lead to increased revenue. The law of demand states that price and demand are inversely related, all other factors held constant. However, at a low price, there is a limit to the amount of water anyone would use, even if it were free. On the other hand, there is a certain minimum quantity of water that anyone would require, even if it were very expensive. Unfortunately, water price is an inconvenient parameter for inclusion in estimation models.

In South Africa, the matter is further complicated by FBW allocations, non-payment, water account arrears, short-term price fluctuations brought about by seasonal water restrictions and relatively complicated block tariff structures. Agthe and Billings (1980) presented a detailed comparison of three different price variables and concluded that the use of average price alone produces less accurate results than a marginal price (highest block rate) and a “difference value” combined. Howe (1982) concluded that the exact interpretation of the “difference value” and the rationale for the magnitude of its estimated coefficient remain something of a mystery. Subsequent researchers included household income and property value instead of price. Water price was also not considered as a model input in this study.

The consumer “buying power” (financial ability to pay) in relation to the actual value paid for water influences the volume consumed by a particular consumer. Common sense suggests that household income could be linked to water use – with higher-income homes using more water than similar homes with lower-income occupants. However, accurate household income data is not readily available. Property value is often used as a proxy for household income, since property value is relatively easy to obtain.

Different levels of service, as described in this study, are indirectly linked to household income and property value. However, the service level alone does not adequately account for the impacts of household income on water use. Although some of the levels of service, such as yard taps or CABs, may be linked quite closely to household income, others are not. Studies show that there is a correlation between household income and water use (Ferrara, 2008; Van Zyl et al., 2008; Beal and Stewart, 2011). The increase in water use with increased income may be due to landscaped gardens that require more water, more water-intensive appliances being present in the household and a smaller regard for the price of water.

2.9 GEOGRAPHY AND CLIMATE

The location of a household affects water consumption as the climate, terrain and nature of the activities performed in the area all affect the water use habits of the household’s occupants. Climate and temperature have been found to affect water use. Typology and the presence of an irrigated garden and a swimming pool have the greatest impact on water use in summer, while household size and appliance efficiency have the greatest impact on water use in winter (Rathnayaka et al., 2014). The effect of temperature and rainfall on water use is more significant in areas with warmer climates. The effect of warmer climates is most prominent in households with large gardens and swimming pools as their outdoor use, which is often weather dependent, is higher (Jorgensen et al., 2009). An increase in rainfall in a season has also been found to decrease water use as there is usually a reduction in outdoor water use (Rathnayaka et al., 2014). The reduction in water use due to the occurrence of rainfall is more psychological. It is not necessarily the quantity of rain that reduces outdoor water use (Martinez-Espiñeira, 2002). However, there is a threshold beyond which rainfall, as well as temperature, no longer have a significant effect on water use. There has, however, been minimal investigation into a rainfall and temperature threshold for different regions (Arbués et al., 2003).

Holiday homes are used periodically, either by the owner or by tourists who occupy the home temporarily. The water use for these houses varies according to the season with water use during peak season being found to be higher than water use in residential areas without holiday homes (Hadjikakou et al., 2013). Therefore, water use in areas with a high population of holiday homes is not a true indication of residential water use.

2.10 LEVEL OF SERVICE

Asefa et al. (2015) defines the level of service as “an informal contract between a utility and its customers for a certain degree of inconvenience”. In other words, the level of service with regard to water is the ease of access to water provided by water utilities. The WHO divides level of service into four categories: no access, basic access, intermediate access and optimal access. The levels of service are defined by the travel distance or time to the access point of clean water, or by the number of access points for higher levels of service (WHO, 2003). Furthermore, the level of service dictates the typical water demand for a household.

The DHS (2019) divides levels of service into access from a standpipe, yard connections and house connections for low-income housing, cluster homes, flats and residential houses. The expected consumption is based on the development level of the dwelling.

CHAPTER 3: ANALYSIS OF PER-CAPITA CONSUMPTION

3.1 OVERVIEW

The per-capita consumption tool developed as part of this project is described in this report as the Litre per Capita per Day Tool, or simply as the LCD Tool. In line with the initial project proposal, the LCD Tool considered the following independent variables: level of service, household size, climate region and water usage level. Six different levels of service were considered, varying from standpipes to fully serviced houses with outdoor use. Household size varied from one to seven people, taking five different climate regions into consideration. Three usage levels were considered in the development of the tool. The LCD Tool was developed in MS Excel, incorporating some Visual Basic (VB) functions, allowing the analyst to select input values for each parameter, with the LCD Tool presenting the subsequently derived per-capita water consumption value (ℓ/c/d).

The CSIR (2005) presented guideline values for estimating water use, which were referred to in the initial project proposal. However, the CSIR (2005) document was revised in the period 2017-2019 and the DHS published an updated guideline in July 2019 as the result of a project that was conducted at the same time as the development of the LCD Tool. The project team was aware of DHS's pending new publication, but only gained insight into the final publication in July 2019. The development of the LCD Tool was subsequently adapted to align with values published by DHS (2019).

The development of the LCD Tool is described in this chapter, with specific reference to the four key input parameters and how limits were set for each parameter. The tool development was also based on three project workshops and subsequent stakeholder input. The description presented below does not incorporate the workshop feedback, which is described separately in the three workshop summaries.

3.2 LEVEL OF SERVICE

In line with the proposal for this study, the DHS (2019) divided the levels of service into the following categories (refer to Table 2.1): standpipe, yard connection and house connection. The levels for yard connections and house connections were further subdivided. The levels of service presented by DHS (2019) were aligned with the following levels of service considered as inputs for the LCD Model:

- Standpipe (LOS 1)
- Communal ablution blocks (LOS 2)
- Yard connection (LOS 3)
- Low-cost or subsidised housing (LOS 4)
- Full house connection: indoor only (LOS 5)
- Full house connection: including outdoor use (LOS 6)

Each level of service was given a sequential number by which it could be identified in the VB code, ranging from LOS 1 for standpipes to LOS 6 for full service with outdoor use.

3.3 HOUSEHOLD SIZE

Per-capita water consumption decreases with increased household size. A baseline per-capita water consumption value was determined for the LCD Tool, based on the number of people in the household for each level of service. In order to determine the per-capita consumption for each level of service and each household size, all available measured South African data was compiled. Attention was given to include only values that relate directly to actual individual household consumption where the number of occupants was also known. Per-capita consumption values based on generalised information (e.g. census or population) were excluded. The results were compared to international publications and to generalised values. A summary of the measured data is given in Figure 3.1.

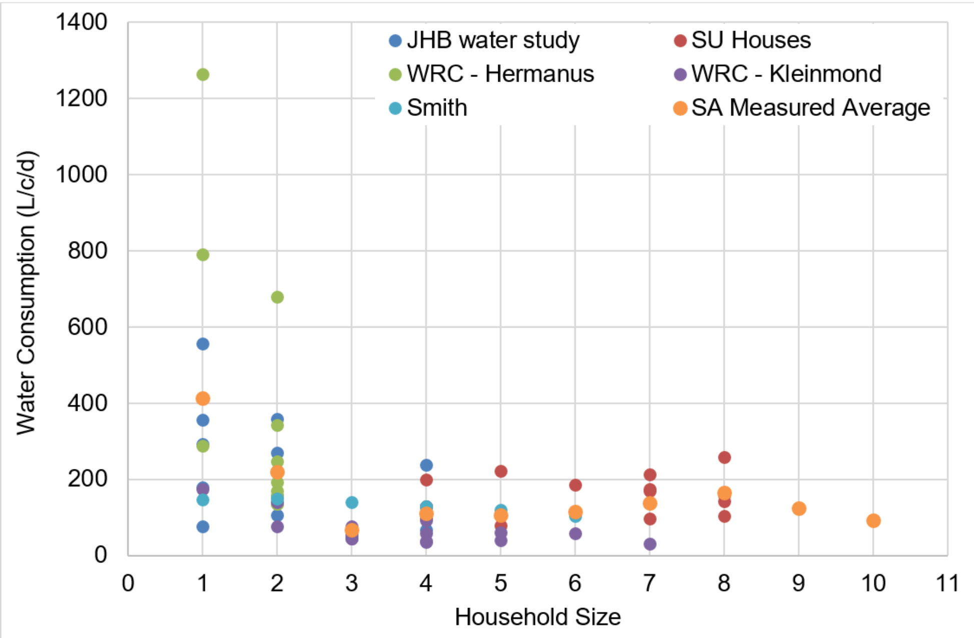

Figure 3.1: Measured South African per-capita consumption data for varying household sizes

The measured data was a compilation of five different data sets, including a study of residences in a gated housing estate in Johannesburg (Ilemobade et al., 2018), data from 17 University of Stellenbosch student homes, data from upmarket homes in Hermanus, Western Cape, and from 20 low-income houses in Kleinmond (Pretorius et al., 2019), as well as data from a few relatively low-income households in Eastwood, Pietermaritzburg (Smith, 2010). Once all the data had been compiled, various curve fits were considered. The data was filtered according to the level of service in each case. The Pretorius et al. (2019) and Smith (2010) data was found to represent a low level of service, while the Johannesburg, Hermanus and Stellenbosch data was found to represent a high level of service. Two trendlines were fitted to the high and low level of service data, independently. The trendlines were used as a basis to derive water consumption values as a function of household size for LOS 6 and LOS 4, respectively, as presented in Figure 3.2.

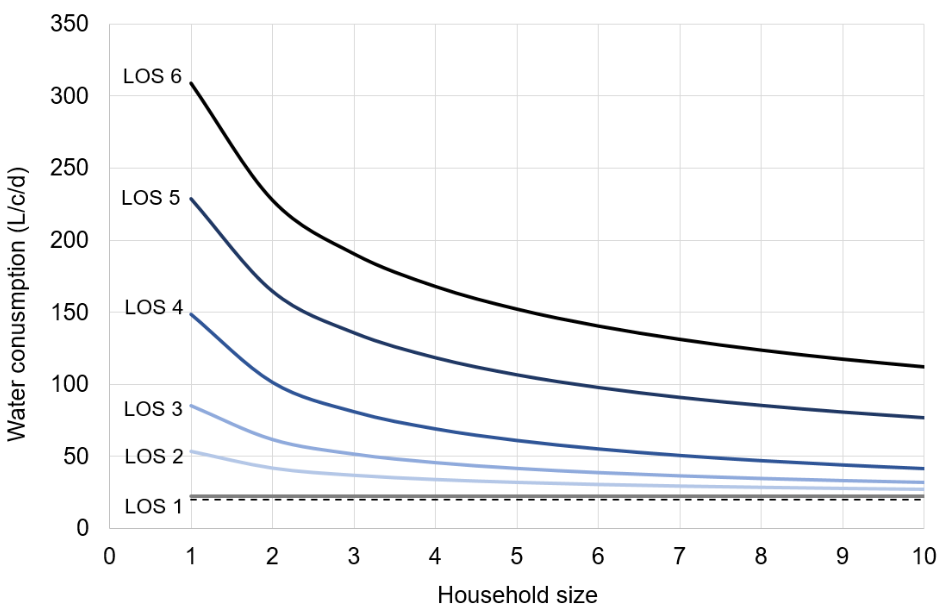

Figure 3.2: Per capita consumption for six levels of service and increasing household size

The baseline water consumption values for LOS 5 were calculated as the average of LOS 4 and LOS 6, because no data was available for LOS 5 specifically. The per-capita consumption for standpipes (LOS 1) was assumed to be constant over the range of household sizes – this was considered appropriate due to the fact that water is carried from the standpipe, and each additional person would typically carry another container (of fixed size) from the standpipe. Research is currently under way to assess water use by South African consumers depending on standpipes, but no measured data was available at the time of this study.

The baseline water use from standpipes (LOS 1) was set equal to 20 ℓ/c/d, although the project team initially used 25 ℓ/c/d in the model for this purpose. The value of 20 ℓ/c/d was considered appropriate, based on input from practitioners at the project workshops, where it was pointed out that the typical container size used to carry water was 10 or 20 ℓ. The baseline value of 20 ℓ/c/d was such that the resultant water use for an arid region, after application of the various multiplication factors in the model, would be 24.4 ℓ/c/d – almost 25 ℓ/c/d. The baseline water consumption values for LOS 3 (yard tap) were calculated as the average of LOS 1 and LOS 4, while LOS 2 (CABs) was, in turn, calculated as the average of values for LOS 1 and LOS 3.

3.4 CLIMATE REGION

The climatic region in which a property is located will affect the overall water use of the property (Van Zyl et al., 2008; Jacobs, et al., 2004). Drier regions will require more frequent irrigation and pool filling than wetter areas for the same garden layout. Climate will have the greatest effect on households with outdoor water use (i.e. LOS 6), as irrigation and pool use are the most affected by climate. Households without outdoor water use may still be affected by climatic regions as households may have small sections that need irrigation and are affected by climate (Fransolet, 2015).

The Köppen-Geiger climate classification can be used to determine the climatic conditions of an area, based on temperature and precipitation (CSIR, 2015). The Köppen-Geiger climate classifications can be simplified in regions based on aridity (CSIR, 2015). The CSIR (2015) defines five aridity regions: humid, moist sub-humid, dry sub-humid, semi-arid and arid. The five aridity regions specified by the CSIR (2015) were used for the development of this tool. The user has to select a climate region from a map in order to identify the region number, which is entered as a model input.

Earlier guidelines for estimating water use (Jacobs et al., 2004) were used to determine the factor by which the climatic region would affect water use for the highest level of service, LOS 5 (i.e. a fully serviced house with outdoor use). Factors for high water use (arid regions) and low water use (humid regions) were determined in relation to the average values. Jacobs et al. (2004) determined AADD values for increasing stand sizes for four different regions with varying climates: Cape Town, Ekurhuleni, Windhoek and George. Even though Windhoek is not located in South Africa, the climatic factors were considered representative of South Africa and are, therefore, considered relevant to South African studies. Cape Town's AADD was considered to be representative of high water use, correlating to water use in an arid region – with dry and hot summers. Windhoek and Ekurhuleni were representative of medium water use, thus correlating to water use in a dry sub-humid region. George was considered to represent low water use, correlating to water use in a humid region.

A multiplication factor of 1 was set for dry sub-humid climates for all levels of service, with an increasing multiplication factor for increasing aridity and a decreasing multiplication factor for decreasing aridity. To determine the LOS 6 multiplication factor for arid regions, the ratio between the AADD for Windhoek and Ekurhuleni and the AADD for Cape Town, as calculated by Jacobs et al. (2004), was determined. For a stand size of 2,000 m^2, the AADD for Windhoek and Ekurhuleni was approximately 1,400 ℓ/d and the AADD for Cape Town was approximately 1,800 ℓ/d. The ratio of 1,800/1,400 is 1.29. Consequently, a multiplication factor for arid regions, for LOS 5, was chosen at 1.3. The multiplication factor for humid regions was based on the ratio between the AADD for Windhoek and Ekurhuleni and the AADD for George.

For a stand size of 2,000 m^2, the AADD for George was approximately 1 000 ℓ/d. The ratio of 1,000/1,400 is 0.71. To be conservative, a multiplication factor for humid regions, for LOS 6, was chosen at 0.75. The multiplication factor for the moist sub-humid region was calculated by averaging the multiplication factors for the humid and dry sub-humid regions. The multiplication factor for the semi-arid region was calculated by averaging the multiplication factors for the arid and dry sub-humid climate regions. Climate was considered to have a minimal effect on water use for LOS 1. A 10% increase and decrease in water use was assumed for LOS 1 for arid and humid climates, respectively. Therefore, multiplication factors for arid and humid climates were 1.1 and 0.9, respectively. The multiplication factors for the other regions were calculated in the same manner as those for LOS 6.

Water use between each level of service does not increase in a linear manner (DHS, 2019). Therefore, a relationship between the water use for each level of service was determined in order to interpolate between the multiplication factor for LOS 1 and LOS 6 for the humid and arid climatic regions. The expected water use values, as set out by the DHS (2019), were used to determine the proportional increase in water use per service level. In order to interpolate the climate multiplication factors from LOS 1 to LOS 6, the factors were scaled in the same proportions as water use increased from LOS 1 to LOS 6. The interpolation was only performed for humid and arid regions. The multiplication factors for moist sub-humid and semi-arid regions were calculated in the same manner as those for LOS 1 and LOS 6, by averaging the humid and dry sub-humid, and the arid and dry sub-humid conditions. A summary of all multiplication factors can be found in Table 3.1. For example, the unit value of 1 (for LOS 1 and a dry sub-humid region) would be 20 ℓ/c/d.

Table 3.1: Summary of multiplication factors for climate regions for each level of service

Description	**LOS ratio**	**1**	**1**	**2**	**4**	**8**	**16**
Climate region	**Code**	**LOS 1**	**LOS 2**	**LOS 3**	**LOS 4**	**LOS 5**	**LOS 6**
Humid	A	0.900	0.891	0.881	0.863	0.825	0.750
Moist sub-humid	B	0.950	0.945	0.941	0.931	0.913	0.875
Dry sub-humid	C	1.000	1.000	1.000	1.000	1.000	1.000
Semi-arid	D	1.050	1.056	1.063	1.075	1.100	1.150
Arid	E	1.100	1.113	1.125	1.150	1.200	1.300
Elasticity property value		**0.00**	**0.00**	**0.00**	**0.10**	**0.20**	**0.30**

3.5 USAGE LEVEL

Usage level was used to consider the water conservation efforts of the residents of the households and/or over-/under-use relative to that which could be considered normal – keeping in mind that normal values were those presented in the earlier graphs for household size. Water use may also be higher in houses that have high outdoor use due to landscaped gardens with exotic plants or with numerous fishponds or fountains. A larger pool may also contribute to a higher water use. Therefore, a usage level multiplication factor was considered, allowing for conservative water use and higher-than-normal water use to be considered.

It is was considered appropriate to assume constant use for standpipes. The volume of water that is collected from a standpipe only meets basic human hygiene needs. Therefore, water use cannot be reduced. Furthermore, since water has to be carried from the standpipe, often over long distances, excessive water use will not be relevant to standpipe users. Therefore, the usage level multiplication factor was only applied to LOS 2 to LOS 6. High and low water use will have the greatest effect on households with larger stand sizes (Jacobs, 2007), which is often representative of level of service. In order to determine the multiplication factors, for usage level, for LOS 6, the theoretical household size graphs shown in Figure 2.2 were used. The water use for a single-person household was used to determine the proportion between high, average and low water use. The project team tested this concept at the workshops, appreciating that a factor derived in this manner would not be independent of other inputs.

This approach was considered to be the best available option for determining factors for high and low water use scenarios.

The average theoretical water use value of 240 ℓ/c/d was set as the average use. The lowest theoretical value of 179 ℓ/c/d was used as low water use and the highest theoretical value of 331 ℓ/c/d was used as high water use. Therefore, the low water use ratio for LOS 6 was calculated by dividing the low water use by the average, resulting in a multiplication factor of 0.75 (compared to the average). The high water use ratio for LOS 6 was calculated by dividing the high water use by the average, resulting in a multiplication factor of 1.40 (compared to the average). The multiplication factor for average water use remained constant at 1, while the multiplication factors for high and low water use were interpolated between LOS 1 and LOS 6 in the same manner as the multiplication factors for the humid and arid climatic regions in Section 3.4. The resultant usage level multiplication factors are summarised in Table 3.2.

Table 3.2: Multiplication factors for usage level

Usage level	LOS 1	LOS 2	LOS 3	LOS 4	LOS 5	LOS 6
Low use	1.000	0.984	0.969	0.938	0.875	0.750
Average use	1.000	1.000	1.000	1.000	1.000	1.000
High use	1.000	1.025	1.050	1.100	1.200	1.400

3.6 PROPERTY VALUE

Property value was incorporated into the LCD Model. Property value has been found to be positively correlated to water use (Van Zyl et al., 2008; Husselmann and Van Zyl, 2005). Specific value categories were defined so that the LCD Model would find practical application in South Africa. Three stand value categories were chosen: low income, middle income and high income houses. Specific property value ranges were linked to each category and were based on available information in terms of house prices.

Lemanski (2010) suggested a maximum value of R300,000 for a government-subsidised house in 2008. Government-subsidised housing was considered to represent the low-income portion of the population. The average housing inflation over the last 10 years has been 4.5% (Lightstone Property, 2019). Considering inflation, a maximum property value of R500,000 was determined as an upper limit for low-income properties. Middle-class houses were classified as having a stand value ranging from R500,000 to R1,500,000, while high-income households were classified as having a stand value greater than R1,500,000.

The effect of stand value on water use was modelled by incorporating an elasticity value, informed by earlier work (Husselmann and Van Zyl, 2005). The elasticity of water demand with respect to stand value ranged between 0 and 0.5, with no clear trends reported by Husselmann and Van Zyl (2005). Considering the most basic types of service, no impact of property value on demand was assumed for standpipes, CABs and yard taps. The model was constructed with a property value elasticity that increases with the higher levels of service, as described below:

- Standpipe = 0
- Communal ablution blocks = 0
- Yard connection = 0
- Low cost housing: limited inhouse connections = 0.1
- Full house connection: indoor only (e.g. flats) = 0.2
- Full house connection: including outdoor = 0.3.

CHAPTER 4: CONCLUSION

Limited research into per-capita water use in South Africa has been published to date. Information is also not available in a standard format that is easily referenceable. International references are often used as a proxy for South African conditions. As part of this study, a tool was developed that would be more relevant to local conditions. Per-capita water use was selected as a norm for this study, as it is the most notable driver of water use and relates to internationally applied standards. Some of the levels of service employed in this study, and used as model inputs, are unique to South African conditions.

The study involved applied research to address the research problem by reviewing formerly published per-capita water consumption collected by means of a comprehensive desktop review and targeted email requests from local experts. Expert input was made possible by hosting three project workshops in different regions of the country. Where measured household water consumption was available in combination with the corresponding household size, the per-capita consumption was calculated from the former values. New data was not collected, but data was rather collated from information that was already available among the project team members and stakeholders.

An extensive literature review was completed, including ~105 references that were not specifically cited in this document. The project team obtained 101 data points of the per-capita water use of specific homes from four regions in the country. The actual data was used to develop the first version of the LCD model. The MS Excel model, or LCD Tool, was developed and amended with inputs from three workshops held in Gauteng, the Western Cape and KwaZulu-Natal. The tool was verified by comparing results to current DHS (2019) guidelines for per-capita consumption, and results were within limits deemed to be realistic – also based on workshop inputs.

The per-capita consumption for single-person households was relatively higher than intuitively thought, but based on the best available data (also local data), it was accepted to be the case for single-person households. It should be kept in mind that the average household size in South Africa varies between three and four persons per household. Household size has a notable impact on the resultant per-capita consumption.

The following key input parameters were included in the LCD Model: level of service, property value, geographic region, the number of people per household and water usage level. The tool was developed in such a manner that it is relatively easy to operate.

The tool does not account for on-site plumbing leaks (on a consumer's property), and also ignores water network losses. Allowance could be made for plumbing leakage, say by adding 10 to 25% to the estimated per-capita consumption in line with some earlier studies on consumer leakage. Consideration could also be given to water network leakage and losses by allowing for typical values (as reported elsewhere) in addition to the per-capita consumption.

The LCD Tool is MS Excel-based and is provided separately with this report in e-format. The LCD Tool presents a large result set, based on the various inputs. A set of 270 different result values would be possible for each household size option (e.g. six levels of service with three usage scenarios, five regions and three property value categories). Considering seven household size options, for one to seven persons per household, the tool would produce 1,890 different results for per-capita water use, depending on the selected inputs. In order to summarise the results, two tables were developed to portray the effect of adjusting certain input values. A few example results for typical input values are given in Table 4.1.

Table 4.1 presents results for a household with average water use, average property value and located in the dry sub-humid region, while considering the different levels of service and household sizes. The number of persons per household was varied to portray the variability of water use per capita for the different levels of service.

Table 4.1: Water use per capita for different levels of service and number of persons per household

Level of service		Estimated water use (ℓ/c/d) Number of persons per household 1	2	3	4
LOS 1	Standpipe	22	22	22	22
LOS 2	Communal ablution blocks	54	42	37	34
LOS 3	Yard connection	85	62	52	46
LOS 4	Low-cost housing: limited fixtures	163	111	89	76
LOS 5	Full house connection (indoor)	275	198	163	143
LOS 6	Full house connection (including outdoor)	407	300	251	221

For Table 4.2, a three-person household with average water use and an average property value was selected for each level of service. The climate region was varied in this case to portray the variability of water use per capita for the different levels of service.

Table 4.2: Water use per capita for different levels of service vs climate regions

Level of service		Estimated water use (ℓ/c/d) Climate regions Humid	Moist sub-humid	Dry sub-humid	Semi-arid	Arid
LOS 1	Standpipe	20	21	22	23	24
LOS 2	Communal ablution blocks	33	35	37	39	41
LOS 3	Yard connection	46	49	52	55	58
LOS 4	Low-cost housing: limited fixtures	77	83	89	96	102
LOS 5	Full house connection (indoor)	135	149	163	180	196
LOS 6	Full house connection (including outdoor)	188	220	251	289	326

The results are most sensitive to the level of service and number of people per household. It is therefore essential that users ensure that these parameters are populated with insight into actual conditions. The findings presented in the following chapter were derived based on the analyses and scenario testing of the model and tool.

CHAPTER 5: FURTHER RESEARCH

This study presented a novel way of dealing with per-capita water use estimates. Further research and development, with subsequent knowledge dissemination, would help to establish a sound approach to per-capita use in South Africa. The tool presented in this study was based on the best available data and previous knowledge. The limited data and available research at the time of study suggests that future improvements could improve the model.

It would therefore be beneficial to investigate the following aspects further:

- Install and monitor more water meters at households across the country, and record the number of people per individual home.
- Develop a method where household per-capita use can be accurately derived from census and Municipal Treasury data.
- Expand the LCD Tool to incorporate water loss and peak water use so that actual peak flows in water reticulation pipes could be estimated in a similar manner to the per-capita consumption in this case.
- Further develop a geospatial data set specific for water use that could be applied to the model.
- Develop the tool into a cellular phone application for ease of use.
- Describe model inputs as stochastic parameters and subsequently determine the sensitivity of specific parameters to model outputs, and express results in terms of confidence intervals.

The further development of the tool would improve the model accuracy and would allow for increased acceptance and uptake of the approach in industry.

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ANNEXURE A – PER CAPITA WATER USE STUDIES

Citation	Data date	Country	Location	Micro/ Macro	Level of service	Reported water use (ℓ/c/d)	PPH	Type of study	Number of households	Restrictions (Yes/No)
Jacobs and Haarhoff (2004)	2004	South Africa	Johannesburg	Macro	Full house connection (indoor and outdoor)	326	3,00	Model		No
		South Africa	Cape Town			352				
		South Africa	George			246				
		Namibia	Windhoek			425				
Du Plessis (2007)	2002-2003	South Africa	Kliprand	Macro	Mixed	25		Empirical study		Yes – permanent restrictions
			Vredenburg			97		Empirical study		No
			Hermon			98				
			Riebeek West			98				
			Raithby			103				
			Rietpoort			112				
			Riebeek Kasteel			113				
			Nuwerus			132				
			Bitterfontein			135				
			Paternoster			144				
			Pniel			146				
			Hopefield			147				
			Eendekuil			157				
			Aurora			160				
			Kylemore			170				
			Abbotsdale			173				
			Chatsworth			173				
			Gouda			175				
			Koringberg			177				
			Piketberg			178				
			Kalbaskraal			178				
			Darling			181				
			Riverland			182				
			Elands Bay			194				
			Lutzville			195				
			Moorreesburg			195				
			Clanwilliam			200				
			Saldanha			201				
			Koekenaap			206				
			Klapmuts			213				
			Ebenhaezer			218				
			Velddrif			220				
			Tulbagh			222				
			Vanrhynsdorp			226				

Citation	Data date	Country	Location	Micro/ Macro	Level of service	Reported water use (ℓ/c/d)	PPH	Type of study	Number of households	Restrictions (Yes/No)
			Calvinia			244				
			Strandfontein			249				
			Goedverwacht			251				
			Doringbaai			252				
			Graafwater			262				
			Wittewater			264				
			Citrusdal			266				
			Wellington			275				
			Porterville			277				
			Redelinghuys			284				
			Jamestown			287				
			Malmesbury			295				
			Saron			300				
			Franschoek			303				
			Paarl			321				
			Dwarskerbos			404				
			Klawer			407				
			Lamberts Bay			409				
			St Helena Bay			429				
			Langebaan			442				
			Stellenbosch			445				
			Vredendal			497				
			Yzerfontein			952				
			Leipoldtville			1479				
Shaban and Sharma (2007)	2001	India	Delhi	Macro	Mixed: low cost to full house connections	78		Supply based estimate		No
			Mumbai			90				
			Kolkata			116				
			Hyderabad			96				
			Kanpur			77				
			Ahmedabad			95				
			Madurai			88				
Rathnayaka et al. (2014)	2003	Australia	Yarra Valley, Melboune	Micro	Full house connection (indoor and outdoor)	238	3,02	Empirical study		Yes, Stage 1
Rathnayaka et al. (2014	2011	Australia	Yarra Valley, Melboune	Micro	Full house connection (indoor and outdoor)	124	3,16	Empirical study		Yes, Stage 1
Sadr et al. (2016)	2015	India	Jaipur	Macro	Full house connection: indoor	183		Survey and empirical study		No
					Full house connection: outdoor	215				
Lee et al. (2012)	2002-2006	Korea	Nationwide	Micro	Full house connection: indoor	159		Empirical study	146	No

Citation	Data date	Country	Location	Micro/ Macro	Level of service	Reported water use (ℓ/c/d)	PPH	Type of study	Number of households	Restrictions (Yes/No)
					Full house connection: outdoor	141				
Mayer et al. (1999)	1996	United States and Canada	Nationwide	Micro	Full house connection: outdoor	236	3,00	Empirical study	1,188	No
DeOreo (2011)	2007	United States	California	Micro	Full house connection: outdoor	204	3,00	Empirical study	780	No
DeOreo (2011)	2006-2008	United States	Arizona California Colorado Floria Nevada Oregon Utah	Micro	Full house connection: outdoor	167	3,00	Empirical study	240	No
Loh and Coghlan (2003)	1998-2001	Australia	Perth	Micro	Full house connection: outdoor	335		Empirical study	120	No
Mead (2008)	2008	Australia	Toowoomba	Micro	Full house connection: indoor	112		Empirical study	10	No
Roberts (2005)	2004	Australia	Yarra Valley, Melboune	Micro	Full house connection: outdoor	226		Empirical study	100	No
Willis et al. (2013)	2008	Australia	Gold coast	Micro	Full house connection: outdoor	157		Empirical study	151	
Sivakumaran & Aramaki (2010)	2004	Sri Lanka	Trincomalee	Micro	Limited household connection	139	4,70	Consumer survey	285	No
Smith (2010)	2005-2007	South Africa	Eastwood, Pietermaritzburg	Micro	Full house connection: outdoor	131		Empirical study	194	No
					Limited household connection	89	4,10		34	No
Thiel (2014)	2013	The Netherlands	Amsterdam	Micro	Full house connection: indoor	119		Empirical study	1,349	No
Athuraliya et al. (2012)	2012	Australia	Yarra Valley, Melboune	Micro	Full house connection: indoor	93	2,60	Empirical study	100	No
Athuraliya et al. (2012)	2010	Australia	Yarra Valley, Melboune	Micro	Full house connection: indoor	105	2,60	Empirical study	100	No
Jordán-Cuebas et al. (2018)	2011-2013	United states	New York	Micro	Full house connection: indoor	222		Empirical study	30	No
Hay et al. (2012)	2008	South Africa	Adelaide, Western Cape	Macro	Full house connection: outdoor	190		Meter data		No
			Bedford, Western Cape		Full house connection: outdoor	109				
			Alice, Eastern Cape		Full house connection: outdoor	193				
			Stutterheim, Eastern Cape		Full house connection: outdoor	245				
			Mthatha, Eastern Cape		Full house connection: outdoor	263				

Citation	Data date	Country	Location	Micro/ Macro	Level of service	Reported water use (ℓ/c/d)	PPH	Type of study	Number of households	Restrictions (Yes/No)
			Tulbagh, Western Cape		Full house connection: outdoor	309				
			Beaufort West, Western Cape		Full house connection: outdoor	206				
			Ashton, Western Cape		Full house connection: outdoor	432				
			Plettenberg Bay, Western Cape		Full house connection: outdoor	281				
			Bitterfontein, Western Cape		Full house connection: outdoor	123				
Manzunga and Machiridza (2005)	2003	Zimbabwe	Mabelreign	Micro	Limited household connection	226	6,00	Metered data collected through questionnaires	8	No
			Mt. Pleasant		Limited household connection	353	5,00		6	
			Marlborough		Limited household connection	167	8,00		4	
			Kuwadzana		Limited household connection	58	24,00		4	
			Glen Norah		Limited household connection	105	8,00		12	
			Budiriro		Limited household connection	108	9,00		10	
			Tafara		Limited household connection	69	10,00		6	
			Mabvuku		Limited household connection	29	10,00		4	
Parker & Wilby (2013)	1992-2006	UK	East England Lincoln Ruthamford	Micro	Full house connection: indoor	169		Model	100	No
Rathnayaka et al. (2015)	2010	Australia	Yarra Valley City	Micro	Full house connection: outdoor	113	3,10	Empirical study	117	Yes – Stage 1
Rathnayaka et al. (2015)	2012	Australia	Yarra Valley City	Micro	Full house connection: outdoor	115	3,10	Empirical study	117	Yes – Stage 2
Dias et al. (2018)	2015-2016	Brazil	Jointville	Micro	Full house connection: indoor	102		Empirical study	3,171	No
Guragai et al. (2018)	2016	Nepal	Kathmandu Valley	Micro	Mixed: delivered tank water to full indoor house connections	56	6,40	Empirical study	28	Intermittent water supply
Hussien et al. (2016)	2015	Iraqi Kurdistan	Duhok	Micro	Full house connection: outdoor	274	7,04	Survey	407	No
					Full house connection: indoor	247,0				

ANNEXURE B – LCD TOOL USER GUIDE

Overview

The LCD Tool operates in the MS Office environment in MS Excel. All five input values are entered via drop-down boxes and the result is displayed on the same sheet as the inputs, as discussed in this user guide.

At least one input value –the level of service – is required to obtain a crude estimate of water use. In order to obtain the most accurate estimate, all five input values are required: level of service, property value, geographic region, number of persons per household and a relative indication of water usage level (low, average or high use; where low use could represent consumers who are subjected to water restrictions, for example).

The following cases are dealt with in this user guide:

- Case 1: The most basic case, where only the level of service is known.
- Case 2: All inputs are known.

Case 1: One input known – level of service

The LCD Tool is able to provide an estimate of per-capita water use based on only one input, using typical (average) values for the other inputs. Refer to Figure B-1 and follow the steps outlined below to obtain a crude estimate based only on the level of service:

- In the drop-down box marked “A”, select the level of service: standpipe, communal ablution block, yard connection, low-cost housing with limited indoor use (no outdoor use), full house connection with indoor use only (e.g. flats), or full house connection including outdoor use.
- In the drop-down box marked “B”, select “Increased spending capacity (R500k-MR1), which represents the average value used in the model.
- In drop-down box “C”, select “Dry sub-humid”, which represents the average value used in the model.
- In drop-down box “D”, select “3” for the number of persons in the household, which represents a typical average value for South African homes.
- In drop-down box “E”, select “Average use”.

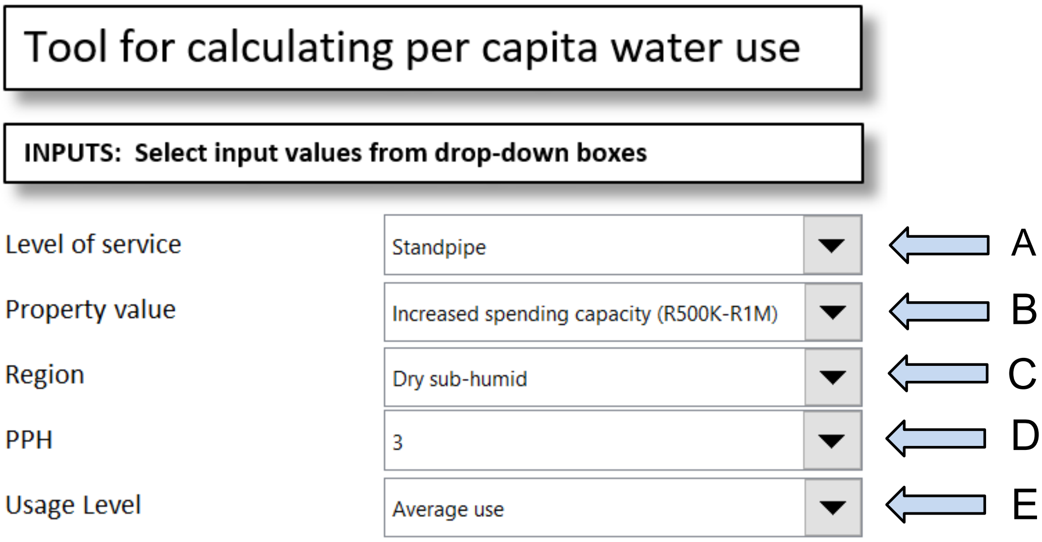


Figure B-1: Input section of LCD Tool

Case 2: All inputs are known

The LCD Tool is able to provide improved estimates of per-capita water use if all the inputs are known. Refer to Figure B-1 and follow the steps outlined below to obtain the estimate based only on all known inputs:

- In the drop-down box marked “A”, select the level of service: standpipe, communal ablution block, yard connection, low-cost housing with limited indoor use (no outdoor use), full house connection with indoor use only (e.g. flats), or full house connection including outdoor use.
- In the drop-down box marked “B”, select the appropriate property value, selecting one of the three available choices. Note that property value has no impact on water use from standpipes.
- In drop-down box “C”, select the geographic region, using the map in Figure B-3 (CSIR, 2015) to find the approximate region type, based on location.
- In drop-down box “D”, select the typical number of persons in the household, between one and seven.
  Notes:
  Household size has no impact on water use from standpipes.
  For all other levels of service, the resulting water use decreases sharply from one to three persons per household, which is supported by data presented in this report and by international studies.
- In drop-down box “E”, use best judgement to select the appropriate usage level by considering low use, average use or high use. If in doubt, use the average use scenario.

Results

Results are presented on the same sheet as the inputs. Refer to Figure B-2, showing the results for Case 1 and a full consumer connection with indoor use only. Note that the result was adjusted for property value, because the baseline value for property value is the lowest value category (and for Case 1, the middle property value category was selected).

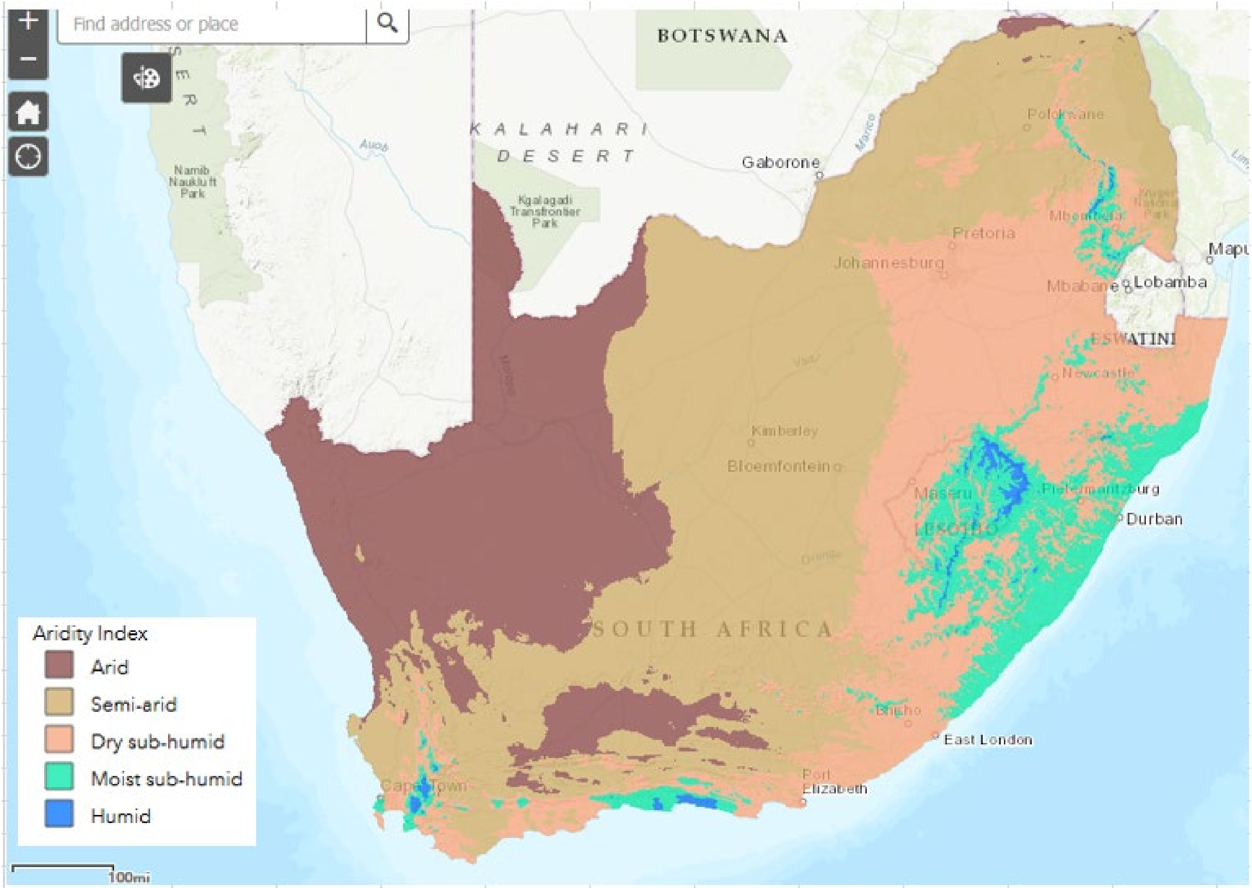
RESULTS: Estimates of water use (per person)

Water use - Excluding adjustment for property value:
136 Litres per capita per day

Water use - Adjusted for Property value:
163 Litres per capita per day

Note: Property value adjustment only applies to the highest three levels of service.

Figure B-2: Results of LCD Tool for Case 1 (example case shown)



https://csir.maps.arcgis.com/apps/webappviewer/index.html?id=3e1096df52a3426dbd57b192d1827fce

Figure B-3: Map for selecting geographic regions (CSIR, 2015)