ASSESSING THE AFFORDABILITY OF WATER SERVICES FOR RESIDENTIAL CONSUMERS IN SOUTH AFRICAN MUNICIPALITIES

Report to the

WATER RESEARCH COMMISSION

by

Kim Walsh
Lerato Shai
Themba Mbangata

Palmer Development Group

WRC Report No. 2584/1/18

ISBN 978-0-6392-0086-6

March 2019

Obtainable from
Water Research Commission
Private Bag X03
GEZINA, 0031

orders@wrc.org.za or download from www.wrc.org.za

DISCLAIMER

This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

The authors would like to thank the following members of the reference group for assistance and the constructive discussions for the duration of the project: Dawie Mullins (Conningarth), Iqbal Mohamed Alli (National Treasury), Melanie Wilkinson (Sustento), Louisa Dunker (CSIR) and William Moraka (SALGA). We also acknowledge GLS Consulting and StatsSA for providing the data required.

This page was intentionally left blank

Executive Summary

Introduction

Households connected to municipal water systems in South Africa are likely to see rising water bills over the years to come due to rising costs of raw water supply and an increase in municipal water tariffs. In a country where more than half of the population is classified as poor[1], this raises concerns about the affordability of water. This study presents a more nuanced measure of water affordability for residential customers in four municipal case studies (A, B, C and D). The study focuses on the ability to pay aspect of water affordability and calculates both the affordability ratio and residual income. This is made possible through matching billing data to Census 2011 data to produce a dataset that contains three crucial variables for understanding affordability: income, water bill and consumption data. The match also facilitates an investigation of household characteristics across the different measures resulting in a more comprehensive picture of water affordability.

Literature review

This literature review elucidated several factors regarding the affordability of water services. The first is with respect to the definition of affordability, particularly that it is a normative concept which is a function of both willingness and ability to pay. Secondly, there are two main approaches to measuring affordability: the affordability ratios and residual income approach. The former calculates the bill as a proportion of income and compares it to a threshold while the latter compares the difference between income and the bill to a poverty line. A third important finding is that the human rights perspective requires a determination of a minimum standard with respect to access and quantity of water services consumed before affordability can be measured. Finally, the literature review points to income, price, climate, household size and composition by age, on-site leakage rates, behaviour and stand area as important determinants of the quantity of water households consume.

Methodology and analytical framework

The unit of analysis selected for this research was a small area layer (SAL), a geographic unit defined by Statistics South Africa and created by combining all enumerator areas (EA) with a population of less than 500 with adjacent EAs within the same sub-place. SALs typically contain between 150 and 200 households.

---

[1] 55.5% of South Africans fell below the upper-bound poverty line of R992 per person per month in 2015, according to Statistics South Africa's 'Poverty Trends in South Africa' report (Statistics South Africa, 2017).

The proposed analytical framework was revised after piloting it in one municipality. The revised framework defines eight cases which are a combination of three key criteria: (1) the high bill criteria where an SAL's average ratio is above a 3% threshold, (2) low residual income criteria where the residual income is below the upper bound poverty line and (3) under-consumption which refers to SALs that consume less than 20 lpcd, the minimum required for short term survival. SALs in case 1 meet all the criteria, those who fall into case 2 to 4 only experience one of the constraints and those in case 5-7 only satisfy one of the criteria. Lastly, there are also SALs that face no constraints. The overall analysis results are then synthesised to answer the following key questions:

- Which households face affordability constraints due to the price of water being too high?
- Which households face affordability constraints due to their incomes being too low?
- Which households face affordability constraints due to both the price of water being too high and their incomes being too low?
- Which households cannot afford to purchase the minimum quantity of water required?

Census 2011 data from Statistics South Africa and the SWIFT dataset managed by GLS Consulting are combined to apply the framework in four municipal case studies. Tariff code descriptions and tariffs were also collected from each municipality. The case studies were initially planned to be socio-economically diverse, however due to data collection limitations the final sample is based on what was available and feasible at the time of analysis.

There are several limitations associated with the methodology, analytical framework, data and the unit of analysis. These include amongst others the heterogeneity of households within a SAL and the Census data structure which affects the calculation of the representative income; the lack of sanitation data in the SWIFT dataset which precluded an analysis of water services; and the focus on billed data due to lack of payment information in the SWIFT dataset. Additionally, an important limitation is the fact that water affordability is assessed in isolation of the affordability of other municipal services used by residential customers which means that while some households may find water affordable, it is still possible that they are unable to pay their total household bill.

Key findings

Affordability in municipalities based on two approaches. Both approaches at the macro level hide constraints that are present at the micro-level. Municipality A, B and D all face some constraints across both measures, however Municipality C faces the most significant challenges.

Determinants of affordability constraints. The ratios are explained in part by the relationship between median income and consumption with relatively lower income households consuming a lot of water. The residual income results are explained by either high consumption by low income SALs or payment of water bills by households who were already poor.

Combination of constraints. Most of the SALs facing constraints in all four municipalities simultaneously experience both bills that are more than 3% of their income and residual incomes that fall below the poverty line.

Assumptions of the IBT. The assumption underlying the IBT, that consumption increases with income, holds true in all four municipal case studies. However, consumption at the top of the income distribution is not much higher than consumption at the bottom in some cases. High consumption (more than 150 lpcd) by some households suggest that the assumption that IBTs discourage waste does not necessarily hold.

Analytical approach and implementation. The study finds that macro-level measures hide constraints and shows the presence of affordability constraints in all four municipalities when assessing affordability at the SAL level. Moreover, the affordability ratio and residual income approach produce different results in terms of the proportion and composition of small areas facing constraints.

Unit of analysis and data quality. The SAL is more granular than looking at the entire municipality, however the study finds heterogeneity of households within a small area pointing to more accurate and robust results if the analysis is conducted at a household level. The SWIFT dataset had efficiency benefits, however it required extensive cleaning and there are some questions regarding its completeness and thus the extent to which it can provide a representative overview of affordability for all residential customers.

Ease of replication in local municipalities. Municipalities require water billing data in spatial form, software to spatially join census data to billing data and data analysis skills. Any municipality that faces any challenge with either of these requirements will be unable to replicate this study internally. Even if municipalities meet all these requirements, time and capacity constraints make it a challenge for them to undertake a similar analysis for all their small areas. Drawing a representative sample of SAL is a solution to this problem and yields similar results.

Conclusions

Is water affordable for municipal residential customers? The study suggests a degree of water unaffordability in all four municipal case studies. However, these do not occur to the same extent, nor are they driven by the same factors. The key determinants of affordability constraints in all cases are income and consumption, i.e. those SALs experiencing constraints either had low incomes, high consumption or some combination of the two that explained their ability to pay for water. The study points to the necessity of multiple approaches to fully understand affordability. While there was some overlap, SALs facing constraints under the affordability ratio are not the same as those facing constraints under the residual income approaches.

Implications for policy, practice and regulation

The findings from this study point to the following implications:

- A need for the regulation of tariff setting to include a comprehensive analysis of the affordability of municipal tariffs, particularly the overall effect of their IBT design on the affordability of water.
- A review of IBTs application in practice and testing the extent and conditions under which the assumptions underlying their successful implementation hold.
- A review to ascertain to ascertain whether the level of support provided is sufficient and whether the right households are receiving support.
- Investigation of different option to address varying forms of constraints. Households with affordability constraints that are largely driven by high consumption levels could be protected through programmes that encourage reduction in consumption through efficient use or adoption of water saving technologies.

Recommendations for future research

- A follow up study is recommended to apply the approaches presented in this report to a sample of households from a representative mix of municipalities within the country to facilitate conclusions on the affordability constraints nationwide which can then be used to inform current policy on free basic water, provide guidance to municipalities on criteria for selecting households that are eligible for support and guidance for how to regulate municipal tariff setting to include affordability analysis.
- This study also recommends future research into and the development of a user-friendly affordability tool that municipalities can utilise to assess the affordability of their tariffs. The tool needs to address the challenge with obtaining income data and matching it to the municipality's billing data.
- An extension of this study could include a simulation or an experiment to test the impact of different tariff structures and levels on affordability for residential customers.

TABLE OF CONTENTS

1 INTRODUCTION AND OBJECTIVES 1
2 LITERATURE REVIEW 2
2.1 Defining affordability 2
2.2 Why does affordability matter? 3
2.3 Measuring affordability 5
Affordability Ratios: What proportion of household income is allocated to water services? 5
Residual Income Approach: How much income does the household have left for other goods after purchasing the utility service? 10
Affordability ratio using residual income: What proportion of a household income after spending on food is allocated to water services? 11
2.4 Setting affordable water prices: the inclining block tariff 11
2.5 The minimum quantity of water services required 13
Determinants of household water demand 15
2.6 Conclusion 20
3 METHODOLOGY 21
3.1 Proposed analytical framework 21
3.2 Limitations of the proposed analytical framework 23
3.3 Sources of data 24
3.4 Selecting a unit of analysis 25
3.5 Selecting municipal case studies 26
3.6 Creating a dataset 26
3.7 Data limitations and implications 29
3.8 Revised analytical framework 33
4 ANALYSIS RESULTS 34
4.1 Municipal descriptive statistics 35
Household income distribution 36
Water consumption and the human rights perspective 37
Relationship between water consumption and income 39
Relationship between average income and household size 40
Relationship between water consumption and household size 40
Water bills 41
4.2 Affordability ratio approach 43
Using macro-affordability ratios 43
Using micro-affordability ratios 44
Household characteristics of those experiencing affordability constraints 44
4.3 Residual income approach 46
Using a micro approach 47

Household characteristics of those experiencing affordability constraints 50
4.4 Do the same SALs experience multiple affordability constraints? 51
5 KEY FINDINGS 55
6 CONCLUSIONS 57
7 IMPLICATIONS FOR POLICY, PRACTICE AND REGULATION 58
8 RECOMMENDATIONS FOR FUTURE RESEARCH 59
9 LIST OF REFERENCES 61
APPENDIX A: MUNICIPALITIES WITH SWIFT DATA 66
APPENDIX B: DATA CLEANING PROCESS 67
Cleaning the SWIFT dataset 67
Step 1: Identify variables of interest 67
Step 2: Remove invalid records 68
Step 3: Remove vacant plots 68
Step 4: Distinguish residential records 68
Step 5: Identify duplicate meter records 68
Step 6: Compare total meters in an SAL with total number of households 69
Step 7: identify and remove consumption outliers 70
Cleaning the Census 2011 dataset 71
Identifying the correct households to include 71
Calculating median household income per small area layer 71
Other variables of interest: Household size 72
APPENDIX C: TESTING THE ROBUSTNESS OF THE APPROACH TO SAMPLING 73

LIST OF FIGURES

Figure 1 Trade-offs affecting water tariff setting 4
Figure 2: Hierarchy of water requirements 14
Figure 3: Analytical Framework 22
Figure 4: Revised analytical framework 33
Figure 5: Median household income by household size deciles 40
Figure 6: Water consumption by household size deciles 41
Figure 7: Macro-affordability ratios by municipality 43

LIST OF TABLES

Table 1: Thresholds used by international agencies 7
Table 2: WHO Minimum Guidelines... 14
Table 3: Outcome of merging SWIFT and Census 2011 datasets 28
Table 4: Comparison of average and median household income in the municipal case studies.. 31
Table 5: Nominal annual percentage change in total disposable household income 31
Table 6: Average water bill per household calculation method.. 32
Table 7: Descriptive statistics for municipalities.. 35
Table 8: Income distribution in the municipalities (based on nominal Rand value in 2014).. 36
Table 9: Consumption distribution in the municipalities 37
Table 10: Residential customers consuming less than the required amount of water 38
Table 11: Water consumption by median household income bracket 39
Table 12: Non-indigent customers water bills for different consumption levels (nominal Rand value in 2014)... 42
Table 13: Indigent customers water bills for different consumption levels (nominal Rand value in 2014) 42
Table 14: Distribution of SALs into affordability ratio bands 44
Table 15: Characteristics of SALs constrained according to affordability ratio measure compared to unconstrained SALs... 46
Table 16: Residual incomes by municipality (all in nominal Rands in 2014)......................... 47
Table 17: Distribution of SALs by residual income 49
Table 18: Number of SALs in each municipality that are moved into or further into poverty by the water bill 49
Table 19: Characteristics of households constrained according to residual income measure compared to unconstrained households 50
Table 20: Specifying unique groups of SALs facing constraints 52
Table 21: Number and percentage of SALs falling into risk profiles 52
Table 22: Summary of outcome of the data cleaning process... 70
Table 23: Municipality D statistics: all SALs vs. sample 73
Table 24: Affordability ratio frequency distribution: all SALs vs sample................................ 74
Table 25: Residual income 75

LIST OF ABBREVIATIONS

AADD	Annual Average Daily Demand
CAR	Conventional Affordability Ratios
CVM	Contingent Valuation Method
EA	Enumerator area
EPA	United States Environmental Protection Agency
FPL	Food poverty line
IBT	Inclining block tariff
IES	Income and Expenditure Surveys
IWA	International Water Association
LBPL	Lower bound poverty line
OECD	Organisation for Economic Co-operation and Development
SAL	Small Area Layer
StatsSA	Statistics South Africa
UBPL	Upper bound poverty line
UNDP	United Nations Development Programme
WHO	World Health Organisation
WRC	Water Research Commission

This page was intentionally left blank

1 INTRODUCTION AND OBJECTIVES

Households connected to municipal water systems in South Africa are likely to see rising water bills over the years to come for two reasons. Firstly, according to analysis by National Treasury, water tariffs in most municipalities in South Africa are below cost; this means that tariffs must rise in future to become cost-reflective and ensure the sustainable provision of services. Moreover, South Africa is a water scarce country, but municipal tariffs are set to meet budgets which do not take resource constraints into account. Secondly, water costs themselves are likely to increase in future as new resource development becomes ever more expensive. In a country where more than half of the population is classified as poor[2], this raises concerns about the affordability of water.

It is vital that municipalities assess the affordability of their tariffs periodically if not during the annual tariff setting process: the result of setting tariffs that are unaffordable is likely to be increasing levels of non-payment. It is against this background that the Water Research Commission (referred to as WRC hereafter) commissioned research on how best to assess the affordability of water services for residential consumers in South Africa. The focus of the study is to present a nuanced approach to measuring water services affordability that takes the South African context into account.

The report firstly presents a literature review that provides an understanding of current available research on the affordability of water services with a focus on how it is defined and measured. It then proposes an analytical framework that draws from the literature to present a comprehensive approach for measuring affordability in the South African context. A key innovation proposed is the matching of water services billing data to Census 2011. The study applies two measures of affordability identified in the literature, an affordability ratio and a residual income method, in a disaggregated manner across four municipal case studies. It attempts to determine which households face affordability constraints either because their water bills are a high proportion of income; because their water bills force them below a poverty line; or because they consume less than a minimum quantity of water. The intention is to provide a holistic picture of affordability which goes beyond determining whether there are constraints, to understanding the different constraints that households face and determining the characteristics associated with these households.

[2] 55.5% of South Africans fell below the upper-bound poverty line of R992 per person per month in 2015, according to Statistics South Africa's 'Poverty Trends in South Africa' report (Statistics South Africa, 2017).

The study advances our understanding of how to measure water affordability constraints and can be used to guide municipalities in their tariff design.

2 LITERATURE REVIEW

On 28 July 2010, the United Nations General Assembly explicitly recognised the human right to water and sanitation through resolution 64/292 (United Nations, 2010). Giving effect to this human right means ensuring every human being has access to water and sanitation (referred to as water services hereafter). A critical component of access to water is affordability. The objective of this literature review is to provide an overview of current research on water services affordability and how it impacts on the realisation of the human right to water services. The review unpacks the definition of affordability, outlines the various measures to assess affordability of water services and considers how the price of water services and the quantity consumed are integral to understanding affordability.

2.1 Defining affordability

Affordability is a function of both ability and willingness to pay. Subject to a budget constraint, the ability to pay refers to whether consumers can purchase goods or services given the prevailing prices. The amount that can be consumed is therefore constrained by the income available to the consumer. Willingness to pay refers to the maximum amount an individual is willing to sacrifice to acquire a good or receive a service. It therefore emphasises the consumer's preferences and taste.

In the case of willingness to pay, affordability considerations refer to the acceptability of prices. A good or service set above the maximum price a consumer is willing to sacrifice to acquire it will thus be unacceptable (Pontius, 2003). The literature on water affordability has sought to estimate willingness to pay for improvement in service levels and determine the value placed on goods (Brown, 1997; Griffin et al., 1995). The contingent valuation method (CVM) is the most common method used to investigate how much consumers are willing to pay for hypothetical improvement in services (Filippidis, 2005). Despite its limitations, Tussupova et al. (2015) used the CVM to determine willingness to pay for improvements and found that more than 90% of consumers were willing to pay more for better water quality and regular water supply in the Pavlodar Region, Kazakhstan. Similar studies in America suggest that American citizens are willing to pay more to maintain and ensure access to water resources (Mack and Wrase, 2017). This approach to determining affordability is particularly important for developing countries where a disproportionate number of households remain unserved.

Estimating willingness to pay for improved services contributes to better design of tariff rates that should be charged to serve these households.

Ability to pay is a necessary condition for affordability. While a consumer that is unable to pay for a good or service can be said to be facing affordability constraints, the ability to purchase a good or service does not necessarily translate into a willingness to do so. Determining ability to pay requires a value judgment regarding what the price level should be. MacLennan and Williams (2002) define affordability as a situation where a household is able to secure a given standard of living at a price which does not impose, from the perspective of a third party (such as government), an unreasonable financial burden on household incomes. Robinson et al. (2006) specify two ways of understanding financial burden: firstly, how much of the consumer's income is going to this purchase? Secondly, how much income is left over for other goods once the purchase has been made? The requirement to define "unreasonable financial burden" in order to assess affordability makes it a normative concept (Niëns et al., 2002). The inherent problem is the need to invoke some benchmark for which no objective definition exists, i.e. the percentage of income that *should* be spent on water consumption and the income that a household *should* have remaining after spending on water.

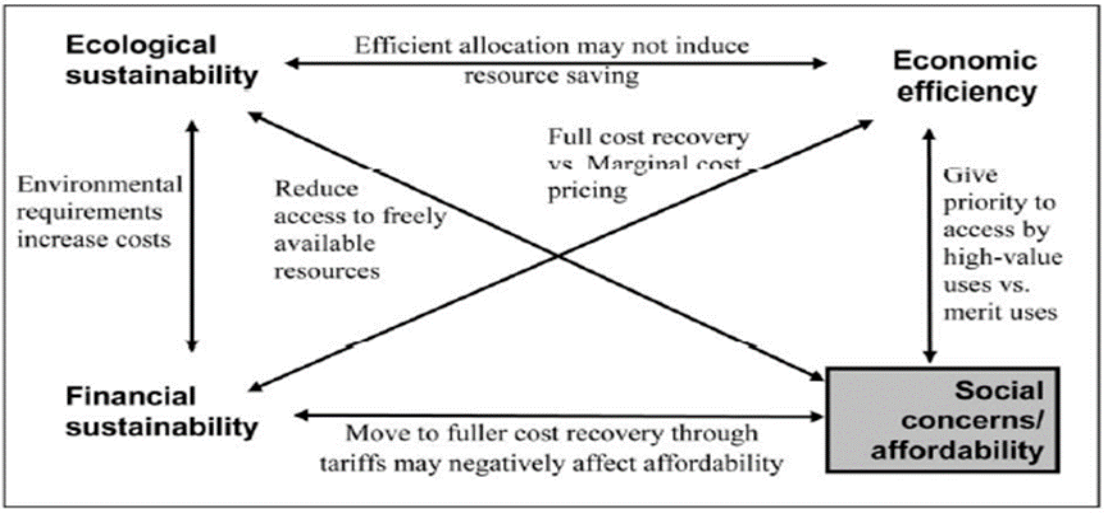
Willingness to pay refers to the acceptability of the price charged and setting tariffs to reflect the value that is placed on the good. It is particularly useful to consider in cases where service providers want to determine an acceptable increase to tariffs to improve cost recovery. Ability to pay focuses on the resources available to consumers and whether these are sufficient to pay the tariff level. It is especially relevant when the objective is to determine whether tariff levels preclude a portion of the target population from consuming the service.

While willingness to pay is a key factor in determining affordability, the available data for this study requires a focus on the ability to pay aspect of affordability. The remainder of the literature review thus focuses on this dimension of affordability.

2.2 Why does affordability matter?

Affordability matters because of two main, often contradictory, objectives of utilities and the state: (1) financial sustainability and (2) social protection. In an ideal setting, the tariffs charged to municipal customers for services would ensure cost recovery; however, the tariffs required to recover all cost may be too high, making the services unaffordable to some households. For instance, an affordability study in France founded that female-headed households and households with substantial number of people who receive social grants are more likely to face affordability constraints (Mark and Wrase, 2017). Furthermore, unaffordable tariffs may lead to high levels of non-payment which further impacts negatively on financial sustainability. The human rights perspective to water services necessitates an additional social protection objective to ensure tariffs are set to levels that do not inhibit access. Where they do, the state has a responsibility to step in to create safety nets for the poor and low-income households.

From a basic needs perspective, unaffordability of water may infringe on the capacity to fulfil other basic human needs which are necessary for survival such as cooking (Bos, 2016). Bos (2016) adds that from the human rights perspective, it hampers progressive realization since unaffordability of water may imply that one or more human rights cannot be enjoyed by the individual. Therefore, a nuanced understanding of affordability of water is important.



Source: Leflaive, 2009

Figure 1: Trade-offs affecting water tariff setting

Figure 1 from Leflaive (2009) shows the diverse set trade-offs to be considered when setting water tariffs. While technically feasible, it becomes politically and practically difficult for municipalities to set tariffs at levels that would make the service unaffordable for a proportion of their target population (Gawel and Bretschneider, 2011a). Reconciling social protection and cost recovery objectives requires an understanding of affordability. It is important for the municipality to understand by how much tariffs can be raised to reach cost recovery without harming the most vulnerable. Similarly, the state needs to know how large the safety net needs to be to ensure the most vulnerable are protected.

2.3 Measuring affordability

Two prevalent approaches to measuring affordability from an ability to pay perspective are the affordability ratio and the residual income approaches. These have been applied to varying degrees in the water services sector with affordability ratios having clear dominance. A third and alternative approach combines both methods and calculates the ratio of water services expenditure to residual income where residual income is household income less food expenditure.

Affordability Ratios: What proportion of household income is allocated to water services?

The most common and popular measure of affordability of water services is affordability ratios. These ratios indicate what proportion of household income is spent on water services. The OECD (2003) differentiate between macro-affordability ratios and micro-affordability ratios. The former calculates average national water services expenditures divided by average household income and the latter does the same but for different subgroups such as income groups, family type and composition and geographic region (Cruz et al., 2015). Macro-affordability ratios are what Gawel et al. (2011) refer to as Conventional Affordability Ratios (CAR).

The calculated ratio is compared to a pre-defined threshold. Prices are considered affordable where the ratio is below the threshold and considered to be creating a financial burden where it is above the ratio (Hutton, 2012). This section presents findings from the literature on the different measures of water expenditure used to calculate the ratio as well as the relative merits of using income versus expenditure as denominators. It also presents some perspectives on how the threshold is determined and a critique of macro-affordability ratios.

What numerator to use?

$$Affordability\ ratio = \frac{Expenditure\ on\ water\ services}{Total\ household\ income\ or\ expenditure}\ x\ 100 \quad (1)$$

Equation 1 above presents the general formula used to calculate affordability ratios. The first issue when calculating affordability ratios is deciding what numerator to use, i.e. defining 'expenditure on water services'. Hutton (2012) suggests three possible definitions of ‘expenditure’: (1) financial cost, which is the size of the water bill the household must pay, (2) financial cost plus other costs such as treatment and storage and (3) capital cost or connection fee. The first two refer to affordability of consumption while the third is a measure of the affordability of access which, depending on the number of unserved households in a country, may be as important as that of consumption. Some studies consider water services to refer only to water while others also include waste water in the bill.

Cruz et al. (2015) compute the water bill (water and waste water) value for 275 Portuguese mainland municipalities using a consumption level of 70 litres per capita per day (WHO, 2011), the average household size per municipality and the associated tariff schemes in charge. Christian-Smith et al. (2013) conducted a pilot study in two regions of California, the City of Sacramento and Tulare Lake Basin to assess water (drinking water only) affordability. They calculate water expenditure for a water system as the amount households pay to use 1500 cubic feet of water per month. The price per unit of water and the rate structure thereof was considered. The authors also consider water expenditure as the average monthly bill plus replacement costs, the cost to purchase non-contaminated water.

Fankhauser and Tepic (2005) note that utility expenditures can be defined as actual payments instead of billed amounts. They use self-reported water payments from household data for both water and waste water. The difference in billed and actual amounts can be substantial due to poor collection rates.

What denominator to use?

The second issue when calculating affordability ratios is deciding what denominator to use. The literature considers whether household income or household expenditure is the most appropriate denominator. Studies use either the median or the average income as the denominator to calculate the ratio.

Hutton (2012) finds that most ratio calculations use income data but where this is not available or is found to be unreliable, expenditure is used as a proxy. Expenditure data is often a better indicator of living standard and preferable to income especially in developing countries where households receive incomes from informal activities and agricultural production. In addition, Mark and Wrase (2017) suggest that in a developing country with a large informal sector, expenditure data provides a better understanding of affordability when compared to household income data which may not include all sources of income. These sources of income may also be poorly recorded making expenditure data better estimates of welfare (Deaton, 2001).

Expenditure data is however laborious and costly to collect leading to the appeal of income data despite its apparent limitations.

Income and Expenditure Surveys (IES) are prominent sources of data for obtaining all the inputs required to calculate these affordability ratios. These are however not administered in all countries and where this is the case alternative data sources need to be used. Furthermore, household income and expenditure surveys are prone to potential sources of error. These include: recall errors due to memory failures; reporting errors and the number of items covered and conditioning effects from being in the survey (Deaton and Grosh, 2000; Scott and Amenuvegbe, 1990). It is also widely acknowledged that richer groups are under-sampled in household surveys (Szekely and Hilgert, 1999; Deaton, 2001). In many household surveys, including those in South Africa, some of the poorest people are also not captured.

Cruz et al. (2015) use average household disposable income obtained from the Directorate-General for Taxation. Fankhauser and Tepic (2005) prefer to use expenditure data obtained from household surveys as they believe that this is more reliable than income.

What should the threshold be?

The threshold used to measure the ratios against is imperative to assessing affordability. Table 1 below shows the thresholds used by several international agencies. Some of these refer to thresholds for water only and some to water services (including wastewater). These range from 3% to 5%, however poorer households, especially those residing in developing countries, face much higher percentages (OECD, 2009).

Table 1: Thresholds used by international agencies

International agency	Threshold
UNDP (water only)	3%
World Bank: Africa Infrastructure Diagnostic (water services)	5%
OECD (water only)	4%
African Development Bank (water services)	5%
Asian Development Bank (water services)	5%

Source: Hutton, 2012; Smets, 2009; Fankhauser and Tepic, 2005

Besides the international agencies listed in Table 1, the Universalist Services Committee advocates for 2.5% of household income and the U.S Environmental Protection Agency (EPA) standard is that households pay no more than 2% for water only (Mark and Wrase, 2017).

Deciding the level for the threshold requires a certain value judgement. Following an analysis of thresholds used globally, Hutton (2012) notes that, regrettably, these thresholds are often not backed up by empirical analysis. Gawel et al. (2011) attempt to rectify this problem and apply a microeconomic household model to understand affordability. They normatively define two quantities: a minimum quantity of the utility (the index good) that is necessary to reach a decent standard of living and a minimum quantity of all other consumer goods except the utility. Once these are determined or decided, and the prices and income are known, an implicit target ratio can be derived.

Hutton (2012) further notes that the mechanism through which a subsidy is provided will generate different results on affordability. A subsidy that reduces expenditure on water will reduce the proportion of the cost of water more substantially than an income top up of the same amount (Hutton, 2012). Hence, the threshold should also vary depending on the mechanism of support provided to low income households.

Pitfalls of the affordability ratios

Gawel et al. (2011) contend that affordability ratios suffer from severe shortcomings that render them of limited usefulness for policy design. Firstly, there is no correlation to a minimum consumption level. This means that poor households that are consuming very small quantities of water can also be reflected as having no affordability problem. Secondly, Mack and Wrase (2017) explain that the other primary pitfalls of expenditure-based ratios is that households with above average income, who consume huge amounts of water for non-essential reasons, may be deemed water poor. Hence, there is no correlation to a maximum and so some well-off households consuming large quantities of water may also be identified as having affordability problems.

A study by Christian-Smith et al. (2013) highlights how the macro-affordability ratios can conceal underlying heterogeneity among households when applied too broadly. They implemented the ratio using three different scales namely the (1) water system scale, (2) block group scale and (3) the household scale and found that affordability measures calculated at different scales of analysis lead to different results. The more granular the scale the greater the degree of unaffordability. For the rural case study, the authors reported 17% of the units to be paying unaffordable rates at the water system scale. This percentage increased to 27% when replacement costs were accounted for. The respective figures at the household scale, are 29% and 51% respectively.

The Organisation for Economic Cooperation and Development (OECD) notes that while donors and international financial institutions use a benchmark of 3% to 5% of household income as an indicator of affordability of water tariffs, this rule of thumb is often disconnected from local situations (OECD, 2009). The study recommends defining criteria for assessing affordability locally because the actual share of income spent on water and sanitation by households can be much higher. This is typically the case where unserved households that rely on vendors who charge prices higher than those for network services. In this case, charging for water above the international thresholds but below actual expenditure on water would represent improvement in affordability (OECD, 2009). The point being emphasised here is the importance of assessing actual willingness and ability to pay in local populations when determining the relevant threshold. Willingness to pay for improved services may be higher than expected.

The extent that water rates are deemed affordable depend on the water consumption level analysed and the affordability benchmark applied (Mark and Wrase, 2017). However, there is no consensus on the minimum level of water consumption to meet the basic human needs.

Micro-affordability ratios: addressing some of the shortcomings of the macro-affordability ratios

As discussed above, micro-affordability ratios apply the measure to different subgroups such as income groups, family type and composition and geographic region (Cruz et al., 2015). Micro-affordability ratios help to address the shortcomings related to heterogeneity of households that get masked when using macro-affordability ratios.

Cruz et al. (2015) use observed water consumption levels and actual income at the household level to calculate the percentage of households in Portugal's municipalities with a ratio greater than 3%. They find a range between 2.4% to 27.1% across 13 municipalities. Looking at affordability for low income households, they find that 32% of Portuguese municipalities face affordability problems. This contrasts with the macro level ratio at national level that shows that on average water affordability is not an important issue in Portugal. These results support the findings from Christian-Smith et al. (2013) that prevalence of unaffordability increases when a more granular scale is considered.

Residual Income Approach: How much income does the household have left for other goods after purchasing the utility service?

The residual income approach introduces a normatively determined residual income as an alternative threshold to the ratios (Gawel and Bretschneider, 2011a). The residual income is the amount of money that a household has left over after paying for the utility. The actual residual income is compared to a normatively defined residual income that a household should have remaining after paying for the utility to assess the affordability of the utility. What should the threshold be?

Niëns et al. (2009) set the normatively determined amount to the poverty line. A household is said to be impoverished by the expenditure on the service if their income was above the poverty line prior to purchasing the utility service and are now below it post purchase. The authors alternatively refer to the residual income approach as the impoverishment method to further emphasise the point that the approach is concerned with ensuring that expenditure on water does not result in poverty.

Poverty is popularly measured using poverty lines making these a first step to determining a threshold to measure residual income against. Two types of poverty lines can be set: an absolute poverty line and a relative poverty line. Absolute poverty lines determine the minimum basket of goods that is required to be considered non-poor. In contrast, relative poverty lines directly link to a society's standard of living where this is some function of the national income or median income (Bundlender, Leibbrandt and Woolard, 2015). An example is the OECD's poverty lines which are set at 50% or 60% of median national income. Absolute poverty lines are mostly applied in developing countries while developed countries have moved to relative lines.

Ravallion's (1998) Cost of Basic Needs is the commonly applied method to determining absolute poverty lines in South Africa. Ravallion (1998) proposes calculating three lines: (1) a line based on minimum food needs for daily energy requirements, plus essential non-food items called the lower bound poverty line, (2) a line below this threshold that indicates extreme poverty called the food poverty line and (3) a line above it to indicate a broader level of household income adequacy called the upper bound poverty line. The food poverty line is established by calculating the cost of food that would meet the minimum caloric intake a person needs to survive. Determining the basket of goods requires studying the consumption habits of the poor, a reference group which must be chosen up front. This group's average caloric intake is calculated, and the food expenditure associated with this is linearly adjusted (keeping food item shares constant) until the minimum caloric intake is met (Bundlender, Leibbrandt and Woolard, 2015).

The calculation of the other two lines is more controversial because there is no minimum caloric intake equivalent for benchmarking. Ravallion (1998) proposes calculating the non-food expenditure of households that have a total expenditure that is similar to the food poverty line and adding the amount to the food poverty line to arrive at the lower bound poverty line. Taking the food poverty line as the total food expenditure of a household and examining what these households spend on non-food items and adding this to food poverty line produces the upper bound poverty line.

Statistics South Africa (StatsSA) typically uses decile two to four as the reference group and a minimum caloric intake of 2100 kilocalories for calculating poverty lines for the country (Statistics South Africa, 2015). Following a rebasing in 2015, the latest poverty lines are R335 per person per month for the food poverty line, R501 for the lower bound poverty line and R779 for the upper bound poverty line. These are updated annually to adjust them to consumer price index. Application of the residual income approach would consider all three poverty lines as benchmarks for understanding how water expenditure creates affordability constraints of other goods.

Affordability ratio using residual income: What proportion of a household income after spending on food is allocated to water services?

An alternative measure using residual income calculates the ratio of water expenditures to income after the household has spent money on basic necessities (usually food). This is non-discretionary expenditure and thus the ratio serves as an indicator of household ability to pay for water without reducing food expenditures for example. Water charges exceeding 10% of household residual income in this sense are considered a signal of probable affordability problems (Niëns et al., 2009).

2.4 Setting affordable water prices: the inclining block tariff

Regardless of the approach used, it is evident from the discussion above that the price of water is a crucial factor to understanding affordability. The objective of pricing water is to set rates that are affordable for consumers but also sufficient to recover the fixed and variable costs of building and maintaining infrastructure (Mark and Wrase, 2017). The price a household faces is a function of the tariff structure. Pro-poor tariff structures are designed to cushion the poorest households from unaffordable rates. To this end, South Africa implements an inclining block tariff structure (IBT) for water services. This tariff structure has found popularity in developing countries for its redistributive and efficient resource allocation appeal. IBTs are a volumetric form of nonlinear pricing where the households who consume less face lower average prices. IBTs are argued to ensure affordable consumption of water for most households by charging below cost prices for basic consumption in the first block and higher prices in later blocks. An underlying assumption of the former is that high income households have higher consumption levels than low income households while the latter suggests that consumer respond to the rising marginal prices. Most South African municipalities use an IBT structure for water. This section reviews literature on the impact of IBTs on affordability, outlines the drawbacks and considers the conditions under which IBTs are effective.

One drawback of inclining block tariffs and other block pricing systems is the potential welfare loss for society. Ruijs (2007) conducts a comparison between welfare and distribution effects of alternative pricing systems and finds that pro-poor price systems may result in lower average welfare than a flat price system although individual welfare for the poor increases. Furthermore, while pro-poor pricing systems improve income distribution, they tend to lower revenues for water utilities suggesting a trade-off.

Testing IBTs for electricity use in California, Borenstein (2010) finds that the rate structure redistributes income to lower income groups, but the effect is only modest. Looking at demand quantities, he also finds preliminary evidence that consumers do not respond to the tariff structure they face which puts the efficient allocation motive into question. The efficient allocation motive only prevails if consumers respond to the tariff structure and change their consumption patterns.

Pashardes and Hajispyrou (2002) criticise the distributive effect of IBTs because water consumption is affected by household size and age structure within a household. In this case, the notion of income is no longer equivalent to that of welfare. IBTs create a financial burden for households whose income is low but still consume high amounts of water because of size and age composition. They construct a relative equivalence scale to measure welfare effects by family size in Cyprus and find that the cost of water consumption for households at low budget levels increases due to the IBT by 6.3% of the average water bill when one adult is added and by 3% when one child is added to the household.

The case of South Africa is unclear due to a limited number of studies conducted to investigate the effects of the IBT structure. The country is one of a few in the world where the first block is often a lifeline block, i.e. the volume of water corresponds to the essential minimum consumption, which in South Africa is set to 6 kl. Poor households with consumption levels up to 6 kl are exempt from paying tariffs in many municipalities, with some providing up to 15 kl of water free.

2.5 The minimum quantity of water services required

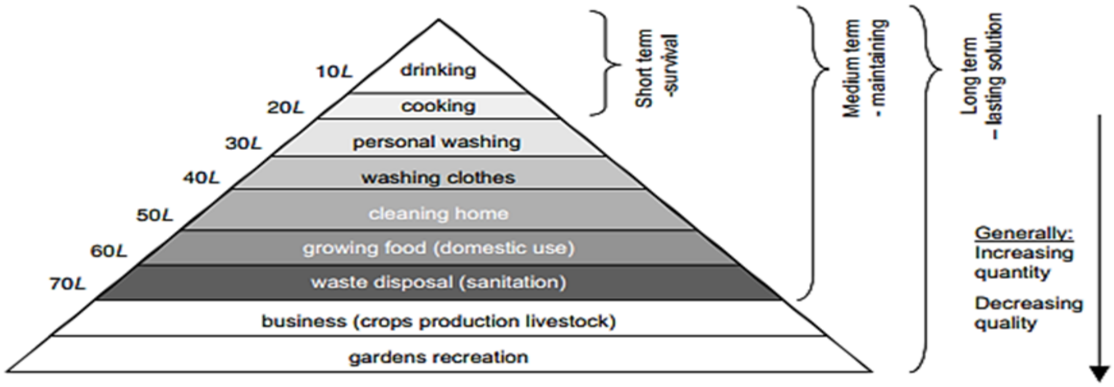
Effecting the human right to water services requires setting a minimum standard with respect to access and quantity consumed. Setting the minimum standard of water consumption is challenging not only due to different climatic and cultural characteristics, but also because it is difficult to differentiate between essential and non-essential uses of water (Mark and Wrase, 2017). The perceptions of essential uses of water are likely to vary based on the income, culture, religion, and diet of people.

The design of progressive IBT structures ensures that consumption in the first block is priced such that the criteria of affordability is met. This requires a minimum quantity to be defined and the price set to correspond to the first block. The World Health Organisation's South East Asia's technical note provides guidelines for required quantity of water based on uses. The standard used is that all people have safe access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points need to be sufficiently close to shelters to allow use of the minimum water requirement.

This standard is measured against the following set of indicators:

- At least 15 litres per capita per day (lpcd) is collected.
- Flow at each water collection point is at least 0.125 litres per second.
- There is at least 1 water point per 250 people.
- The maximum distance from any shelter to the nearest water point is 500 metres.

The note acknowledges that water has many uses with varying degrees of importance. Figure 2 is from the note and is inspired by Maslow's hierarchy of needs to show guidelines for water consumption by use. The point made here is that each additional use has health and other benefits, but with decreasing urgency.



Source: WHO, 2011

Figure 2: Hierarchy of water requirements

The WHO recommends the following guidelines (Table 2) for minimum short-term survival and minimum medium-term allocation. Survival requirements can be up to 20 lpcd depending on climate and individual physiology, social and cultural norms and food type. Similarly, medium term requirements can be up to 70 lpcd depending these factors and also on access to a flush toilet.

Table 2: WHO Minimum Guidelines

Guidelines: Minimum short-term survival	Guidelines: Minimum medium-term allocation
7 lpcd (sustainable for only a few days) • Drinking 3-4 lpcd • Food preparation, clean-up 2-3 lpcd	*15-20 lpcd (sustainable for a few months)* • Drinking 3-4 lpcd • Food preparation, clean-up 2-3 lpcd • Personal hygiene 6-7 lpcd • Laundry 4-6 lpcd

Gleick (1996) argues that at least 50 lpcd are required to meet human and ecological needs. This is divided as follows: 5 lpcd for drinking in tropical climates, 20 lpcd for sanitation, 15 lpcd for bathing and 10 litres lpcd for food preparation.

According to the South African constitution, each person has the right to clean water. The free basic water policy was implemented in 2001 to provide poor families with 6000 litres of free water every month. This amount was based on 25 lpcd for a household of 8 people and is just above the WHO's recommended 20 lpcd, however it has been criticised as being too low to meet the poorest households' basic needs (Smith, 2010). For example, the amount does not include water for home-grown vegetables and is also not sufficient to cater for the special of the sick (Goldin, 2005). As a result, a number of municipalities deviate from this minimum figure (South African Government, 2016).

Determining the minimum quantity therefore depends on several variables which include but are not limited to uses of water, the desired health level, the sources of water available and whether the solution implemented is for the short, medium or long term.

Determinants of household water demand

Based on the literature reviewed thus far, it is evident that the quantity of water consumed is an essential element to understanding affordability and designing pro-poor pricing structures. It is therefore worthwhile to investigate the water demand function. There is an extensive body of literature on the determinants of water consumption. Determinants emerging from studies include, but are not limited to: household income, attitudes towards water conservation, household size and composition, mean age of individuals in the household, the cost of water to the household, education levels, the percent of water efficient stock (for example, low flow taps) as well as water conservation intentions (OECD, 2008 and Beal et al., 2011). This section discusses the various methods used to estimate this relationship, the key determinant and their respective effects on water consumptions.

Estimating the effect: methodologies

The studies reviewed all use a variation of econometric models to estimate the effects of several independent variables on water consumption. The studies considering the effect of behaviour on water consumption use randomised controlled trials and natural experiments to estimate the effect.

The choice of econometric model is driven by theory, the available data and the relationships to be estimated. Ogunbode and Ifabiyi (2014) apply multiple linear regression model to primary data collected in the state of Osun, Nigerian. This method models the relationship between a scalar and continuous variable and a set of explanatory variables. Grafton et al. (2011) conduct their assessment of the determinants of residential water consumption using ten country household surveys. Two models are estimated. The first is a multiple regression analysis and the other an ordered probit regression. The former estimates the relationship between water consumption and a set of socioeconomic variables and residential characteristics. The latter is a method that applied to ordinal variables and allows for an analysis of relative odds for each category of the variable. The authors apply it to a set of self-reported water saving behaviours to determine what drives presence of these behaviours.

In addition to a linear regression model, Schleich and Hillenbrand (2009) apply instrumental variable techniques to address potential endogeneity in their linear model. Endogeneity refers to a case where one or more of the independent variables included in the model are correlated with the error term violating one of the crucial assumptions for linear regression modelling. Romano et al. (2014) apply a set of linear mixed models which extends the conventional linear model by considering random effects, hierarchical effects, repeated measures and spatial correlations. Linear models assume that observations in the data are independent, an assumption that does not hold when there are clusters of data. An example is data collected at a water system level. Although data between different water systems is likely to be independent, observations within a water system are likely to share some properties.

Studies on the determinants of water in South Africa include one by Jansen and Schulz (2006) who studied determinants of water demand in the Cape Metropolitan Area using primary data collected from randomly selected households in five suburbs and water consumption data from the City of Cape Town. They also apply instrumental variable techniques using two-stage least squares to address the fact that the IBT structure means that high levels of water consumption will always be observed for high marginal price and hence higher prices will interact with higher random elements. Van Zyl and Griffeon (2014) use the SWIFT software package that is used by a few municipalities to capture water bill and consumption information to investigate factors affecting the average domestic demand of a large number of suburbs in South Africa using standard linear regression analyses.

Dependent variable: water consumption

The main variable of interest in all the models reviewed is water consumption. It is largely measured as average water use per capita per day in litres (Romano et al., 2014; Schleich and Hillenbrand, 2009) or kilolitres per year (Grafton et al., 2011). The key difference between studies is the type of water consumption that is modelled. Grafton et al. (2011) consider household water consumption more broadly while Schleich and Hillenbrand's (2009) average water per capita per day is calculated from the total of amount of water sold to the household by the water utility and sewage works and the total number of persons connected to the system. Romano et al. (2014) calculate the average consumption of drinking water for domestic use in the chief towns of each Italian province. Van Zyl and Griffeon (2014) model water consumption as Annual Average Daily Demand in kilolitres per day.

Key determinants

The discussion below presents results for determinants of water consumption. While most models control for a comprehensive set of variables, the variables discussed below are those with a statistically significant effect on water consumption. Only a few studies have looked at household behaviour.

Price

The law of demand suggests a negative relationship between the price of water and its consumption. Several empirical studies have found this to be true although the size of the effect differs between them. A linear model is estimated in some studies while others estimate a natural logarithm model which allows for the estimation of the price elasticity of demand. Schleich and Hillenbrand (2009) point to two broad types of water use, water used for necessities and for non-necessities. A low price elasticity is expected for necessities because of the lack of substitutes where the price elasticity is expected to be higher than for non-necessities.

In models that include household characteristics, water-saving devices, environmental concerns and attitudinal characteristics as explanatory variables, Grafton et al. (2011) find that the average volumetric price of water is an important predictor of water consumption. The model finds the average price elasticity of water to be -0.429, i.e. a 1% increase in the average price of water reduces water consumption by 0.429%. The tariff applied on water is found to have a strong negative effect on residential water consumption in the chief towns of Italy (Romano et al., 20). A unit increase in the tariff decreases the average litre per person per day by 0.169 litres per capita per day. Jansen and Schulz (2006) calculate the price elasticity for different income groups and find a price elasticity of -0.23 for the poorest group and -0.99 for the richest group of consumers.

While economic theory states that economic agents respond to marginal prices, this relies on the assumption that consumers are aware of the price and structure of tariffs. A contention in the literature is whether consumers, especially when faced with block tariffs, respond to average or marginal prices. Arbues et al. (2003) contend that the rate structure may not be sufficiently known by consumers to react to marginal prices.

Income

A positive relationship is found between income and water consumption across all the studies. Grafton et al. (2011) use income after tax as an explanatory variable and finds a positive relationship between water consumption and income. The estimated income elasticity at the mean income is 0.11, i.e. a 1% increase income increases water consumptions by 0.11%. Schleich and Hillenbrand (2009) conduct their analysis separately for old federal German states and new states and find the income elasticity is 0.241 and 0.658 respectively confirming that water is a normal good whose consumption increases with income. Households with higher levels of income consume more complementary commodities linked to water such as gardens, saunas, pools and dishwashers. Romano et al. (2014) uses average taxable income per capita and also finds a positive relationship. Van Zyl and Griffeon (2014) use stand value as a proxy for income and find a small but positive effect on water consumption. Stand value is a better proxy for wealth than it is for income and is thus likely underestimating the effects of income on water demand. For the purposes of understanding determinants of water, changes in income likely play a bigger role in than changes in the value of ones stand.

Household size and age groups

The estimated effect of household size is found to be positive. Grafton et al. (2011) control for number of adults and number of children which speaks to both household size and composition of the household. They find that adding an adult to the household increases water consumption by 13.3% while adding a child increases consumption by 5.9% where consumption is measured as kilolitre per year. Jansen and Schulz also find a positive relationship between household size and water consumption. When water consumption is measures in per capita terms, adding an additional household member is found to have a negative impact on consumption. This is likely because water for non-basic uses does not change with the addition of more household members. Schleich and Hillenbrand (2009) a negative relationship between average household size and per capita water use.

The results by Grafton et al. (2011) suggest that children consume less water than adults. Schleich and Hillenbrand (2009) control average age in the population and their results indicate that as people get older, they appear to use more water. In their study the average age is 42 years, if this increases by one year, the consumption per person increases by 1.5 litres per day.

Stand area

A key finding of the study by Van Zyl and Griffeon (2014) is the importance of stand area in determining water consumption. They find that all else constant, a metre squared increase in stand area increases the water consumed by 0.47 kilolitres. It is important to note however that their model does not control for price of water which is an important determinant of demand. The results reported therefore have a degree of bias.

Climate

An important driver of water demand is climate because it is believed that variables such as temperature and rainfall have an influence on the frequency and amount of activities such as personal hygiene and gardening which involve water use. Schleich and Hillenbrand (2009) control for cumulated rainfall in mm and find a negative relationship between summer rainfall and water demand. In particular, a ten percent decrease in summer rainfall would lead to an increase in daily water consumption per person of 1.2 litres. Romano et al. (2014) also report a negative relationship between average annual precipitation and per capita water use.

Leaks

Poor quality plumbing products and resulting on-site leaks are a considerable driver of water consumption in South Africa. A 2008 study by van Zyl et al. found that around 50% of plumbing products used in South Africa are non-compliant with standards. Spot checks of low cost housing developments indicated that more than 90% of the plumbing products were non-compliant and that these failed and leaked at an early age. “While the average house visited was only 1.5 years old, 50% of the toilets were already leaking” (van Zyl et al., 2008, p.vi). The same study found that 59% of 182 properties assessed had on-site leaks and that average leakage rates on properties with leaks were 30 kl per month.

Incidence of on-site leakage in middle to high income suburbs in Cape Town and Mangaung was 17% and 28% respectively, lower than that of 67% found in a previous study by Lugoma et al. (2012) in Johannesburg (Couvelis and van Zyl, 2015). Couvelis and van Zyl (2015) notes further that literature suggests that on-site leakage is highest on low income properties, not covered under their study. They indicate that the monthly on-site leakage rates in Cape Town, Mangaung and Johannesburg can be estimated as 2.6, 8.0 and 11.0 kl per month per property.

Behaviour

Recent studies in behavioural economics have highlighted behaviour as an important non-pecuniary determinant on demand. A few studies have been conducted to test the effect on water conservation. Datta et al. (2015) use a randomised controlled trial to determine the impact of simple and replicable interventions on water consumption in Costa Rica and find a positive and significant effect on reduction. Three interventions using stickers added to water bills were tested: (1) communicating the average household’s consumption in the neighbourhood, (2) communicating the average household’s consumption in the city and (3) communicating the household’s consumption and facilitating goal setting and plans regarding by how they would reduce consumption. The first interventions led to statistically significant reductions in water consumption of between 3.6% and 5.7%. The results for the third intervention is between 3.4% and 5.6% reduction. Furthermore, their results indicate that the comparison treatment was more effective for high income users whereas the planning treatment was more effective for low income users. Ferraro and Price (2013) partnered with a metropolitan water utility in Atlanta, Georgia and implement a natural field experiment to test social comparison messages on water demand and find that social comparison messages are more effective than general pro-social messages. Moreover, the highest effect is observed among high users. An important note the authors make is that the effectiveness of the messages wanes over time.

2.6 Conclusion

This literature review has elucidated several factors regarding the affordability of water services. The first is with respect to the definition of affordability, particularly that it is a normative concept which is a function of both willingness and ability to pay. How affordability is measured depends on which of these aspects is of interest. Willingness to pay is typically measured using contingent valuation methods and aims to establish the value of goods and how much users are willing to sacrifice for improvements. Ability to pay is measured using either affordability ratios or residual income and aims to understand the financial burden that expenditure on water exposes households to.

Secondly, there are two main approaches to measuring affordability: the affordability ratios and residual income approach. The literature review finds that ratios calculated at a broad level and assessed against internationally recognised thresholds tend to underestimate affordability constraints at the household level. Furthermore, ratios ignore the quantity of water consumed and hence some customers may appear to face constraints despite consuming too much water. Conversely, households consuming too little water may appear to face no constraints. The residual income approach is particularly useful for understanding poverty. It is therefore important to use a comprehensive set of measures, applied at various levels and measured against a set of thresholds that capture the local context to paint a complete picture of the affordability situation in an area.

A third important finding emerges when affordability is approached from the human rights perspective. This human rights approach requires a determination of a minimum standard with respect to access and quantity of water services consumed before affordability can be measured. Studies applying affordability ratios and the residual income approach have thus far ignored this aspect leading to cases where households are marked as having no constraints despite consuming water below subsistence level.

Finally, the literature review points to income, price, climate, household size and composition by age, on-site leakage rates, behaviour and stand area as important determinants of the quantity of water households consume. These are important subgroups that can be considered when calculating micro-affordability ratios. For example, households can be grouped by household size and affordability ratios calculated to establish whether affordability differs by this factor.

This study aims to contribute to the South African literature on water services affordability by taking the above factors into account to produce a more nuanced measure of affordability. The study focuses on the ability to pay aspect of water affordability and calculates both the affordability ratio and residual income for households across five different cases. Furthermore, an exercise to match billing data to Census 2011 data allows investigation of household characteristics across various thresholds for all the different measures resulting in a more comprehensive picture of water services affordability in the country. The next section presents the methodology applied to achieve this objective.

3 METHODOLOGY

This section presents the analytical framework applied, discusses sources of data used and the process followed to create a dataset from analysis. It also introduces the unit of analysis used, the small area layer (SAL), and the four case study municipalities to which the analysis was applied.

3.1 Proposed analytical framework

Research on water affordability in South Africa is limited due to the lack of household level datasets that contain both billing information, water consumption and household income, the main variables required to understand affordability. A key innovation is this study is the overlay of Census 2011 data (which contains income data) and the SWIFT dataset (which contains billing data) to create a dataset that makes it possible to investigate affordability for a subset of municipalities.

Drawing from the literature review, this section sets out a proposed analytical framework for measuring the affordability of water services in South Africa. The framework is intended to contribute to a nuanced understanding of affordability in the South African context by providing a comprehensive analysis of affordability that considers three main factors: expenditure on water, income and water consumption. The proposed analytical framework is presented in

Figure 3 below. This framework was applied to a pilot case study and revised based on findings. The revised analytical framework is presented in section 3.8.

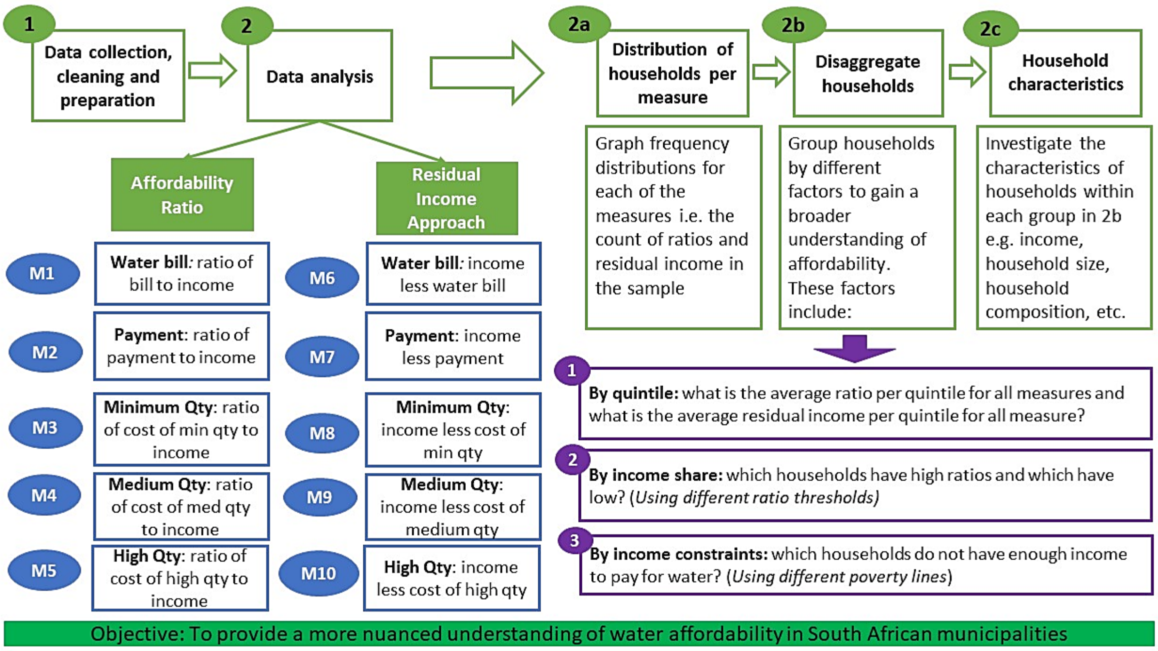


Figure 3: Analytical Framework

The literature review identified two common approaches to determining affordability: (1) affordability ratios and (2) the residual income approach. To understand affordability across the three factors listed above, the two approaches are applied to five different cases resulting in a total of ten different measures for water affordability.

Case 1: Water services bill

This scenario considers what consumers are billed for water services and not necessarily what they pay. A ratio of the water bill to income is calculated for each unit of analysis[3] as well as a residual income which is the unit's average income less the average expenditure on water. The quantity of water consumed in this case is taken as what is stated on the bill.

Case 2: Water payment

In contrast to the previous scenario, this one considers what consumers actually pay for water services which, as discussed in the literature review, is often less than the bill. The actual payment is influenced by affordability: in not paying the bill in full, the household may be providing some indication of how affordable they perceive that bill to be. A ratio of the payment

[3] The unit of analysis used was a small area layer (SAL) as discussed in Section 3.4 in the Methodology.

for water to income is calculated for each unit of analysis as well as a residual income which is the unit's average income less the average payment for water.

Case 3: Minimum quantity of water consumed

The minimum quantity of water refers to a normatively set amount that an individual requires for short term survival to cover their basic needs of drinking and cooking. The proposed minimum quantity of water to be used is 20 lpcd as suggested by the WHO. In this case, the analysis assumes every unit of analysis is consuming the minimum quantity and calculates the associated cost. The ratio of this cost to income is then calculated. This measure is therefore intended to assess the social protection aspect: can households afford the amount of water required to meet their basic needs?

Case 4: Medium quantity of water consumed

This analysis goes one step further to consider affordability constraints for a quantity of water that would be required for medium term maintaining. In addition to drinking and cooking, activities include personal washing, washing clothes, cleaning home and waste disposal. The assumption made here is that in the medium to long term, the minimum quantity of water is inadequate to fulfil the full set of activities that satisfy all human needs. The proposed medium quantity of water to be used is 70 lpcd as suggested by the WHO. Hence, the analysis assumes every unit of analysis is consuming some medium quantity of water and calculates the associated cost. The ratio of this cost to income is then calculated.

Case 5: High quantity of water consumed

A high quantity of water consumed is associated with activities such as garden recreation, business (crops production, livestock) in addition to the activities listed above. Due to the lack of a standard guideline, the proposed high quantity of water to be used is a minimum of 100 lpcd and a maximum of 150 lpcd. This is so that an affordability range can be considered. The cost associated with consuming a predetermined high quantity of water is calculated as well as the proportion of this cost to income.

3.2 Limitations of the proposed analytical framework

It must be noted that the proposed analytical framework considers water affordability in isolation of the affordability of other municipal services used by residential customers.

The tariff setting approach in municipalities involves several strategic decisions[4] that affect the size and composition of the household bill for all services. Hence, despite an affordable water bill, it may still be the case that households are severely vulnerable due to high total household bills.

3.3 Sources of data

Two primary sources of data are required to calculate water affordability, namely data on household income and data on household water demand. Additional data on household characteristics is also required to provide further nuance.

Data on household income and household characteristics was obtained from StatsSA's Census 2011. Data was obtained on household income, household size and access to piped water. Household composition (mix of adults and children) is also of interest but was not available at the level of granularity required for the analysis.

Data on water demand by residential customers is available in municipal billing datasets. PDG initially proposed sourcing billing data directly from municipalities but, following discussions with Professor Kobus van Zyl, an alternative option to use the SWIFT dataset managed by GLS Consulting emerged as a more efficient method to gather the data. This dataset contains stand number, portion, sub-portion, and property rate information (rate tariff codes, stand owner and market value). Depending on the billing system there is also water account information (name, tariff code) as well as the water usage information. GLS receives the cadastral information from the municipalities and pulls this into the SWIFT system. For every meter, they calculate the Annual Average Daily Demand (AADD) and link this information to the cadastral shape files.

Given the focus on affordability of residential water tariffs, the study is only concerned with residential customers with access to municipal water. While the SWIFT dataset only includes billed customers, Census data includes all households. Hence, the Census data was filtered to include only incomes of households with access to piped water in the yard and to the

[4] These include decisions on how to allocate the local government equitable share and how much surplus to generate on services. The more equitable share a municipality allocates to water services, the lower the price of water is. Similarly, the more surplus the municipality aims to generate on water, the higher the price.

property. This improves the accuracy of the analysis, however given the focus on customers that are tariffed, this study by design excludes those who do not have access to piped water on stand, which may include the poorest of the poor. It is important to note, however, that in South Africa households who access water via a level of service lower than piped water on the stand receive the service free. Affordability is not an issue for them; access is the key issue here. The implication is that this study is focused on the affordability of municipal water for those who receive it and are required to pay for parts or all of their consumption.

3.4 Selecting a unit of analysis

As discussed in the literature review, affordability ratios are often calculated using an entire municipality as the unit of analysis. In this case, the average expenditure on water in the municipality is compared to the median municipal household income. At the other end of the granularity spectrum would be a calculation of the affordability ratio for each individual household in a municipality. This would allow for a very nuanced analysis, but availability of data is a key constraint here: there is no way to link data on household income for individual households obtained from StatsSA to specific billing records from SWIFT[5].

The unit of analysis selected for this research was a small area layer. A SAL is a geographic unit defined by Statistics South Africa and created by combining all enumerator areas (EA) with a population of less than 500 with adjacent EAs within the same sub-place. SALs typically contain between 150 and 200 households. These SALs are used by StatsSA to aggregate spatial census statistics. By overlaying cadastral data provided by the municipality with SALs and intersecting the data using the geographic information system (GIS), it is possible to determine which properties are in each respective SAL. Therefore, it is possible to 'join' aggregated SAL household data from StatsSA to the SWIFT database.

An underlying assumption of using the SAL as the unit of analysis is that a SAL is relatively homogenous, and so the average income, water consumption level and socio-economic characteristics of the SAL apply relatively consistently across all households within the SAL.

[5] Statistics South Africa are also very careful about releasing census data for individual households although we understand that this is possible under controlled conditions (working on the data at Statistics South Africa premises only, for example) and with stringent confidentiality controls.

3.5 Selecting municipal case studies

The intention of the research was to apply the analytical framework proposed earlier in this section to several case studies. The decision to use SWIFT data instead of requesting data directly from the municipality limited the total sample of municipalities to the 16 municipalities that provide data to GLS. Appendix A provides a list of these municipalities. Some of the municipalities have not submitted data consistently over the last five years, which further limits the sample as the analysis is for the same year across all municipalities to allow for comparison. Initially, the objective was to include three municipalities of different socio-economic contexts for an in-depth analysis and a few other municipalities where a sample would be drawn to test the approach. Due to data availability challenges, the final sample is instead based on what was available and feasible at the time the analysis was completed. As a result, four in-depth case study municipalities were selected. The analytical framework was piloted on one municipality and adapted based on the findings. The revised framework was then used to conduct the analysis for the other three municipalities. The names of the municipalities are anonymised in the analysis to maintain the focus on understanding the affordability constraints and not a comparison of the municipalities to each other. Municipality A was the pilot with Municipality B and C and D making up the other three municipalities included in the in-depth analysis. Descriptive statistics for each municipality are discussed in Section 4.1 of the report.

3.6 Creating a dataset

The data collection process involved obtaining billing data from the selected municipalities discussed above and matching the small areas within each municipality to the small areas in the Census 2011. The result of this matching process is the ability to create a dataset that contains both water services consumption and billing information as well as socio-demographic variables by small area layer. The main advantage of this approach is the ability to understand how socio-economic characteristics that are associated with water demand drive water affordability. Once gathered and matched, the data collected is consolidated, cleaned and prepared for analysis.

The two main inputs that were required to create the dataset for analysis are SWIFT dataset that contains water consumption and billing data in spatial form and socio-economic data from Census 2011 at a small area layer level. Obtaining the data in spatial form was crucial to the analysis as this facilitates the merger of the two datasets using the SAL codes.

The SWIFT dataset is cleaned in the following seven steps that comprise:

(1) Identifying key variables of interest: the data set contained 119 variables of which only 13 variables were required for the analysis. Only these variables were kept in the dataset.
(2) Removing any records that do not have a meter serial number: these records do not have any meters and consequently consumption associated with them
(3) Removing any records for vacant stands: vacant stands in the dataset are those with an average daily demand less than 0.1 kl. These stands have no one residing on them and hence no water consumption
(4) Identifying and removing non-residential customers: the dataset contains tariff codes, these were used to identify the customer type and remove all non-residential customers as the focus of the study is on residential customers.
(5) Identifying and removing duplicate meters: the geographic overlay of small areas creates several duplicates if a stand is split into multiple small areas. These are removed to avoid double counting.
(6) Determining anomalies by calculating the number of meters per SAL and comparing it to the number of households. SALs where the number of meters exceeds the number of households by more than 10% are removed from the analysis.
(7) Identifying outliers based on consumption and removing these SALs from the analysis.

The outcome of the cleaning process is a dataset of annual average daily demand (AADD) for each meter record that has billed consumption associated with it in the municipality. The SAL code, availability and water consumption tariff codes are also kept in the dataset for merging and bill calculation purposes. The variable that indicates whether the record belongs to an indigent household is also kept in the dataset to distinguish indigents from other residential customers. This is particularly important in municipalities where free basic water is only provided to indigent households only. A detailed outline of the data cleaning process is provided in Appendix A.

The Census 2011 dataset contains three key variables of interest namely access to piped water, household income and household size. Access to piped water was used to determine the subset of households that are likely to have access to municipal water. Household income was also only limited to the income of households with access to piped water. Household size was included to assess its correlation with consumption and consequently affordability.

The final dataset used for the analysis is a merger of the key variables of interest from SWIFT and Census. After data cleaning, we found that the number of SALs in the SWIFT dataset did not match the number in the Census dataset. Table 3 compares the total number of small areas in the SWIFT after the data cleaning process[6] with those in the Census dataset.

Table 3: Outcome of merging SWIFT and Census 2011 datasets

	Municipality A	**Municipality B**	**Municipality C**	**Municipality D**
Number of SALs in Census	313	886	577	232
Number of SALs in SWIFT before cleaning	312	542	109	222
SWIFT SALs before cleaning as % of Census SALs	100%	61%	19%	96%
Number of SALs in SWIFT after cleaning	234	445	91	149
SWIFT SALs after cleaning as % of Census SALs	75%	50%	16%	64%
Total meter records	21 011	16 245	9 947	10 581
Total households	45 936	80 952	16 113	22 980
Average households per meter	2.2	5.0	1.6	2.2

Municipality A and D have the least variation between Census and SWIFT prior to data cleaning, while Municipality C's SWIFT data contains only 19% of the total SALs in the municipality. Unlike the former two where the removal of non-useful data in the cleaning process explains the difference, the difference in Municipality C seems to be due to external factors to the analysis. A check of the SALs in Census that are not in SWIFT showed that these all contain households with access to piped water suggesting that the mismatch between the two data sources is likely due incompleteness of billing data submitted to GLS. It is also possible that the municipality only bills and collects revenue from a subset of the households provided with water services. A similar issue may be the reason for the variance in Municipality B.

Only the SALs that matched between the two datasets were used in the analysis, the number of data points is therefore small. The implication is a sample of SALs that is not necessarily representative of all households within the municipality that have access to piped water.

[6] The data cleaning includes removing outlying ratios. The interquartile range is used to determine extreme values and outliers. The effect on average income, consumption and the household bill when outliers and extreme values are kept was used to determine whether to include them in the final dataset.

The total meter records and households included in the analysis are also shown in the table. Based on this data, the average households per meter in municipality A, B and C is no more than two, which is reasonable given that some properties, e.g. complexes and flats are likely to house more than one household. With an unreasonably high household per meter average, Municipality B's results provides further evidence of possible data incompleteness. It also suggests that using households with access to piped water in the dwelling and the yard may overstate the number of households with access to municipal water in the SWIFT data.

3.7 Data limitations and implications

The available data and the data cleaning resulted in a dataset that allowed for an analysis of water affordability, however some gaps in the data and decisions in the cleaning process limit the extent to which the data can reliably and completely answer the research questions set out in the proposed analytical framework. This section outlines the limitations and discusses their implications for the analytical framework and approach.

Obtaining representative income for each SAL

Household income data in the Census 2011 is provided as a distribution per small area layer, not an average or median income per small area. Two approaches are considered to arrive at a representative income for the small area. The first calculated an average income by calculating a weighted average of the midpoint for each income bracket. This approach assumed that the incomes within each small area would be relatively homogenous. However, the Census 2011 income data has a relatively high range of incomes per household in each small area. Moreover, the size of the brackets is increasingly larger as one moves up the income distribution which results in higher midpoints for income brackets at the end of the distribution. Using average income per small area as a reflection of all household incomes likely overstates the average household income and may thus be misrepresentative. The second approach calculates the median income per small area by determining the income bracket where 50% of the households earn within the bracket or less. The midpoint of this income bracket is taken to be the median income for the small area.

Table 4 compares the average and median income in each municipal case study.

Table 4: Comparison of average and median household income in the municipal case studies

Household income	Municipality A	Municipality B	Municipality C	Municipality D
Weighted average **monthly income** (nominal Rand value in 2014)	12 240	15 718	9 288	14 546
Median income (nominal Rand value in 2014)	6 015	6 015	3 034	6 015

The average monthly income is significantly higher than the median in all municipal case studies. The measure chosen for household income has a significant impact on the results because income is the key variable of interest in both the approaches applied in the study. Holding the household water bill constant, a higher income reduces the affordability ratio and residual income and hence the affordability constraints that a household faces. Given South Africa's context of high inequality and acute poverty, the median income is used in the analysis as a closer representation of household income at the small area layer compared to the weighted average household income.

Adjusting income from 2011 to 2014

The water consumption data for Municipality A was available from 2011 but GLS only has SWIFT data from 2014 for the other three case studies. For comparability across municipalities, the data used in the analysis is for 2014. Since household income data is from Census 2011, the figures required adjustment to make them comparable to 2014. The South African Reserve Bank publishes total household disposable income data online on a quarterly and annual basis. Table 5 shows the annual nominal percentage change in total disposable income since 2011.

Table 5: Nominal annual percentage change in total disposable household income

Year	National disposable income (R millions)	Annual % change
2011	1 778 448	0%
2012	1 944 909	12%
2013	2 095 875	7%
2014	2 236 484	7%

The income data is thus adjusted using nominal annual change in household disposable income between 2011 and 2014. Nominal disposable income increased by 8% per annum on average within this period.

No sanitation data in the SWIFT dataset

The analytical framework applied allows for the analysis to go beyond just looking at water consumption to assess water services (both water and sanitation). Apart from Municipality A, however, the SWIFT data available does not contain any information on sanitation tariff codes for use to calculate sanitation bills. Hence, the analysis can only consider water and not water services.

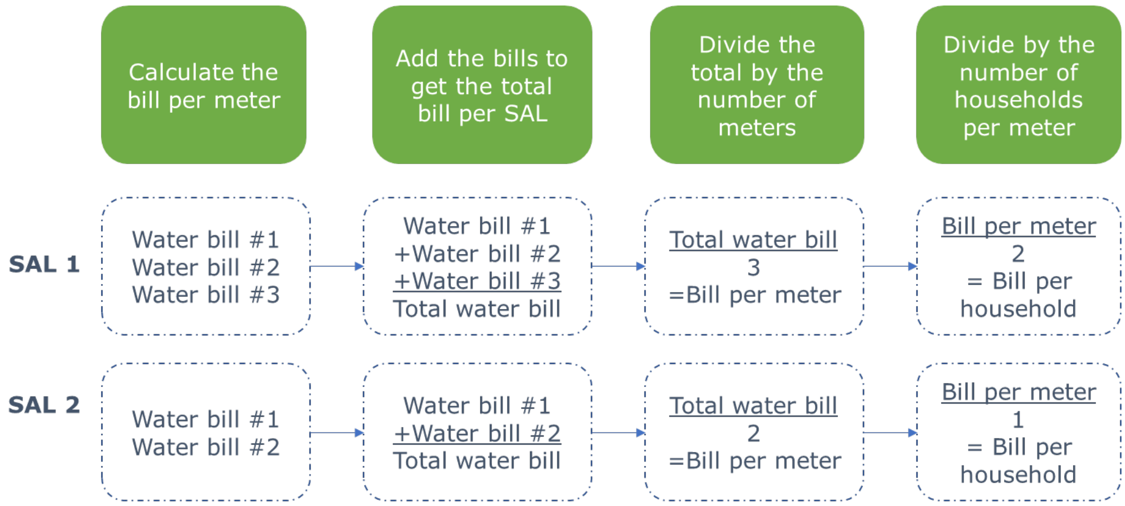
SWIFT data only contains billing information and not payments

The actual amount paid is important to include as water bills tend to underestimate affordability constraints by assuming the entire amount can be paid. Non-payment can serve as an important signal for affordability constraints where a household responds to the cost of water by not paying the bill or only paying a proportion of it. The SWIFT data does not contain household water payment data which made it impossible to consider the water payment variable for the analysis. This aspect of the analytical framework therefore could not be included in the analysis.

Water bill calculation

The water bill per household is calculated as shown in the diagram below. Individual bills are calculated for each meter and summed to get to the total bill per SAL. This is divided by the number of metres to calculate the average bill per meter. Finally, the average bill per meter is divided by the number of households per meter to calculate the average bill for each household within the SAL. A similar approach is used to calculate the average water consumed in the SAL.

Table 6: Average water bill per household calculation method



Sometimes inaccuracies may occur within the billing system of the municipality. As a result, some households may not be billed for their water consumption even though data for household with access to piped water is available. In these cases, the number of households used to determine household per bill factor that is used to estimate the average bill and consumption in a small area may overstate the number of water customers within the small area and consequently understate the average bill and consumption. Using the average might have some degree of error especially in cases where a single household has more than two meters.

3.8 Revised analytical framework

The analytical framework presented earlier in this section was revised following findings from applying it to the Municipality A pilot case study. The new analytical framework used is presented in Figure 4.

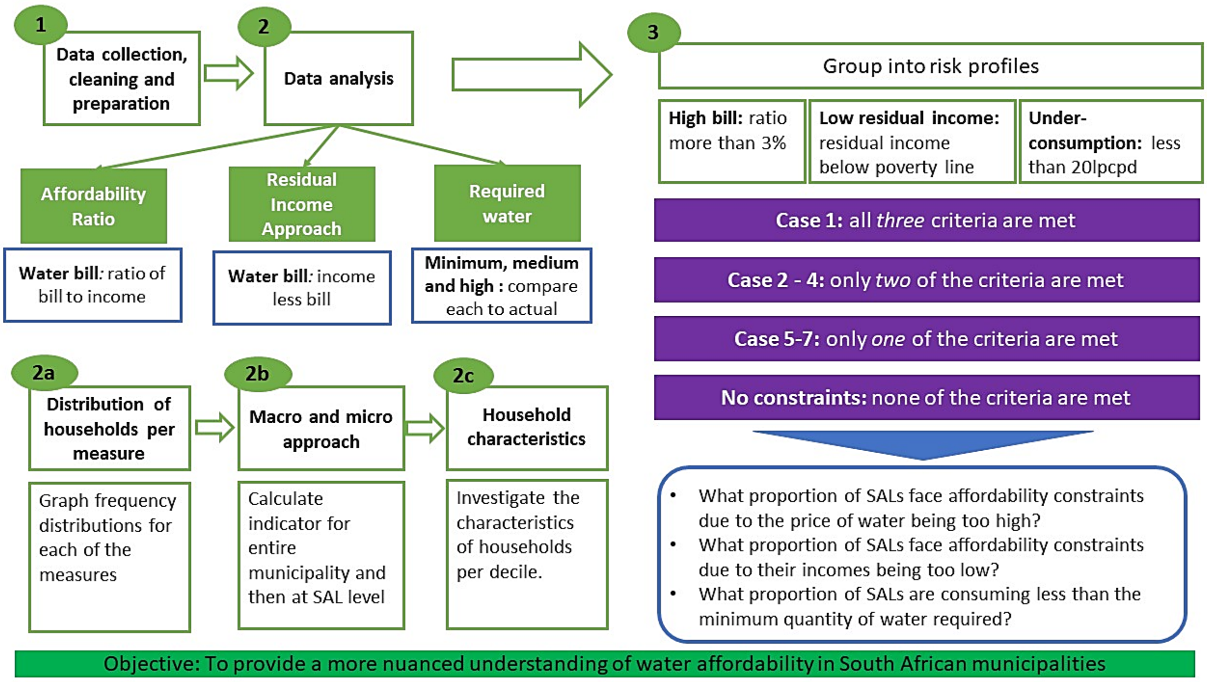


Figure 4: Revised analytical framework

The key difference between the framework in Figure 3 and the one above is the introduction of cases that SALs can fall into. Instead of ten measures under the affordability ratio and residual income approach, we calculate the ratios and residual income using the water bill. We then compare the actual average consumption per SAL to the minimum, medium and high quantity of water required. The new framework does not include the water payment due to lack of data.

Once determined, we plot the distribution of SALs for each indicator. Following this, we compare the results from a macro approach that considers affordability at a municipal level to a micro approach implemented at the small area layer. The framework investigates the household characteristics of the SALs to determine their role in affordability constraints.

The new framework defines eight cases which are a combination of three key criteria. The first is where an SAL's average ratio is above 3%, the high bill criteria. The second is the low residual income criteria where the residual income is below the upper bound poverty and finally under-consumption refers to SALs that consume less than 20 lpcd, the minimum required for short term survival. SALs in case 1 meet all the criteria, those who fall into case 2 to 4 only experience on of the constraints and those in case 5-7 only satisfy one of the criteria. Lastly there are also SALs that face no constraints. The overall analysis results are then synthesised to answer the following key questions:

- Which households face affordability constraints due to the price of water being too high?
- Which households face affordability constraints due to their incomes being too low?
- Which households face affordability constraints due to both the price of water being too high and their incomes being too low?
- Which households cannot afford to purchase the minimum quantity of water required?

This analytical framework is applied to the data in each municipality to provide an overview of affordability constraints. The next section presents the results of the analysis.

4 ANALYSIS RESULTS

Noting the limitations of both the analytical framework and the available data, this section of the report contributes to our understanding of affordability in four South African municipalities by applying the two main approaches to understanding affordability identified in the literature review. It also shows the different sets of affordability constraints households face and how the household characteristics of SALs facing constraints differ from those with no affordability constraints.

4.1 Municipal descriptive statistics

Before presenting the results, it is useful to introduce each of the four municipal case studies. The descriptive statistics in Table 7 provide information about the socio-economic context in each municipality which is important for interpreting the results presented later. The reader is reminded that the analysis focussed on municipal water customers, hence all the summary statistics below exclude households without access to piped water in the dwelling and in the yard.

Table 7: Descriptive statistics for municipalities

	Municipality A	Municipality B	Municipality C	Municipality D
Total SALs used in analysis	234	445	91	149
District	Cape Winelands	uMgungundlovu	Waterberg	Cape Winelands
Median monthly income (nominal Rand value in 2014)	6 015	6 015	3 034	6 015
Average **household size** (number of people)	3.8	3.2	3.2	3.4
Average household water **consumption per month** (kl)	12	6	13	12
Average household **water bill per month** (nominal Rand value in 2014)	103	83	102	114

Two of the municipalities are in the Cape Winelands district in the Western Cape, one from uMgungundlovu in KwaZulu-Natal and another from Waterberg district in Limpopo. Municipalities A, B and D have the same median monthly household income while Municipality C has the lowest household income, an indication of higher poverty levels. The average household size is similar in Municipality B and C while D's figure is slightly higher. Households in Municipality A are relatively bigger. Water consumption and associated water bills also vary. The differences are explained to some extent by different underlying patterns in the municipalities, however it is important to note that these averages are likely also due to data limitations[7] discussed in Section 3.7. This particularly true for Municipality B where the average consumption is very low. Despite this, it is still useful to keep the municipality in the analysis to explore affordability patterns.

[7] The mapping of consumption per meter to consumption per household in cases where the consumption data is not fully representative of the total number of households with access to piped water in the municipality results in an underestimation of consumption.

Based on Census 2011, Municipality A had a total of 59 774 households of which 80% had access to piped water. It has two main urban centres located close to a major highway and smaller rural settlements. The main economic sectors in the municipality are finance, insurance and real estate.

Municipality B municipality is one of the smallest municipalities in the uMgungundlovu District but the largest in the sample with 164 772 households. Of these, 48% had access to piped water. It encompasses the main economic hub in the district with community services and finance as key economic sectors.

Municipality C is a largely rural municipality in the Waterberg District of Limpopo province. Based on Census 2011 data, this municipality had a total of 78 632 households of which 20% had access to piped water inside dwelling. Mining and agriculture constitute the main economic activity in the municipality.

Lastly, municipality D is the smallest of the municipalities in the Cape Winelands district with 43 417 households of which 72% had access to piped water. A major portion of its land area is dedicated to agricultural purposes, however the main economic sectors in the municipality are community services, finance and business services; and manufacturing.

Household income distribution

Income is an important variable in affordability calculations, hence the distribution of household income provides a first insight into the possible distribution of constraints within the municipality. Table 8 shows the distribution of SALs across four income brackets with the first one identifying the proportion of SALs that have median incomes below the upper bound poverty line.

Table 8: Income distribution in the municipalities (based on nominal Rand value in 2014)

	Municipality A	Municipality B	Municipality C	Municipality D
<R3000	14%	18%	33%	13%
R3000-R5000	27%	21%	47%	25%
R500-R10000	32%	19%	8%	34%
>R10000	27%	42%	12%	28%

While it is evident that Municipality C is facing significant socio-economic challenges with 33% of SALs earning incomes that are less than R3000, it also notable that Municipalities A, B and D have a non-negligible proportion of poor households, despite higher overall income levels. Based on this distribution, we can expect relatively more constraints in Municipality C compared to the other three.

Water consumption and the human rights perspective

A key contribution of this study relative to similar research on affordability is the consideration given to whether residential customers in South African municipalities are consuming water at levels that allow them to attain their human right to water. Table 9 unpacks the average consumption figures presented above into deciles. The consumption data is sorted from lowest to highest and divided into 10 equal parts such that the first decile represents the lowest 10% of water consumption in the municipality and the 10th decile represents the highest 10%. The average consumption in each decile is shown in the table below.

The distribution of water consumption

Table 9: Consumption distribution in the municipalities

Consumption decile	Municipality A	Municipality B	Municipality C	Municipality D
1	0	0	4	1
2	2	2	8	3
3	4	4	10	7
4	5	5	11	9
5	7	6	13	11
6	9	6	14	13
7	10	7	14	15
8	13	8	15	17
9	16	9	19	19
10	23	11	23	24

Municipality C has the highest consumption at each decile for the first six deciles. The income and consumption distributions suggest that Municipality C is operating in a context of low income and high consumption, both factors that make it susceptible to a prevalence of affordability issues. Municipality D has the highest consumption at each decile for the last 4 deciles, i.e. the highest consumers in this municipality consume relative more water than in all the other municipalities. Municipality B, as suggested by the average level, has the lowest consumption across all the deciles.

The minimum quantity of water required

The human rights perspective to water affordability requires further analysis of consumption beyond the distribution to look at whether the levels of water consumed are enough. Figure 2 in Section 2.5 of the literature review presented the WHO's guideline on water requirements for different activities. This guideline was used to compare the average consumption per SAL to amounts required for short term survival, medium term sustenance and high consumption levels.

Table 10 shows number of proportion of SALs that consume below the minimum required for short term survival (20 lpcd), those consuming between the minimum and the medium (20-70 lpcd), those consuming between the medium and high (70-150 lpcd) and those consuming high levels of water (more than 150 lpcd).

Table 10: Residential customers consuming less than the required amount of water

	Municipality A	Municipality B	Municipality C	Municipality D
Number of SALs consuming:				
less than 20 lpcd	35	60	2	16
between 20 to 70 lpcd	59	235	9	18
between 70 and 150 lpcd	86	142	46	66
more than 150 lpcd	54	8	34	49
% of SALs consuming:				
less than 20 lpcd	15%	13%	2%	11%
between 20 to 70 lpcd	25%	53%	10%	12%
between 70 and 150 lpcd	37%	32%	51%	44%
more than 150 lpcd	23%	2%	37%	33%

Apart from Municipality C, all municipalities have a sizable proportion of SALs consuming less than the minimum for short term survival. The majority of SALs in Municipality B consume between 20 and 70 lpcd which is what is required for medium term sustenance. Most of the SALs in Municipalities A and D consume between 70 and 150 lpcd which caters for activities such as gardening which are low priority, therefore suggesting that while consumption at the lower end of this range is probably reasonable, the top end of this bracket is probably associated with some degree of water wastage. A key assumption underlying IBTs is that they serve to discourage wasteful use of water. Evidence of water consumption exceeding 150 lpcd in all municipalities suggests that this assumption does not necessarily hold true in all cases. Most notable is Municipality C where almost 37% of the SALs consume more than 150 lpcd on average. This finding suggests that IBTs do not necessarily work as intended or that their design and application in local municipalities is potentially ineffective.

Relationship between water consumption and income

In addition to discouraging wasteful use, a key underlying assumption in the design of an inclining block tariff is that higher income households consume more water or, conversely, that lower income households can and/or will reduce their water consumption to make their water bills more affordable. The results in Table 11 show the extent to which this is prevalent in the four municipal case studies.

Table 11: Water consumption by median household income bracket[8]

Income	Municipality A	Municipality B	Municipality C	Municipality D
<3000	10	4	14	11
3000-5000	10	5	12	10
5000-10 000	10	6	15	11
>10 000	18	6	16	15

All the municipalities show a weak positive linear relationship with correlation coefficients of 0.306, 0.221, 0.100 and 0.316 respectively for Municipality A, B, C and D respectively. High consumption for SALs with high median incomes is observed in all four municipalities. SALs with incomes below the UBPL in municipality C consume more water than SALs in the second bracket which are above the poverty line.

Certainly, the underlying assumption of inclining block tariff design that consumption increases with income seems to hold, however in some cases poor income households do not consume significantly lower levels of water. Households with lower income do not consume significantly less water than those with higher income in Municipalities A, C and D in particular and we may thus expect to see some affordability problems in the lower income SALs.

[8] Consumption outliers, defined as consumptions outside 1.5 times the inter-quartile range, have been removed from this analysis.

Relationship between average income and household size

Figure 5 below shows the relationship between household income and household size. All four municipalities show a negative relationship between average income and household size although the strength of the relationship differs (correlation coefficients of -0.460, -0.238, -0.137 and -0.010 respectively for Municipality A, B, C and D).

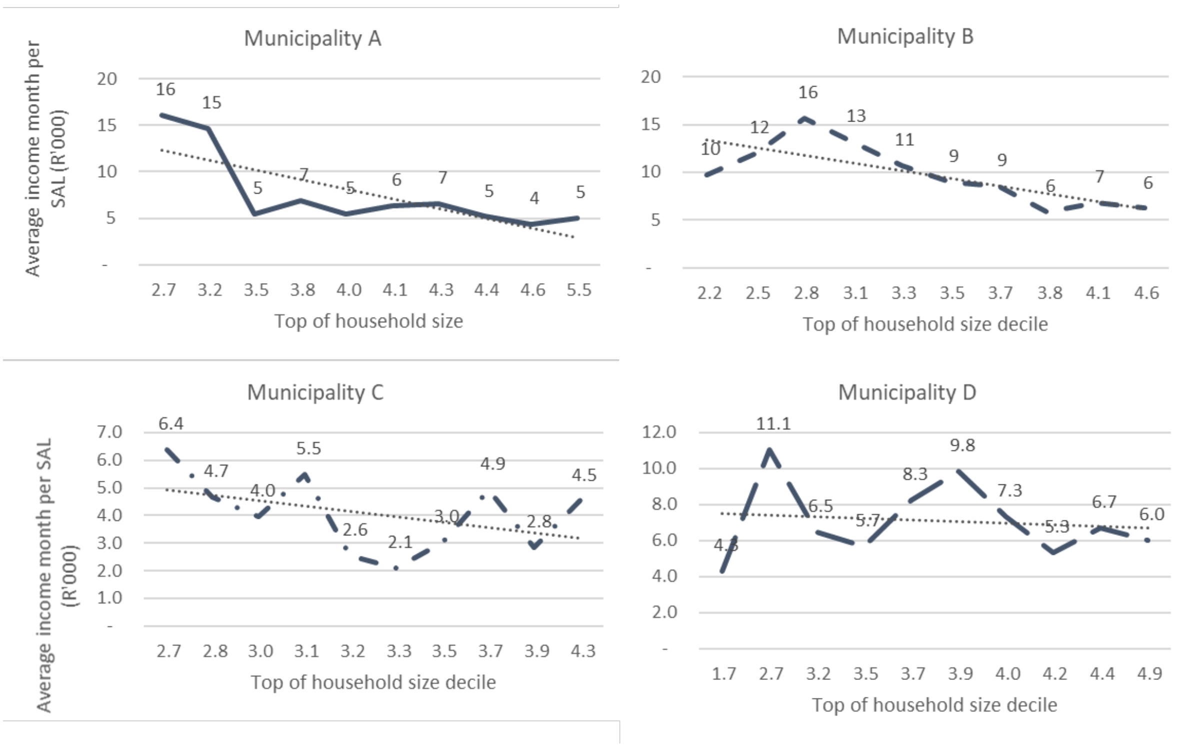


Figure 5: Median household income by household size deciles

Relationship between water consumption and household size

As discussed in the literature review, most studies find a positive relationship between water consumption and household size. Figure 6 below shows the relationship between water consumption and household size in the municipal case studies.

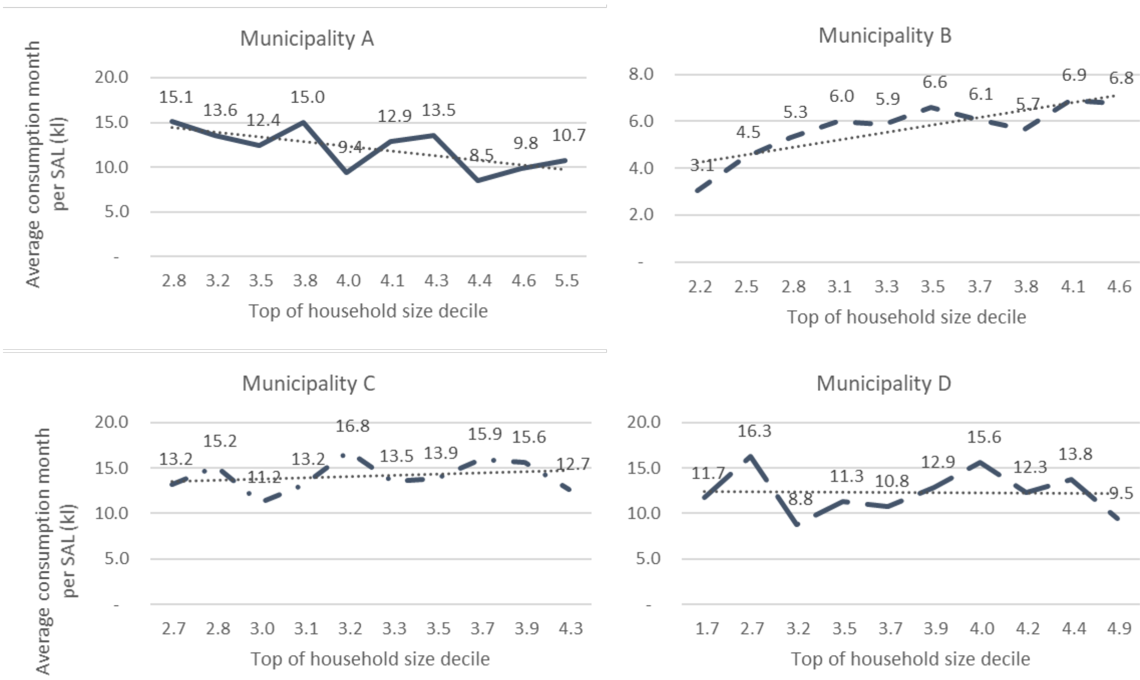


Figure 6: Water consumption by household size deciles

The relationship between water consumption and household size is positive in Municipality B and C (correlation coefficients 0.321 and 0.186 respectively). Municipality A and D show a negative relationship between water consumption and household size (correlation coefficients -0.218 and -0.020 respectively), with smaller households consuming more water than larger ones. Combining this finding with the results above on the relationship between household size and income suggests that high income earners in these municipalities reside in small households which consume more water. It is therefore important to note that the simple correlation between water consumption and household size observed above may be confounded by income, i.e. the negative relationship is due to fact that the analysis does not control for the effect of income on water consumption.

Water bills

Together with income, water expenditure is a key variable to understanding affordability. The descriptive statistics provide the average bill in each municipality however, it is essential to understand how the water bill rises with increasing consumption in each municipality to comment on the relative cost of water.

Table 12 compares water bills for non-indigent households in the municipalities for different levels of consumption.

Table 12: Non-indigent customers water bills for different consumption levels (nominal Rand value in 2014)

	Municipality A	Municipality B	Municipality C	Municipality D
Total SALs	234	445	91	149
Bill for 10 kl	69	112	40	82
Bill for 25 kl	198	320	201	177
Bill for 40 kl	378	593	361	308

It is immediately clear from the table that the tariff structure implemented in each municipality has an impact on the water bill. At R40, the bill for 10 kl of water consumed is the cheapest in Municipality C. Municipality B's water is the most expensive at each level of consumption revealing a very steep slope. Households consuming 25 kl per month in Municipality B paid R320 which 4% more expensive than the bill for 40 kl of water Municipality D. The tariff design provides some explanation for this difference. Whereas municipalities A and D charge a standard IBT and an availability charge, Municipality B charges a fixed charge of R41 for the first 6 kl, a per kilolitre charge for all water consumption after that and an availability charge. Municipality C charges only a consumption-based tariff.

It is important to note that the policy on providing free basic water also has an influence on the bill. Table 13 shows the bills for indigent customers in the different municipalities and provides insight into both the degree of support provided by each municipality and the effect of free water on the bills.

Table 13: Indigent customers water bills for different consumption levels (nominal Rand value in 2014)

	Municipality A	Municipality B	Municipality C	Municipality D
Total SALs	234	445	91	149
Bill for 10 kl	0	55	40	21
Bill for 25 kl	155	263	201	116
Bill for 40 kl	335	536	361	247

Municipality A provided 10 kilolitres of free water only to households that qualify as indigent. By comparison, Municipality B and D's indigent customers receive only 6 kilolitres of water free. Municipality C provided the first 6 kilolitres of water free to every residential customer. This policy explains the relatively low bill for the 10 kl of water consumed because customers effectively pay for 4 kl. Municipality B and D's indigent customers pay 49% and 26% of the non-indigent customers' water bills respectively. It is interesting to note that while

Municipality C's non-indigent customers face the lowest bills for 10 kl of water, indigent customers are paying more for 10 kl of water than similar customers in Municipality A and D.

For Municipality A, the analysis uses the indigent variable in the SWIFT dataset to identify which record represents an indigent residential customer to calculate the bill appropriately. Municipality C provides free water to all customers, hence no adjustments are made to the bill. Municipality B and C's data did not include an indigent variable, hence the support provided to vulnerable households in these municipalities is not considered.

4.2 Affordability ratio approach

This section presents results for affordability of water when using the ratio approach. Results for both macro and micro-affordability ratios are presented below. This study defines a macro-affordability ratio as the average bill in the municipality divided by the median income. Micro-affordability ratios are the bill to median income ratio but calculated at a small area layer level. The results are compared to the UNDP's threshold of 3% for water.

Using macro-affordability ratios

Figure 7 shows the results for macro-affordability ratios in all the municipalities. This approach is useful for understanding affordability constraints on a macro level.

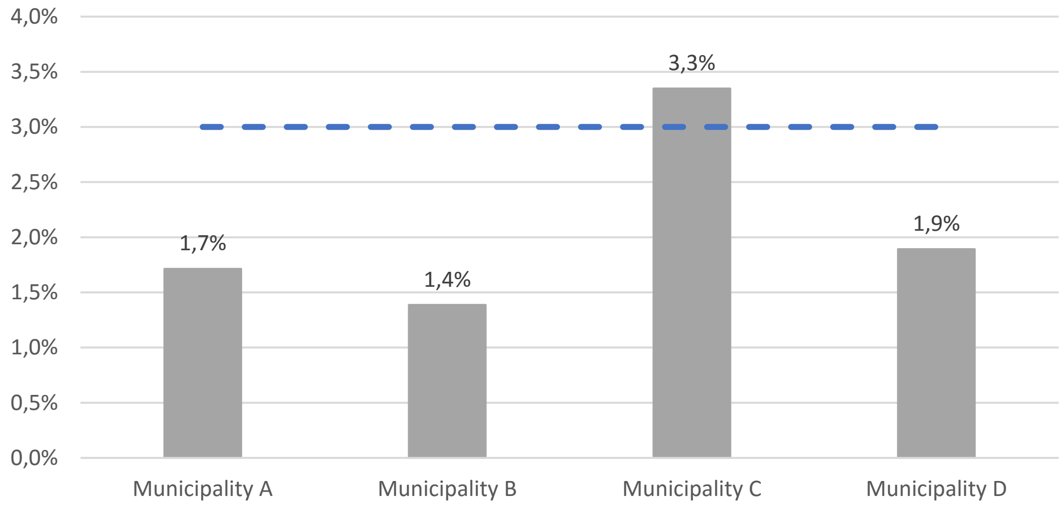


Figure 7: Macro-affordability ratios by municipality

Based on a comparison of the bill to income ratios to the UNDP threshold, the conclusion at a macro level is that Municipality A, B and D face no affordability constraints while Municipality C faces some challenges.

Using micro-affordability ratios

As discussed in the literature review, macro-affordability ratios can typically hide affordability constraints at the micro level that leave some households vulnerable. Table 14 shows the distribution for micro-affordability ratios at the SAL level various affordability ratio bands.

Table 14: Distribution of SALs into affordability ratio bands

Affordability ratio band	Municipality A	Municipality B	Municipality C	Municipality D
Number of SALs				
<3%	152	321	27	79
3-5%	53	72	39	52
5-10%	17	33	20	8
>10%	12	19	5	10
% of SALs				
<3%	76%	80%	45%	70%
3-5%	11%	9%	27%	18%
5-10%	7%	7%	22%	5%
>10%	5%	4%	5%	7%

The distributions in Municipality A, B and D explain the low macro-ratios in Figure 7 above. Most of the SALs in these municipalities have ratios below the 3% threshold. Nonetheless, there are SALs with ratios above the threshold which would be ignored if only the macro-ratio was relied on as an indicator of affordability constraints. Overall, 82 (24%) of the SALs in Municipality A face challenges, 124 (20%) in B and 70 (30%) in D. The macro-ratio for Municipality C suggested potential issues with affordability. The distribution above, with 55% of SALs experiencing constraints, suggests that the macro-ratio underestimates the degree of the problem.

Household characteristics of those experiencing affordability constraints

Table 15 below shows the characteristics of households constrained according to the affordability ratio (i.e. with affordability ratios of 3% or above) compared to those that are unconstrained.

Table 15: Characteristics of SALs constrained according to affordability ratio measure compared to unconstrained SALs

Household characteristics	Municipality A	Municipality B	Municipality C	Municipality D
No. of constrained SALs	82	124	64	70
Median income				
Constrained	3 034	1 533	2 283	3 034
Unconstrained	6 015	12 083	3 034	6 015
Constrained as % of unconstrained	50%	13%	75%	50%
Household size average				
Constrained	3.72	3.40	3.35	3.05
Unconstrained	3.81	3.16	3.09	3.56
Constrained as % of unconstrained	98%	108%	108%	86%
Consumption average				
Constrained	16	7	16	15
Unconstrained	11	5	11	11
Constrained as % of unconstrained	154%	141%	147%	135%

The median income of constrained SALs is smaller than that of unconstrained SALs in all the municipalities while average consumption is higher across all municipalities. Some minor differences are observed with average household size. In Municipality A and D, constrained SALs reside in smaller households than those in unconstrained SALs whereas the opposite is true for Municipality B and C. All constrained SALs in all the municipalities consume more water than unconstrained SALs.

In summary, in Municipalities B and C affordability problems as measured by the affordability ratio are a problem of high consumption in low income SALs and are related to large household size. In Municipality A and D, the problem is due to high consumption by low income, but not necessarily poor, SALs residing in smaller households.

4.3 Residual income approach

This section presents results for water affordability using the residual approach. The residual income refers to the difference between average household income in a SAL and the average household water bill. Similar to the analysis on affordability ratios, the section outlines results from a macro-approach and a micro-approach. The three poverty lines discussed in section of the literature review are all shown in the macro-approach, however the micro-approach only considers the upper bound line as this is the level of income that ensures a household can purchase necessary food and non-food items. The Statistics South Africa poverty lines are presented on a per capita basis. The average household size is used to convert the poverty lines to a household basis for each municipality. Hence, the poverty lines differ per municipality due to differing average household sizes.

Using a macro approach

Table 16 is an overview of the average residual income in each municipality for all three poverty lines. The descriptive statistics presented in section 4.1 are repeated here for ease of reference.

Table 16: Residual incomes by municipality (all in nominal Rands in 2014)

	Municipality A	**Municipality B**	**Municipality C**	**Municipality D**
Total SALs used in analysis	234	445	91	149
Average monthly household consumption	12	6	13	12
Average monthly household bill	103	83	102	114
Average monthly household income	6 015	6 015	3 034	6 015
Residual monthly household income	5 912	5 932	2 932	5 901
Food poverty line per household (FPL)	1 533	1 297	1 307	1 378
Lower bound poverty line per household (LBPL)	2 115	1 790	1 803	1 902
Upper bound poverty line per household (UBPL)	2 961	2 506	2 524	2 662

The residual incomes across all four municipal cases at the macro level are above all the poverty lines suggesting that the water bill is not poverty inducing on average. After paying for their water bills, residential customers in the municipalities have sufficient income remaining to meet their other needs. Hence, using the residual income on a macro level leads to the conclusion that affordability is not a problem in any of these municipalities.

Using a micro approach

The micro-approach is displayed in

Table 17 which shows the number and percentage of SALs that fall below each of the three poverty lines after paying the water bill.

Table 17: Distribution of SALs by residual income

Poverty line	Municipality A	Municipality B	Municipality C	Municipality D
Number of SALs				
Below FPL	33	20	5	11
Below LBPL	0	60	25	9
Below UBPL	28	0	0	0
Above UBPL	173	365	61	129
% of SALs				
Below FPL	14%	4%	5%	7%
Below LBPL	0%	13%	27%	6%
Below UBPL	12%	0%	0%	0%
Above UBPL	74%	82%	67%	87%

Similar to the results observed using the affordability ratio approach, the majority of SALs in each municipality do not face poverty inducing water bills, however there are a proportion that fall below each of the poverty lines. Most SALs in Municipality B, C and D fall below the LBPL while Municipality A has some SALs below the FPL and other that are above this but fall below the UBPL after paying for the bill.

Are these household pushed into poverty by the water bill or were they already poor prior to paying the bill? In the case of the latter, the water bill pushes them further into poverty and increases their vulnerability. The results in Table 18 below answer this question by showing the number of SALs where paying the bill results in poverty or pushes the households further into poverty.

Table 18: Number of SALs in each municipality that are moved into or further into poverty by the water bill

Top of affordability ratio band	Municipality A	Municipality B	Municipality C	Municipality D
Number of SALs				
Moving from below LBPL to below FPL	0	0	0	2
Moving from below UBPL to below LBPL	0	0	0	0
Moving from above UBPL to below UBPL	28	0	0	0

Table 18 shows that while some SALs in each municipality experience affordability constraints in paying their water bill because they are below a poverty line, it is rare that it is the water bill that pushes them below the poverty line. In Municipalities B and C, there is no case of the water bill pushing a SAL below the UBPL. The SALs experiencing constraints were already below the respective poverty line and paying the water bill deepens their poverty. In Municipality D, however, there are 2 SALs where the water bill pushes the SAL from below LBPL to below the FPL and in Municipality A 28 SALs that were above all the poverty lines are pushed to below the UBPL after paying for water. These SALs are impoverished by the water bill.

A key question at this point is how the results from the residual income approach compare to those observed using the affordability ratio approach. The latter suggested higher incidence of affordability constraints. Moreover, analysis presented later in Section 4.4 shows that the SALs that face constraints when using the residual income approach are not always the same as those facing constraints under the affordability ratio approach. This suggests that measuring affordability is not only sensitive to the thresholds that are used but also to the overall approach.

Household characteristics of those experiencing affordability constraints

Table 19 below shows the characteristics of households constrained according to the residual income measure (i.e. with residual incomes below the UBPL) compared to those that are unconstrained.

Table 19: Characteristics of households constrained according to residual income measure compared to unconstrained households

Household characteristics	Municipality A	Municipality B	Municipality C	Municipality D
No. of constrained SALs	58	80	30	20
Median income				
Constrained	1 533	1 533	1 533	1 144
Unconstrained	6 015	6 015	3 034	6 015
Constrained as % of unconstrained	25%	25%	51%	13%
Household size average				
Constrained	3.91	3.18	3.20	2.45
Unconstrained	3.75	3.21	3.25	3.56
Constrained as % of unconstrained	105%	99%	98%	69%
Consumption average				
Constrained	13	4	14	11

Household characteristics	Municipality A	Municipality B	Municipality C	Municipality D
Unconstrained	12	6	13	12
Constrained as % of unconstrained	107%	66%	104%	86%

The constrained SALs are all earn much lower median incomes than the unconstrained groups. Moreover, the median incomes are all below the UBPL with the median income in Municipality D already below the FPL prior to paying the bill. Hence, at least 50% of constrained households in all municipalities were already poor prior to paying for water. There is a minor difference in the household sizes of the constrained and unconstrained in Municipality A, B and C, while households in constrained SALs in Municipality D are smaller than those in unconstrained households. The major difference between the municipalities is in the levels of consumption in the constrained groups compared to the unconstrained. Municipality A and C's constrained SALs consume more water than unconstrained SALs on average. The opposite is true for Municipality B and D.

In summary, constraints in Municipality A are due to poor SALs in large households consuming relatively more water. High consumption by poor SALs in relatively small households explains the constraints observed in Municipality C. Municipality B and D's constrained SALs consume less water, hence the constraints here are largely due to already poor households paying for water.

4.4 Do the same SALs experience multiple affordability constraints?

The analysis up until this point has looked at the various affordability constraints in isolation. In this section, the results obtained through the different measures are compared to determine whether the same SALs are identified as facing affordability constraints under all or a combination of the measures. Three criteria are used to group the SALs facing constraints into eight cases of vulnerability. These are low residual income, high bills and under-consumption and are defined as follows:

- *Low residual income* refers to SALs that have residual incomes (median income less the water bill) that are less than the upper bound poverty line.
- *High bill* refers to SALs that pay bills that make up more than 3% of their median income.
- *Under-consumption* refers to SALs that consume less than 20 lpcd of water on average.

Table 20: Specifying unique groups of SALs facing constraints

Affordability constraints	Residual income below minimum (UBPL)	Affordability ratios above threshold (3%)	Quantity below the minimum (20 lpcd)
Case 1: Low income, under-consumption and high bill	X	X	X
Case 2: Low income and under-low consumption	X		X
Case 3: High bill and under-consumption		X	X
Case 4: Low income and high bill	X	X	
Case 5: High bill		X	
Case 6: Low income	X		
Case 7: Under-consumption			X
No constraints			

Case 1 refers to SALs that meet all three of the criteria above, Cases 2 to 4 refer to SALs facing any combination of two criteria. Case 5 to 7 refer to SALs that only fit one of the criteria while no constraints refers to all SALs that do not meet any of the criteria and hence face no constraints. These cases are mutually exclusive, i.e. if a SALs is classified as Case 1, it cannot also be classified as low Case 2. Table 21 below shows the number and percentage of SALs in each municipality that fall into each of these cases.

Table 21: Number and percentage of SALs falling into risk profiles

Affordability constraints	Municipality A	Municipality B	Municipality C	Municipality D
Number of SALs				
Total SALs	234	445	91	149
No constraints	110	286	33	83
Constraints	124	159	58	66
Case 1: Low residual income, under-consumption and high bill	1	1	0	0
Case 2: Low residual income and under-low consumption	7	31	1	4
Case 3: High bill and under-consumption	0	0	0	0

Affordability constraints	Municipality A	Municipality B	Municipality C	Municipality D
Case 4: Low residual income and high bill	41	65	35	23
Case 5: High bill	13	24	15	22
Case 6: Low residual income	35	10	6	5
Case 7: Under-consumption	27	28	1	12
% of total SALs				
No constraints	47%	64%	36%	56%
Constraints	53%	36%	64%	44%
Case 1 to 3	3%	7%	1%	3%
Case 4: Low residual income and high bill	18%	15%	38%	15%
Case 5: High bill	6%	5%	16%	15%
Case 6: Low residual income	15%	2%	7%	3%
Case 7: Under-consumption	12%	6%	1%	8%

A sizable portion of SALs do not face any constraints with these SALs in the majority in Municipality B and D. Case 4, where households simultaneously experience incomes that fall below the UBPL after paying for the bill and bills that are more than 3% of their income, is the most prevalent in Municipality A, B and C, with burden experienced in Municipality C. Municipality D has 15% of SALs that only experience Case 4, bills that make up more than 3% of their incomes. Although the portion is very small, it is concerning to note that one SAL in both Municipality A and B respectively that face all three constraints simultaneously.

Several SALs in Municipality A, B and D SALs (12%, 6% and 8% respectively) and a few in Municipality C consume less than 20 lpcd. An immediate question with respect to these SALs is whether they are consuming such low levels of water because they cannot afford to buy more water. A simulation to calculate what their water bills would be if they consumed at least 20 lpcd suggests that these SALs would not face constraints under both the affordability ratio and residual income approach. Hence, their consumption patterns are not a response to high water bills and are rather likely due to either a decision to consume at these levels or limitations in the data used for this analysis.

The results above show that the SALs facing constraints when using the affordability ratio approach are not the same as those facing constraints under the residual income approach, although some overlap exists. The table is therefore a useful source of information to respond the four key research questions outlined in the revised analytical framework in Section 3.8.

What proportion of SALs face affordability constraints due to their incomes being too low?

These SALs are classified as case 6, i.e. their bills make up less than 3% of their median income, they consume more than 20 lpcd however, their residual incomes fall below the UBPL. Municipality A has the highest proportion of SALs with incomes that fall below poverty after paying for their water bills. The problem exists in all the other municipality but to a lesser extent.

What proportion of SALs face affordability constraints due to the price of water being too high?

SALs that fit this criterion are classified as case 5, i.e. their residual incomes above the UBPL and consumption levels are above the 20 lpcd but they experience bills that are more than 3% of their incomes. These households can consume an adequate amount of water and they are not defined as poor, but the water bill makes up a larger than desirable share of their income. Of the total, 6% of SALs in Municipality A, 5% in Municipality B, 16% in Municipality C and 15% in Municipality D fit this profile.

What proportion of SALs face affordability constraints due to both the high price of water and low income?

This refers to SALs that are classified as Case 4, i.e. those with consumption levels that are more than 20 lpcd but with residual incomes that fall below the UBPL and bills that are more than 3% of the median incomes. This constraint is the most prevalent in Municipality A (18%), B (15%) and C (38%). The analysis previously shown in Table 18 on page 49 of this report showed that while, in most cases, it is not the water bill that forces the median income of the SAL below the UBPL because the SALs were already impoverished prior to paying the bill, there are cases of this happening in Municipality A.

What proportion of SALs consume less than the minimum quantity of water required?

SALs that fit this criterion are specified by Case 7, i.e. they consume less than 20 lpcd but have no affordability constraints. This problem is most prevalent in Municipality A where 12% of SALs consume less than the minimum required for survival and least prevalent in Municipality C where only 1% of the SALs face this constraint. The analysis into whether households in these SALs consume below the minimum due to an inability to pay for water suggests that this is not the case in any of the municipalities, rather it is either a decision on the part of the household, or likely the result of a limitation with the data used in the analysis.

5 KEY FINDINGS

Affordability in municipalities based on two approaches

This study investigated the affordability of water for residential customers in South African municipalities through case studies in Municipalities A, B, C and D. The affordability ratio approach provided the first insight into affordability constraints for residential customers in South African municipalities. The macro approach suggests no constraints in Municipality A, B and D while Municipality C faces some challenges. A micro-level analysis, however, highlights that while not large, there are SALs that face constraints in Municipality A, B and D. Furthermore, SALs in Municipality C have ratios that are significantly above the threshold.

The residual income approach suggests no constraints for any of the municipalities at a macro level. The micro-level highlights that there are a few SALs in all four municipalities that are facing constraints. Similar to the affordability ratio results, Municipality C faces the most challenges under the residual income approach, but the composition of the SALs differs.

Determinants of affordability constraints

The ratios in all municipalities are partly explained by the relationship between median household income and consumption, i.e. relatively lower income households consuming a lot of water. The relationship between household size and income in Municipality A and B suggests that some of the constraints are due to non-poor SALs consuming a lot of water. The residual income results are explained by either high consumption by low income households or consumption by households who were already poor prior to paying the bill, hence any payment would have pushed them into deeper vulnerability.

Combination of constraints

The study finds that most of the SALs in Municipality B and D do not face any constraints. Most of the SALs facing constraints in all four municipalities simultaneously experience both bills that are more than 3% of their income and residual incomes that fall below the poverty line. There is also a portion of SALs in each municipality were households consume less than the minimum daily need (20 lpcd) on average; but there are also some consuming very high levels of water (more than 150 lpcd).

Assumptions of the IBT

The relationship between consumption and income suggests that the assumption underlying the IBT, that consumption increases with income, holds true in all four municipal case studies.

However, consumption at the top of the income distribution is not much higher than consumption at the bottom in some cases. Additionally, IBTs are often championed for their ability to discourage water usage. With evidence of a portion of SALs consuming more than 150 lpcd in all four municipal case studies, the study suggests that this assumption either does not hold, or municipalities' application of the IBT is not effective.

Analytical approach and implementation

The study demonstrates the limitations of macro-affordability ratios discussed in the literature review and shows the presence of affordability constraints in all four municipalities when assessing affordability at the SAL level. Moreover, the affordability ratio and residual income approach suggest different results in terms of the proportion and composition of small areas facing constraints. The study also the finds presence of consumption below the minimum level required for short term survival in all four municipalities.

Unit of analysis and data quality

This study analysed affordability at the small area layer level. While this is more granular than looking at the entire municipality and a layer below the ward level, the study finds that the heterogeneity of households within a small area suggests that the analysis would yield more accurate results if conducted at a household level. Moreover, the SWIFT data used for the analysis came with the benefit of convenience and time saving relative to gathering data directly from the municipality, but the data required extensive cleaning and there are some questions regarding its completeness and hence the extent to which it can provide a representative overview of affordability for all residential customers.

Ease of replication in local municipalities

The study finds that completing this analysis using the analytical framework requires water billing data to be available in spatial form, the capacity and software to join Census data to billing data at the small area layer and capacity to conduct data cleaning to create a useful dataset for analysis. Municipalities that face any challenge with either of these requirements will be unable to replicate this study internally. Even if municipalities meet all these requirements, time and capacity constraints make it a challenge for municipalities to be undertake a similar analysis for all their small areas. Drawing a sample of SALs is a possible solution in this case. In addition to the affordability analysis, the study conducted a test of the robustness of this approach to sampling (see Appendix C) and found that selecting a sample of SALs that is representative of the income profile is sufficient to provide insight into the affordability context within the municipality.

6 CONCLUSIONS

Is water affordable for municipal residential customers? The study suggests a degree of water unaffordability in all four municipal case studies. However, these do not occur to the same extent, nor are they driven by the same factors. Most of the SALs in three of the four case studies investigated can afford to pay for water, but even in these municipality at least 13% of SALs face constraints. In contrast, more than 50% of SALs in one of the municipalities cannot afford to pay for water. The key determinants of affordability constraints in all cases are income and consumption, i.e. those SALs experiencing constraints either had low incomes, high consumption or some combination of the two that explained their ability to pay for water.

This study also considered whether households are consuming the required amount of water required for their human rights to be met. The study finds cases where SALs are consuming below the minimum required for short term survival, but further analysis suggests that there are no cases where the consumption level is a response to prevailing water prices. This finding is therefore likely to be the result of a choice by households to consume less water, or limitations in the data used for the analysis. At the other extreme, the study also finds cases of high consumption that suggests that the tariff design in the municipal case studies is not sufficiently effective in discouraging wasteful use.

Two key approaches were applied to understand affordability using both macro and micro measures to understand the efficacy of the snapshot provided by the macro measures. The study points to the necessity of multiple approaches to fully understand affordability. While there was some overlap, SALs facing constraints under the affordability ratio are not the same as those facing constraints under the residual income approaches. It is possible for a household's bill to be less than 3% of their median income but for the residual income to be below the UBPL. In cases where the household was already impoverished prior to paying the bill, this finding suggests that the support available for poor households in the municipality is either insufficient or does not adequately target all vulnerable households[9]. This finding is missed if only the affordability ratio is used to determine affordability. In terms of measures, the SAL provided insight into affordability that would have been ignored if only a macro level indicator was used.

The data used for the analysis presented both advantages and limitations. A key advantage is the ability to join two datasets that allow for consumption and billing data to be merged with

[9] Note that this only applies to Municipality A and C, where the support provided was accounted for in the bill calculation.

income data, making analysis of affordability at the municipal level possible. However, the calculation of a representative income per small area, the adjustment of income from 2011 to 2014 figures and the adjustment of per meter averages to per household averages are some of the limitations that affect the degree to which the results are representative.

Despite these limitations, the study provides a nuanced approach and understanding of affordability in the South African municipal context. Firstly, the study interrogates the relationship between key variables that explain affordability. Secondly, it provides a snapshot of affordability at the municipal level across two approaches and a breakdown thereof at a more granular level. Thirdly, it shares insights into the drivers of affordability patterns observed in each municipality. Lastly, the study considers whether current consumption levels in the municipality fulfil households' human right to water. The findings provide a baseline for future studies into affordability of water for residential customers in South African municipalities.

7 IMPLICATIONS FOR POLICY, PRACTICE AND REGULATION

Implications for the regulation of tariff setting

The study points to a need for the regulation of tariff setting to include a comprehensive analysis of the affordability of municipal tariffs, particularly the overall effect of their IBT design on the affordability of water. As the study shows, implementation of the tariffs in the municipalities studied resulted in various combinations of constraints which could have been mitigated through undertaking an affordability analysis and designing appropriate interventions to protect households in response.

Implications for the use of IBTs

The implementation of IBTs has become almost ubiquitous in the South African context. This study suggests that the assumptions that underlie the effectiveness of IBTs either do not hold or do so to only a marginal extent. Moreover, evidence of high consumption, especially at the lower end of the income distribution, suggests that IBTs are not necessarily effective in managing waste and while offering protection to vulnerable households. The findings call for a review of IBTs to understand whether the assumptions simply do not hold or whether municipalities' application of the tariff structure is ineffective. In the case of the former, a consideration of alternative tariff structure would be required while the latter calls for better guidance and regulation of how municipalities implement IBTs.

Implications for targeting of households that require support

For two of the municipalities where indigent qualification was considered in the bill calculation, the results point to a limitation with the current approach used by most municipalities to provide free water to indigent households to protect vulnerable households from high water prices. The study suggests that despite this intervention, there are still households that face affordability constraints. This is particularly concerning for the cases observed where SALs fall below the poverty line after paying for the bill but were not poor, and hence did not qualify for support, prior to paying for the bill. In cases where households qualify but do not receive support, possible limitations in the current application of the criteria used to select the households that qualify for support could explain this. A review and update of the indigent registers in these municipalities to ensure that the right households are receiving support would alleviate constraints faced by these households.

Implications for the nature of support offered to vulnerable households

The provision of free basic water is currently the main intervention used by municipalities to offer support to households that qualify. Based on the results, a set of interventions should be considered to address the diverse types of vulnerability in each municipality. The study suggests that households with affordability constraints that are largely driven by high consumption levels could be protected through programmes that encourage reduction in consumption through efficient use or adoption of water saving technologies. Households that face high bills in the face of low incomes and low consumption can benefit from relief through design of the IBT to protect consumers at the lower end of the consumption distribution.

8 RECOMMENDATIONS FOR FUTURE RESEARCH

Improve accuracy and reliability by using household level data

This study contributed to a more nuanced understanding of water affordability for residential customers through analysis at the SAL level in only four municipalities. Two key limitations of this approach are the heterogeneity within an SAL and the non-representative nature of the municipal case studies. The effect of this is possibly large variances in the results at the household level and an inability to draw conclusions on water affordability within the country. Hence, a follow up study could apply the approaches presented in this report to a sample of households from a representative mix of municipalities within the country to facilitate conclusions on the affordability constraints nationwide which can then be used to inform current policy on free basic water, provide guidance to municipalities on criteria for selecting households that are eligible for support and guidance for how to regulate municipal tariff setting to include affordability analysis.

The development of a comprehensive tool for municipalities

The limitations and extensive data cleaning followed in this study present a significant challenge to the ease of replication at the municipal level. Hence, this study recommends future research into and the development of a user-friendly affordability tool that municipalities can utilise to assess the affordability of their tariffs. The tool needs to address the challenge with obtaining income data and matching it to the municipality's billing data. If it uses spatial combination of Census data with municipal data, this step should be partially incorporated into the tool itself such that municipalities only need to perform a minimal cleaning of their billing data to the format required by the tool, upload into the tool and perform a few steps to obtain results. The results should be accompanied by understandable narrative and options for interventions depending on the results.

Review IBTs and test the effect of alternative tariff structures on affordability constraints

The study suggests the need for a review of how IBTs are currently implemented in local municipalities and investigate the extent to which the underlying assumption hold true. Moreover, this study tests the effect of prevailing structures and tariff levels in municipalities on water affordability. An extension of this study could include a simulation or an experiment to test the impact of different tariff structures and levels on affordability for residential customers. It would need to account for elasticities and behavioural responses from customers as well as cost recovery and ease of implementation for the municipality.

9 LIST OF REFERENCES

Arbues, F., García-Valiñas, M.Á. and Martínez-Espiñeira, R. (2003). The Literature on the Estimation of Residential Water Demand, *The Journal of Socio-Economics*, vol 32(1), pp 81-102

Beal, C., Stewart, R.A. and Fielding, K. (2011). A novel mixed method smart metering approach to reconciling differences between perceived and actual residential end use water consumption.

Blundlender, J., Leibbrandt, M. and Woolard, I. (2015). South African poverty lines: a review and two new money-metric thresholds, South African Labour and Development Research Unit, Working paper No

Borenstein, S. (2010). The Redistributional Impact of Non-linear Electricity Pricing, NBER Working Paper No. 15822

Brown L. (1997). Water markets and traditional water values: merging commodity and community perspectives, Water International, IWRA, 22, 2-5.

Couvelis, F.A. and van Zyl, J.E. (2015). Apparent losses due to domestic water meter under-registration in South Africa. Water SA. Volume 41 No. 5. 5 October 2015

Christian-Smith, J., Balazs, C., Heberger, M. and Longley, K. (2013). Assessing water affordability. A pilot study in two regions of California, Pacific Institute

Cruz, L., Barata, E. and Martins, R. (2015). Assessing water services affordability: macro and micro approaches, International Conference on Economic Modelling, Boston United States

Datta, S., Darling, M., Lorenzana, K., Calvo Gonzalez, O.C., Miranda J. and de Castro Zoratto, L. (2015). A Behavioral Approach to Water Conservation: Evidence from a Randomized Evaluation in Costa Rica, Ideas 42 and World Bank

Deaton, A. and Grosh, M. (2000). Consumption in Grosh, M. and Glewwe, P. (2000) Designing household survey questionnaires for developing countries: Lessons from 10 years of LSMS experience, Vol 1, Washington DC: World Bank

Deaton, A. (2001. Counting the world's poor: Problems and possible solutions, World Bank Research Observer, 16(2): 125-48

Environmental Finance Center (2016). Water & Wastewater Residential Rates Affordability Assessment Tool, University of North Carolina, Chapel Hill. Available online: http://www.efc.sog.unc.edu/reslib/item/water-wastewater-residential-rates-affordability-assessment-tool

Fankhauser, S. and Tepic, S. (2005). Can poor consumers pay for energy and water? An affordability analysis for transition countries. European Bank for Reconstruction and Development, Working paper No. 92

Ferraro, P.J. and Price, M.K., (2013). Using nonpecuniary strategies to influence behavior: evidence from a large-scale field experiment. *Review of Economics and Statistics*, 95(1), 64-73.

Filippidis, E.I. (2005., A willingness to pay survey for improved water supply conditions in Taxiarchis municipal district of Halkidiki prefecture, Greece, *New Medit,* No. 2

Gawel, E. and Bretschneider, W. (2011a). Affordability as an institutional obstacle to water-related price reforms, I. Theesfeld, and F. Pirscher (Hg.): Perspectives on Institutional Change – Water Management in Europe, Studies on the Agricultural and Food Sector in Central and Eastern Europe 58, Halle/Saale.

Gawel, E., Sigel, K. and Bretschneider, W. (2011a., Affordability of water supply in Mongolia – Empirical lessons for measuring affordability, Helmholtz-Zentrum für Umweltforschung GmbH – UFZ

Gleick, P.H. (1996). Basic water requirements for human activities: Meeting basic needs, Water International, 21, pages 83-92.

Goldin, J. (2005). Trust and Transformation in the Water Sector. Doctoral Thesis (Unpublished), University of Cape Town, Cape Town.

Grafton, R.Q., Ward, M.B., To, H. and Kompas, T. (2011). Determinants of residential water consumption: Evidence and analysis from a 10-country household survey, Water Resources Research, 47, W08537, doi:10.1029/2010WR009685.

Griffin C.C., Briscoe J., Singh B., Ramasubban R. and Bhatia R. (1995). Contingent valuation and actual behavior: predicting connection to new water systems in the state of Kerala, India, World Bank Econ. Rev. 9, 373-395.

Griffioen, M.L. and Van Zyl, J.E. (2014). Proposed guideline for modelling water demand by suburb, *Journal of the South African Institution of Civil Engineering*, vol 56, No. 1, pages 63-68

Hutton, G. (2012). Monitoring “Affordability” of water and sanitation services after 2015: Review of global indicator options, Submitted to the United Nations Office of the High Commission for Human Rights

Jansen, A. and Schulz, C. (2006). Water demand and the urban poor: A study of the factors influencing water consumption among households in Cape Town, South Africa, Working Paper Series in Economics and Management

Leflaive, X. (2009). Experience of OECD countries in water pricing, Presentation at ONEMA conference, 9th of December 2009.

MacLennan, D. and Williams, R. (1990). Affordable Housing in Britain and America. Joseph Rowntree Foundation, York.

Mack, EA. and Wrase, S. (2017. A burgeoning Crisis? A Nationwide Assessment of the Geography of Water Affordability in the United States. Plos ONE 12(1): e0169488. 10.1371/journal.pone

Niëns, L., Van de Poel, E., Cameron, A., Ewen, M., Laing, R. and Brouwer, W.B.F. (2009. Practical measurement of affordability: an application to medicines, Institute of Health Policy and Management

O’Sullivan, A. and Sheffrin, S. (2007). Microeconomics: Principles and Tools (4th Edition), Pearson/Prentice Hall

OECD (2003). Social issues in the provision and pricing of water services, OECD, Paris.

OECD (2009). Managing water for all an OECD perspective on pricing and financing key messages for policy makers

OECD (2008). Household Behaviour and the Environment: Reviewing the evidence.

Ogunbobe, T.O. and Ifabiyi, P.I. (2014). Determinants of domestic water consumption in a growing urban centre in Osun state, Nigeria, *African Journal of Environmental Science and Technology*

Szekely, M. and Hilgert, M. (1999). What's behind the inequality we measure: An investigation using Latin American data, IDB Research Department working paper 409, New York: Inter-American Development Bank (IDB)

Statistics South Africa (2017). Poverty trends in South Africa: An examination of absolute poverty between 2009 and 2015, Pretoria: Statistics South Africa

Pashardes, P. and Hajispyrou, S. (2002). Consumer demand and welfare under increasing block pricing, Discussion Paper 2002-07

Pontius, F.W. (2003). Drinking water regulation and health

Ravallion, M. (1998). Poverty lines in theory and practice. (Living Standards Measurement Study Working Paper 133). Washington D.C.: The World Bank.

Robinson, M., Scobie, G.M. and Hallinan, B. (2006). Affordability of housing: Concepts, measurement and evidence, New Zealand Treasury working paper

Romano, G., Salvati, N. and Guerrini, A. (2014. Estimating the Determinants of Residential Water Demand in Italy, *Water,*6, 2929-2945; doi:10.3390/w6102929

Ruijs, A. (2007). Welfare and Distribution Effects of Water Pricing Policies, Environmental Economics and Natural Resources Group, Wageningen University

Scott, C. and Amenuvegbe, B. (1990). Effect of recall duration on reporting of household expenditures: an experimental study in Ghana. Social Dimensions of Adjustment (SDA) in sub-Saharan Africa working paper, no. 6.

Schleich, J. and Hillenbrand, T. (2009). Determinants of Residential Water Demand in Germany, Working paper sustainability and innovation, No. S3/2007

Smets, H. (2009). Access to drinking water at an affordable price in developing countries in El Moujabber M. (ed.), Mandi L. (ed.), Trisorio-Liuzzi G. (ed.), Martín I. (ed.), Rabi A. (ed.), Rodríguez R. (ed.) Technological perspectives for rational use of water resources in the Mediterranean region, pages 57-68

Smith, J.A. (2010). How much water is enough? Domestic metered water consumption and free basic water volumes: The of Eastwood, Pietermaritzburg, *Water SA*, vol. 36, no. 5

South African Government (2016). How do I access free basic municipal services? Available online: http://www.gov.za/faq/south-african-citizens/how-do-i-access-free-basic-municipal-services

Statistics South Africa (2015). Methodological report on rebasing of national poverty lines and development of pilot provincial poverty lines, Report No. 3-10-11

Tussupova, K., Berndtsson, R., Bramryd, T. and Beisenova, R. (2015). *Water*, vol. 7, pp. 3024-3039

WHO (2011). Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies. 9.

United Nations General Assembly (2010). Human rights obligations related to access to safe drinking water and sanitation. Note by the Secretary-General. A/65/254. Available online: http://www.un.org/waterforlifedecade/human_right_to_water.shtml

Van Zyl, J.E., Lobanga, K.P., Lugoma, F.M.T and Illemobade, A.A. (2008). The State of Plumbing in South Africa. WRC Report No 1702/1/08, WRC: Pretoria

APPENDIX A: MUNICIPALITIES WITH SWIFT DATA

Municipality	Category	Median annual household income (Census 2011)
Tshwane	A	R57 300
Ekurhuleni	A	R29 400
Mogalakwena	B	R14 600
Drakenstein	B	R30 000
Stellenbosch	B	R30 000
Overstrand	B	R29 400
Buffalo City	A	R29 400
Mbombela	B	R29 400
Rustenburg	B	R29 400
George	B	R29 400
Msunduzi	B	R29 400
Johannesburg	A	R29 400
Cape Town	A	R57 300
Bergrivier	B	R57 300
Bitou	B	R29 400
Midvaal	B	R29 400

APPENDIX B: DATA CLEANING PROCESS

The following section outlines the SWIFT and Census 2011 data cleaning process as well as how the SWIFT dataset is merged with the Census 2011 data to create a dataset that is used for the analysis.

Cleaning the SWIFT dataset

Following the receipt of permission to access the SWIFT dataset for the municipalities included in the sample, PDG began the process of cleaning the dataset. The SWIFT data from GLS was populated at Census enumerator level whereas the analytical framework requires data at the small area layer level. PDG remapped the data using Census small area layer shapefiles obtained from StatsSA.

Once the SWIFT data remapping was completed, a seven-step data cleaning approach was adopted and applied for each municipality within sample. The following subsection provides a brief description of each of the steps followed to clean the SWIFT dataset

Step 1: Identify variables of interest

The SWIFT data set comes with 119 variables. The following table briefly describes the 13 variables that were used in the analysis.

Table A1: Variables in the SWIFT dataset

Municipality	Category
Serial number	Meter serial number
Availability Code	Water availability code
Water Tariff	Water consumption tariff code
Value Improvement	Value of the improvements on the site
Suburb	Suburb
Suburb Category	The user specified suburb category to which the suburb code is mapped
Stand Number	Stand number
Annual average Daily Demand	Annual average daily demand for the record determined from the readings
Annual Average Daily Demand Units	Average daily demand divided by the number of units supplied by the meter
Stand Annual Average Daily Demand	The sum of the average daily demand for all the records on the stand
Total Measurement	The total water consumption in the last year. If the record period is for less than a year the total water demand = Annual Average Daily Demand x 365

Municipality	Category
Small Area Layer code	Small area layer code
Indigent	Whether the record belongs to an indigent household

Step 2: Remove invalid records

The next step was to identify valid records within the SWIFT dataset. A record is considered valid if there is a serial number associated with it. Hence, where there is a record with no serial number, there is also no consumption and that record is invalid. These records are removed from the analysis.

Step 3: Remove vacant plots

After identifying the invalid records, the next step in the data cleaning process is to remove all the vacant plots. A plot is vacant if it has an average daily demand less than 0.1 kl. The vacant plots need to be removed because they have no one residing on them and hence no water consumption.

Step 4: Distinguish residential records

After removing the plots that have meters but are vacant, the following step in the data cleaning process is to distinguish residential records from the non-residential records. This is important since the focus of the study is only on residential consumers. Residential consumers can be identified using the water tariff codes. The SWIFT data has the water tariff codes which allowed PDG to ask the municipality to indicate which of these codes are for residential customers. Hence, only records associated with residential consumers are kept.

Step 5: Identify duplicate meter records

After identifying residential customers, the next step in the data cleaning process is to identify duplicate meter records. Duplicates occur when the small area line cuts through a stand in a way that causes the stand to fall in more than one small area layer. These duplicates need to be removed because they may lead to the issue of double counting. The approach adopted to identify duplicate meter record was to create a new serial variable that combines several variables including, serial number, water availability code, water tariff code, suburb category, value improvement and average daily demand.

This new variable is used to identify duplicate meters by verifying whether the serial number is distinct and unique. Hence, Records with similar serial number as well as tariff code in the same suburb with the same value of improvements on the property and the same average daily demand are likely to be referring to the same meter.

<u>Example of how duplicates occur</u>

Figure A6: How duplicates occur

Figure A6 shows that the duplicates arise when the small area line slices through a stand in a way that causes the stand to fall in more than one small area layer.

Handling the duplicate meter records

The approach adopted to deal with the issue of duplicate meter records involves calculating the area of each piece of the stand that is cut up. Then identifying the maximum area and the SAL code associated with that area. Hence, only SALs associated with the maximum piece of the stand are kept and all the other duplicates are deleted.

Step 6: Compare total meters in an SAL with total number of households

After duplicate meter records have been identified and removed, the next step of the data cleaning process is the identification of number of meters in each stand to identify the stands with more than one meter. Most residential stands tend to have one meter or sometimes two meters, however, this must be confirmed.

Given that municipalities meter properties, it is common for a single meter to serve multiple households. However, the opposite, where a property has more than one or two meters, is uncommon. Hence, cases where the number of meters are more than households are considered outliers. The analysis removes all SALs where the total number of meters is more than 10% the number of households.

Step 7: identify and remove consumption outliers

Consumption outliers are identified by comparing the consumption levels to inter-quartile range. All consumption outside 1.5 times the inter-quartile range are removed from this analysis.

Outcome of each step in the cleaning process

Table 22: Summary of outcome of the data cleaning process

Data cleaning step	Municipality A	Municipality B	Municipality C	Municipality D
Total SALs in SWIFT data	312	542	109	222
Step 2: remove invalid records	14	0	0	2
Step 3: remove vacant plots	2	44	2	1
Step 4: remove non-residential customers	14	14	3	8
Step 5: remove duplicate records	1	16	0	26
Step 6: remove SALs where meters are more than households	23	1	3	18
Step 7: remove outlier SALs based on consumption	24	22	10	18
Total remaining SALs	234	445	91	149

Table 22 shows the outcomes of the data cleaning process in each municipality. The data cleaning starts with the full set of SALs from the SWIFT dataset and removes SALs with each step. No SALs were removed for Municipality B and Municipality C municipalities since there were no invalid records. A total of 14 SAL codes which were associated with the invalid records in Municipality A and 2 SALs in Municipality D were removed. Municipality B had the highest number of small areas with vacant plots while remaining municipalities only have a few. Municipality A and B have a number SALs were all the records belonged to non-residential customers. The most duplicate records are found in Municipality D whereas Municipality A has 23 SALs were the number of metres is more than the total SALs as per the Census data. Outliers based on consumption are removed from all municipal case studies to finally arrive at the total number of SALs that are included in the analysis.

Cleaning the Census 2011 dataset

The socio-economic data from Census 2011 needs to be cleaned to obtain average income per household at a small area layer level which will then be merged with the SWIFT data to arrive at the final dataset that is used in the analysis. The following subsection will provide a brief description of the process followed to clean the Census 2011 data to obtain the variable of interest.

Identifying the correct households to include

Census data from Statistics SA contains household access to municipal services including water. However, not all the household within a municipality are billed for water consumption. On one hand, households who have access to piped water through community stand are not billed. These households may be supplied by the municipality but do not necessarily face water affordability constraints since their water consumption is not billed. On the other hand, households who have access to piped water inside dwelling/institution/yard may also be supplied by the municipality. These are the households that have to pay the municipality water bills and are more likely to have some water affordability issues. Hence, only households that have access to piped (tap) water inside dwelling/institution or yard are included in the study.

Calculating median household income per small area layer

Since the overall intentions of the research is to test affordability of municipal water tariff rates per household, the focus should only be on the households who have access to water. PDG used small area layer data obtained from StatsSA to only look at the distribution of income for SALs with access to piped water inside the dwelling or the yard.

The variable of interest is the median income per household within a small area. However, the Census 2011 data provides the total number of households in each small area layer that earn within various income brackets. Hence, from the Census 2011 data set, the median income across all households needed to be determined to arrive at a representative household income for each small area. The approach calculates the median income per small area by determining the income bracket where 50% of the households earn within the bracket or less. Since the distribution of each income band is unknown, it is assumed that everyone consumes at a midpoint.

Census 2011 reports income levels for 2011, some of the municipal data from GLS is only available for later years. Municipality A, Municipality C and Municipality B municipalities have consumption data for 2014/15. We use this as our year of analysis to allow for comparisons across the municipalities. The analysis uses South African Reserve Bank data on disposable household income to adjust the income data to 2014. On average, disposable household income increased by 8% per annum in nominal terms.

Other variables of interest: Household size

Based on the literature reviewed, household size is one of the major determinants of household demand for water. Studies estimate that the relationship between household demand for water and number of individuals within household is positive (Grafton et al., 2011). Hence, water consumption is expected to increase with the number of individuals within a household. StatsSA provides data on geography by household size. Hence, the weighted average household size per SAL is calculated and used in the research.

APPENDIX C: TESTING THE ROBUSTNESS OF THE APPROACH TO SAMPLING

All municipality have access to water billing data, however most do not have access to or the capacity to gather income data on customers in the municipality. Where the billing data is available in spatial form, it can be joined to Census data to obtain income at a small area layer and conduct affordability analyses. This study suggests a rigorous and extensive process to arrive at useful data for analysing affordability at the municipal level. Hence, time and capacity constraints make it a challenge for municipalities to be undertake similar analysis for all their small areas. In this context, drawing a sample of SALs becomes an effective way to understand affordability constraints within the municipality.

Using Municipality D as an example, this section demonstrates the robustness of the analytical framework by applying key aspects thereof to a sample of SALs and comparing the indicators to those for the entire municipality. This exercise suggest that a stratified sampling based on income ensures a similar distribution of results in the sample to that in the full population of SALs in the municipality. A stratified sample firstly divides the sample into separate groups and then draws a random sample within each group. In this case, the SALs in Municipality D are divided into deciles and a random sample is drawn from each decile. This ensures that we match income distribution in the sample to that of the full municipality. A total sample of 59 was drawn. This is based on a 10% margin of error and a confidence level of 95%. This margin of error can be reduced to increase the accuracy of the results; however, a larger sample is required. Depending on the available resources, municipalities can draw larger samples to increase accuracy.

Table 23 compares key statistics between the sample and the full population of SALs in Municipality D

Table 23: Municipality D statistics: all SALs vs. sample

	All SALs	Sample SALs
Total SALs used in analysis	149	59
Median monthly income (nominal Rand value in 2014)	6 015	6 015
Average household water **consumption per month** (kl)	12	13
Average household **water bill per month** (nominal Rand value in 2014)	114	126
Macro affordability ratio	1.9%	2.1%
Macro residual income	5901	5889

The macro affordability ratio and residual income are similar between the full population and the sample. The average bill and consumption are slightly higher in the sample, however these are not statistically different from each other. This is based on the results from t-tests to test whether the null hypothesis that the difference in the means is zero. The results yielded p-values of 0.55 and 0.33 respectively. A p-value below 0.1 would suggest that the difference between the means is greater than zero. Hence, in this case we cannot reject a hypothesis that the mean in the sample is not statistically different from the mean in the full population.

Table 24: Affordability ratio frequency distribution: all SALs vs sample

Affordability ratio band	All SALs	Sample SALs
Number of SALs		
<3%	79	40
3-5%	52	10
5-10%	8	4
>10%	10	5
% of SALs		
<3%	70%	68%
3-5%	18%	17%
5-10%	5%	7%
>10%	7%	8%

Using the random sample produces comparable results to those for the full population of SALs with a slightly higher proportion of SALs facing water bill constraints than in the sample. Whereas only 70% of the SALs have ratios below the threshold in the full sample, 68% experience no constraints using the sample. The sample thus slightly overestimates the proportion of SALs facing challenges.

Table 25 shows the proportion of SALs by residual income for the full set of SALs and for the sample.

Table 25: Residual income

Poverty line	All SALs	Sample SALs
Number of SALs		
Below FPL	11	5
Below LBPL	9	3
Below UBPL	0	0
Above UBPL	129	51
% of SALs		
Below FPL	7%	8%
Below LBPL	6%	5%
Below UBPL	0%	0%
Above UBPL	87%	86%

The difference between the distribution of SALs in the full population and the sample is minor. In this case, using the sample would lead to a minor overestimation of the proportion of SALs experiencing problems with water affordability when using the FPL and an underestimation of those facing no constraints.

Based on the simulation results, municipalities using a sample of SALs based on income deciles are likely to obtain an overview of the affordability constraints that is immaterially different from the actual constraints in the municipality. The sample is useful for understanding the overall picture of affordability in the municipality.