EFFECTIVENESS OF WATER SAVING INTERVENTIONS UNDER A SHARED WATER SAVINGS CONTRACT

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DECLARATION

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ABSTRACT

Surface water comprises less than 0.01% of the total volume of water available in the water cycle; however, most of the world's population solely relies on surface water. Issues of rapid population growth, increased industrialisation, and climate change threaten the security of already limited surface water resources. South Africa is classified as semi-arid and a water scarce country, thus efficient management of water resources is of paramount importance. However, water mismanagement is occurring and it has been identified that the implementation of water saving interventions by end consumers, can reduce the impact of water mismanagement and water scarcity.

In view of the issues of water scarcity and water mismanagement in South Africa, a shared water savings contract (SWSC) was initiated to reduce water consumption at institutional facilities within three provinces. The service provider had the mandate of implementing various water saving interventions intended to maximise the water savings at 164 facilities. The facilities consisted of judicial buildings, military/naval bases, police stations and prisons. The study sought to assess the effectiveness of the water saving interventions implemented under the SWSC, focusing on; the significance of the water savings, how the combination of interventions affected the effectiveness of the water savings and the consistency of the water savings.

Prior to the implementation of interventions, a monthly baseline consumption was determined using the facility's historical water consumption. A total of eight water saving interventions could be implemented at a facility, based on the service provider's investigations, and these included leak fixing, pressure management, and awareness campaigns. Some facilities had only one intervention implemented, while others had a combination of interventions implemented. Once water saving interventions were implemented at a facility, water savings were determined by comparing the consumption on the facility's municipal water bill with the facility's monthly baseline consumption.

A data filtering process was undertaken and resulted in 131 facilities eligble for selection. By using a stratified statistical sampling method, 59 facilities were selected for analysis. Using data collected over 12 months in the 59 representative facilities, water saving interventions were found to yield a reduction of 60% in billed water consumption which is highly significant. The water savings were found to be independent of the magnitude of the pre-intervention consumptions of the facilities. It was also found that significant water savings could be achieved when different types of water saving interventions are implemented in isolation or in combination with other interventions. The effectiveness of water saving interventions was found to vary greatly across facilities and, the assessment of facility conditions would therefore be required to inform which interventions could maximise water savings. Leak fixing and retrofitting were popular interventions, although the savings achieved from the implementation of these interventions also varied substantially.

ACKNOWLEDGEMENTS

To my Lord and Saviour, whose grace and mercy is unwavering, I present this body of work as a testament for what You have done in my life. Thank You for giving me the knowledge needed, the patience, the perseverance, and the strength to complete this research.

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To my father, Jonathan Kuntashula; where I am today is through the hard work and sacrifices you have made, and I cannot thank you enough. I would also like to thank my sister Sipho for always being there when I need you. I love how smart you are, yet you are so humble. Only God knew how much I needed you in my life and I am grateful for having walked this Earth with you.

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LIST OF ABBREVIATIONS

°C	Degree Celsius
%	Percent
CAD	Computer Aided Design
DMA	District metred Area
EPA	Environmental Protection Agency
ESCO	Energy Savings Company
ESPC	Energy Savings Performance Contract
GSM	Global System for Mobile Communications
ILI	Infrastructure loss index
IWA	International Water Association
km^3	cubic kilometre
kWh	Kilowatt hour
LEED	Leadership in Energy and Environmental Design
m^3	cubic metre
m^3/annum	cubic metre per annum
m^3/capita/year	cubic metre per capita per year
m^3/month	cubic metre per month
mm	millimetre
mm/year	millimetre per year
MNF	Minimum night flows
NRA	Non-Revenue Assumption
NRW	Non-Revenue Water
PPP	Public-Private Partnership
PRV	Pressure reducing valve
SPSS	Statistical Package for the Social Science
SWSC	Shared water savings contract
UN	United Nations
WDM	Water Demand Management
WDS	Water Distribution System
WSA	Water Saving Authority

CHAPTER 1: INTRODUCTION

Water is a naturally occurring substance that is simple in its molecular structure but complex in its behaviour, availability and the reliance that living organisms have on it. The molecular structure of water is comprised of two positively charged hydrogen atoms and one negatively charged oxygen atom (Brini et al., 2017; Zumdahl, 2021). The hydrogen atoms are attracted to one side of the oxygen atom (making this side positive) and the opposite side is thus negative due to the negative charge of the oxygen atom (Pandey et al., 2017; Sargen, 2019). This results in the water molecule being polar, and it is this polarity that makes water's interaction with other molecules unique (Brini et al., 2017; Sargen, 2019).

Water is the only natural substance that can be found as a liquid, a solid and a gas, at various temperatures (Brini et al., 2017; USGS, 2021). This fact is most notable in the water cycle, otherwise known as the hydrologic cycle. This cycle, provided in *Figure 1-1* below, shows the movement of water in and around the Earth and how water is continuously changing states between liquid, vapour (gas) and ice (solid) (USGS, 2021).

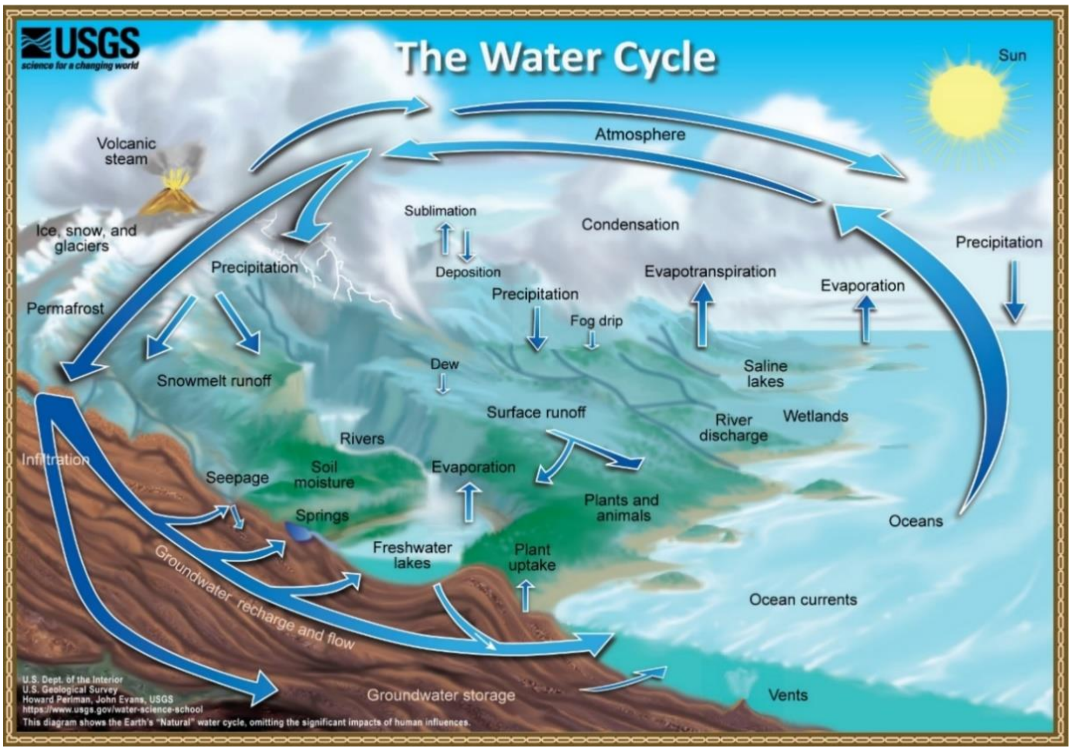

Figure 1-1: The natural water cycle (Perlman & Evans, 2019).

The upward movement of water is caused mainly by evaporation and evapotranspiration, during which water is in its gaseous form, primarily due to the heat caused by the sun. The downward movement of water occurs mainly through precipitation, surface runoff, infiltration, and groundwater flow, during which water is in its liquid form. The ice caps, glaciers and snow fall comprise of water in its solid form.

According to the Bureau of Reclamation California-Great Basin (2020), there is approximately 1.36 billion km^3 of water on Earth at any given point in time. As shown in *Figure 1-2*, of this total, approximately 97% is saline water found in the oceans and only 2.5% is fresh water (Shiklomanov, 1993). Furthermore, as can be determined from *Figure 1-2*, approximately 2.47% of the total global water available is in the form of ice or is in the form of groundwater (some of which cannot be feasibly abstracted) (Bureau of Reclamation California-Great Basin, 2020). This leaves a mere 0.013% (or 176 800 km^3) of surface water in the form of rivers, swamps, and lakes for most of the world's population to utilise, with a small percentage of people being solely reliant on groundwater (Shiklomanov, 1993; Bureau of Reclamation California-Great Basin 2020).

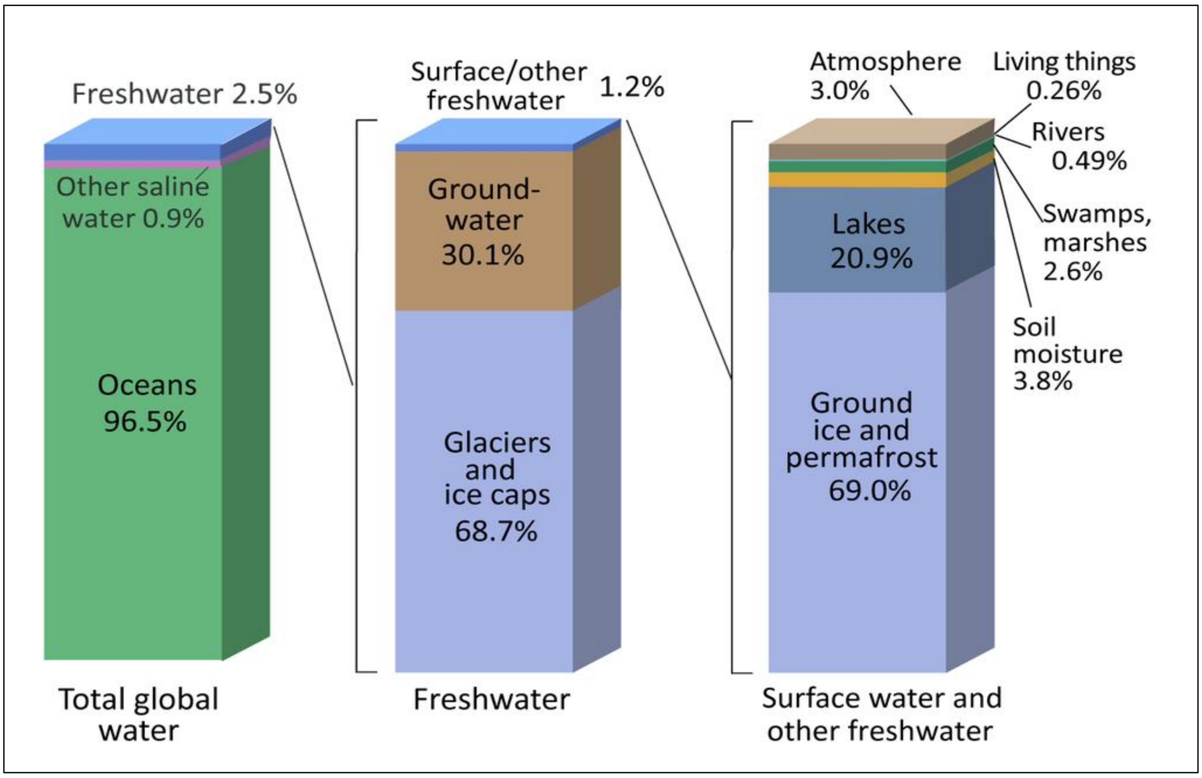

Figure 1-2: Distribution of Earth's Water (Shiklomanov, 1993).

Fundamentally, all living organisms are dependent on water for their physical survival, and as ironically stated by Sargen (2019), *"(water) is vital for all known forms of life even though it provides no calories or organic nutrients"*. For some organisms, water bodies are their natural habitat, while for people, water is not only required for consumption and household use, but also for several commercial and industrial activities. Thus, it is difficult to fathom that the world's population and most living organisms are all reliant on less than 1% of the total available water, for survival (Brini et al., 2017; Sargen, 2019).

It is important to note that the water cycle is a finite and closed system (Dooge, 1968). This means that the quantity of water available at any point in the cycle is approximately the same (finite), and that no further volumes of water can be removed from or added to the system (closed). However, rapid population growth and increased industrialisation is escalating the demand and competition for water (Mogelgaard, 2012). This, in turn, is affecting the water availability and natural habitats of several living organisms. Climate change, which is a by-product of increased industrialisation, is further exacerbating water availability and is adding to water scarcity.

According to Mogelgaard (2012), slowing population growth rates can be an effective strategy to decreasing water demand and ensuring access to adequate water resources. However, this cannot be done in isolation, considering that increased industrialisation (for which water demand is far greater than human consumption) is independent of rapid population growth. As such, there exists a need to focus on how to safeguard water resources on the back of increased industrialisation. It is for this need that this research seeks to fulfil.

1.1 Background Statement

1.1.1 Context of Water Saving Interventions

The first Dublin Principle states that "freshwater is a finite and vulnerable resource that is essential to sustain life, development, and the environment" (World Meteorological Organization-Geneva, 1992). Therefore, freshwater must not only satisfy various domestic needs, but also various commercial needs as well. Commercially, many sectors are dependent on a sustainable water supply, such as the agricultural sector, the mining sector, and the power generation sector. The commercial need must balance the domestic needs that include urban and rural water consumption. However, in many parts of the world, much like in South Africa, water is a scarce resource that must be safe guarded.

South Africa is classified as semi-arid because the country receives an average rainfall of less than 500mm a year (Dallas & Rivers-Moore, 2013; Mwendera, 2016). The water supply system relies mainly on rainfall to fill dams, rivers, and reservoirs, with a small percentage of the population being self-reliant on groundwater. The water supply system, however, supplies approximately 78% to the agricultural sector and other industrial sectors leaving only 22% (18% urban and 4% rural) for human consumption (Department of Water Affairs, 2013). Adding to the scarcity of water in South Africa, is the poor management of water. It was stated at the International Conference on Water and the Environment, that the water crisis is not due to the lack of adequate water, but it is due to the management of water (World Meteorological Organization-Geneva, 1992). Therefore, the need for water saving interventions is thus critical.

Most water saving interventions can easily be implemented on a domestic scale. According to Biggs (2017), installing water efficient fixtures for showers, taps and toilets can reduce a household's consumption by almost 50%. Another useful domestic water saving intervention is reclaiming and re-using wastewater, such as grey water, for irrigation (Christova-Boal et al., 1996; Dixon et al., 1999; Al-Jayyousi, 2003). Rainwater harvesting is another great water saving intervention; however, it may be difficult to implement for many South Africans who live in multi-residential housing (Kahinda et al., 2007; Abdulla & Al-Shareef, 2009; Helmreich & Horn, 2009). Information on several other water saving interventions that can be implemented domestically is readily available (Worldwide Fund, 2016; Western Cape Government, 2017; RPM Drilling, 2019).

As previously mentioned, non-domestic water use consists of 78% of the total potable water usage in South Africa (Department of Water Affairs, 2013). Therefore, a larger focus should be on non-domestic water saving interventions. However, this is not evident in literature. Very few studies have focused on the various water saving interventions that can be implemented by commercial consumers, but those that have, have focused more on the agricultural sector (Mahmood et al., 2015; Tang et al., 2016). At the time that this research was conducted, studies that assessed the effectiveness of water saving interventions that can be implemented at institutional facilities were limited.

1.1.2 Context of Shared Water Savings Contracts

The fourth Dublin Principle states that “water has an economic value in all its competing uses and should be recognised as an economic good” (World Meteorological Organization-Geneva, 1992). This statement emphasizes that a monetary value can be placed on water and therefore, signifies the cost implications of water losses and water wastage.

In 2010, it was estimated that 36.8% of the total volume of the South African municipal water supply, is water that cannot be billed which results in a loss of income to the water service providers (McKenzie et al., 2012). Of the 36.8%, real/physical losses account for 25.4%, commercial losses account for 6.4% and unbilled authorised consumption accounts for 5.0%. However, this 36.8% which is termed as Non-Revenue Water is of concern for the water service provider as it is a result of poor maintenance of water infrastructure, a lack of meters to measure consumption and the theft of water. The need for water saving in this study is due to water wastage “after the meter”, that is, wastage that should be of concern to the consumer.

A shared water savings contract is one in which a service provider is responsible for funding and executing activities with the aim of reducing water consumption of a facility or area. The service provider is then remunerated based on an agreed split of the value of water savings achieved, while the client retains the remainder of the value of water savings. According to Jacobs et al. (2020) a shared water savings contract is a form of performance or risk-reward contract and can be termed as a shared energy contract. These contracts generally involve two parties; namely, the service provider and the client, where the service provider would be privately funding and installing the energy conservation measures on a particular facility, while the client would be the custodian or owner of said facility (Andrews, 2004). The premise on which these contracts function is based on a fixed share scheme of any savings achieved through the energy conservation measures implemented by the service provider (Aldridge, 1995; Andrews, 2004). The risk and rewards lie purely with the service provider as savings are not guaranteed (Preckel et al., 2004).

Performance contracts and risk-reward contracts are used in various sectors, such as the construction, finance, and public sectors, and have been thoroughly researched in these sectors (Farrell & McDermott, 1995; Shirley & Xu, 2001; Zhang & Li, 2014). In the public sector, shared energy savings contracts are typically used by government agencies as a vehicle for procurement, as government departments tend to have budgetary constraints and are not able to implement such projects within their budgets (Aldridge, 1995). Thus, shared energy savings contracts are implemented mainly on state owned or institutional facilities. For the most part, these shared energy savings contracts have focused on reduction in energy consumption, as illustrated by Claridge et al. (1991), Aldridge (1995) and Lee (2008). A few studies, such as the one conducted by Andrews (2004), involved a combination of both water and energy consumption. However, of the research conducted, little to none have focused on water consumption alone. It is for this reason that the focus of this study will be solely on water savings achieved under a shared water savings contract at institutional facilities.

1.2 Significance of the Research

Water is a valuable resource that should be adequately utilised and managed. Therefore, any research that can highlight ways in which this can be done, is of great importance. This research sought to evaluate various water saving interventions that have been implemented at institutional facilities. These water saving interventions were conducted under the constraints of a shared water savings contract, for which, little research has been done. This fact made this research vital and necessary.

The research sought to analyse the effectiveness of various water saving interventions. The practical importance of the outcomes of the research was knowledge of the best water saving interventions that can be implemented under a shared water savings contract. This was significant as this has not been adequately addressed in literature.

The results of this research would be beneficial to any entity looking to enter a large-scale shared water savings contract. However, due to the risk-reward aspect of a shared water savings contract, the results of this research would be most beneficial to the service providers. The service providers would be provided with a good understanding of the effectiveness of various water saving interventions as well as how much water could be saved. Conversely, the client would obtain a clearer view of the benefits that shared water saving contracts can provide, and the associated risks.

1.3 Scope, Aims and Objectives

The aim of this study was to analyse and evaluate the effectiveness of water saving interventions under a shared water savings contract. The research scope was limited to water saving interventions that had been implemented at 164 institutional facilities in South Africa. The research objectives were:

i. To assess whether the water saving interventions that have been applied have significantly saved water,
ii. To determine the combinations of water saving interventions which maximise water savings, and
iii. To determine the consistency of water saving interventions across the facilities.

Achieving these objectives satisfied the research aim of evaluating the effectiveness of water savings interventions under a shared water savings contract.

1.4 Research Questions

The research study will attempt to answer the following questions:

1. What percentage of water has been saved from the implementation of the water saving interventions?
2. Which combination of water saving interventions yields the most water savings?
3. Is there consistency in the water savings interventions implemented in the three provinces?
4. Is there consistency in the water savings interventions implemented across the various types of facilities?

1.5 Research Report Outline

Chapter 1 introduces the research topic by contextualising water saving interventions and shared water savings contracts and highlighting the significance of the research. The scope, aims and objectives of the research are also detailed within this chapter.

In Chapter 2, the literature on water savings and shared savings contracts is reviewed. This involves addressing the need for water saving interventions, analysing various water saving interventions and discussing shared savings contracts. The chapter is concluded with a summary of the review.

The research methodology is described in Chapter 3. Furthermore, the data sourcing, data filtering and data analysis are discussed in this chapter, as well as assumptions that were made in the research.

Chapter 4 is a detailed presentation of the findings and results of the data analysis undertaken, as well as a discussion of the results.

Lastly, in Chapter 5, the research is concluded, and recommendations are made based on the research.

CHAPTER 2: LITERATURE REVIEW

The research sought to analyse the effectiveness of water saving interventions under a shared water savings contract. Prior to undertaking the study, it was imperative to find out what research has been conducted on this topic and associated topics, and to discuss the gaps that exist in literature. This section informs the need for this research by identifying the need for water saving interventions, by identifying and analysing various water saving interventions and by discussing shared savings contracts. The section will conclude with a summary that clearly identifies the gaps in literature that justify this research.

2.1 The Need for Water Saving Interventions

At the International Conference on Water and the Environment held in Dublin, Ireland in 1992, two key statements were discussed regarding water resources management. The first statement was that "freshwater is a finite and vulnerable resource…" and how the overuse of this resource can lead to water scarcity. The second statement focused on how the water crisis stems from the poor management of water and not necessarily from the shortage of sufficient water (World Meteorological Organization-Geneva, 1992). This section will therefore look at water scarcity and water mismanagement as two issues that necessitate the need for water saving interventions.

2.1.1 Water Scarcity

Water scarcity is comprised of both physical water scarcity and social water scarcity (Ohlsson & Turton, 1999; Kummu et al., 2010; UN Environment – DHI Centre, 2017; United Nations Water, 2018). Physical water scarcity is the unavailability of water due to physical shortages, while social water scarcity is a result of a lack of infrastructure and poorly operated/maintained water systems induced by an area's political landscape, policies, or inequality (Ohlsson & Turton, 1999; Kummu et al, 2010; UN Water, 2018). The focus of this sub-section, however, will be on physical water scarcity which necessitates the need for water saving interventions in South Africa.

Physical water scarcity is due to a physical shortage of water that is linked to natural phenomena such as a region's rainfall, temperature, drought occurrence and climate change (Kummu et al., 2010). These factors culminate to determine the water availability of the region. Based on the index developed by Gallart et al. (2002), South Africa is classified as a semi-arid country as it receives an average annual rainfall of between 200mm and 700mm, i.e., 610mm/year (South African Weather Service, 2019). This average annual rainfall was determined from actual data from 18 rainfall stations across South Africa from 1981 to 2010. However, this rainfall figure has been stated to be much lower by other researchers; 497mm/year and 450mm/year (Turton, 2008; Botai et al., 2019). None-the-less, South Africa's average annual rainfall is still well below the global average of 860mm/year (Turton, 2008). The rainfall patterns in South Africa are variable with some regions experiencing summer rainfall and others experiencing winter rainfall, with rainfall averages varying between 200mm/year and 900mm/year (Botai et al., 2018). Thus, this adds to the limitations on the quantity of water available for use, with de Wit and Stankiewicz (2006) predicting a decrease in annual rainfall volumes by as much as 10% by the year 2050.

Adding to the below-average annual rainfall received in South Africa, are the high average temperatures and the high evaporation rates, and these influence the frequency and duration of droughts experienced in South Africa (Wassung, 2010; Nkondo et al., 2012). The average annual temperature for South Africa is approximately 19^{o}C, as compared to the global average of 10^{o}C (Wolski, 2019). On the other hand, South Africa's evaporation rates vary from 1400mm/year to 2800mm/year (South Africa Online, 2021), while the global average evaporation rate is approximately 474 mm/year (Wang & Dickinson, 2012). These low rainfall volumes, high temperatures and high evaporations rates increase the likelihood of drought.

Climate change (brought on by global warming) poses a great threat to South Africa's water availability as it will increase the occurrence and intensity of droughts, putting more strain on an already water-stressed region (Wassung, 2010; Nkondo et al., 2012).

However, due to the variable distribution of rainfall, the influence of climate change will not be consistent across the country, with Schulze (2005) predicting that some regions may benefit while others become even more prone to drought. According to the National Water Resource Strategy published by the Department of Water Affairs, South Africa's freshwater availability is approximately 10 000 million m^3 per year and this water is fully abstracted (Nkondo et al., 2012; Department of Water Affairs, 2013). Areas where water deficits are prominent or where the system is considered to be in equilibrium, the likelihood is that water deficiencies are felt in more than 2 out of 100 years (Nkondo et al., 2012). With the available freshwater being fully abstracted yearly, Wassung (2010) noted that this does not leave any room for future development or allow for water reserves during times of drought. As per the National Water Resource Strategy 2, more than 67% of the mean annual runoff of 49 000 million m^3 is stored in dams, while 25% remains in rivers and estuaries (Nkondo et al., 2012). The remaining portion is contained in remote river basins that are far from the economic hubs and the costs of transferring water to these locations of use are rising with longer distances (Nkondo et al., 2012; Department of Water Affairs, 2013).

Geller et al. (1983), Mwendera (2016), Biggs (2017) and Ruiz et al. (2020), have all asserted that several regions around the world are water scarce and that the existing water infrastructure is under severe stress. Furthermore, population growth has been associated with an increase in water scarcity and according to United Nations Water (2018) the use of water has been increasing at twice the rate that populations have been growing, making water scarcity a global phenomenon (Kummu et al., 2010).

Kummu et al. (2010), sought to track the increase in physical water scarcity globally over the last 2000 years by considering population growth and water resources availability to determine water shortages. As represented in *Figure 2-1*, their results show that water shortages began in the year 1800, and in the year 1900, 2% of the global population were living under chronic water shortage (<1000 m^3/capita/year). This percentage grew to 35% in 2005, with most of these people residing in Africa, the

Middle East and Asia. The results also showed that over the period of observation, population growth had a much greater impact on water shortage than climate change, resulting in the most widespread water shortage being in South Asia where the population was approximately 1.5 billion in 2005 (Kummu et al., 2010; Worldometer, 2020).

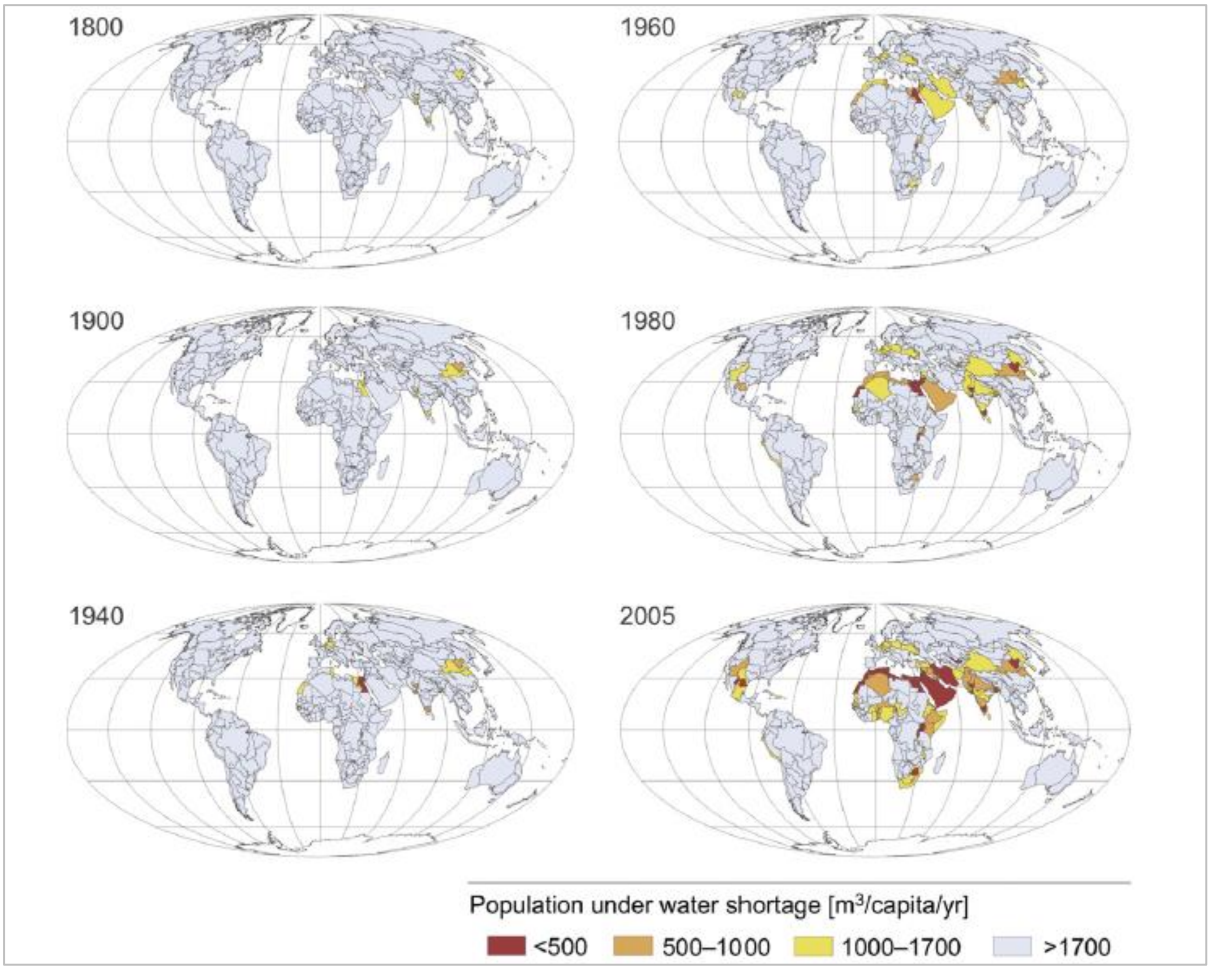

Figure 2-1: Water shortage mapped for each food production unit (FPU) for the time period 1800-2005 (Kummu et al., 2010).

Similar to the study conducted by Kummu et al. (2010), several researchers have developed metrics to assist in determining the annual geographic occurrences of water scarcity. Falkenmark (1989) developed a metric that analysed the ratio of population size to the renewable water supply, while the metric developed by Alcamo and Henrichs (2002) looked at the ratio of water withdrawals to the renewable water supply, and both metrics highlighted the disparity between water demand and water availability.

Further to this, research conducted by Hoekstra et al. (2012) sought to expand on the existing metrics by being the first study to consider three phenomena; (i) considering measured groundwater and surface water consumption rather than water abstraction, (ii) considering flows required to maintain critical ecological functions and (iii) considering monthly (and not annual) variations in water use and availability. The study analysed the blue water scarcity, defined as the ratio of the total blue water footprint to the blue water availability in a river basin, of 405 river basins that make up 66% of the global land area and which serviced 65% of the global population in the year 2000. From the analysis, a world map was generated indicating the number of months during the year when the blue water footprint was greater than the blue water availability between 1996 and 2005 (*Figure 2-2*) (Hoekstra et al., 2012).

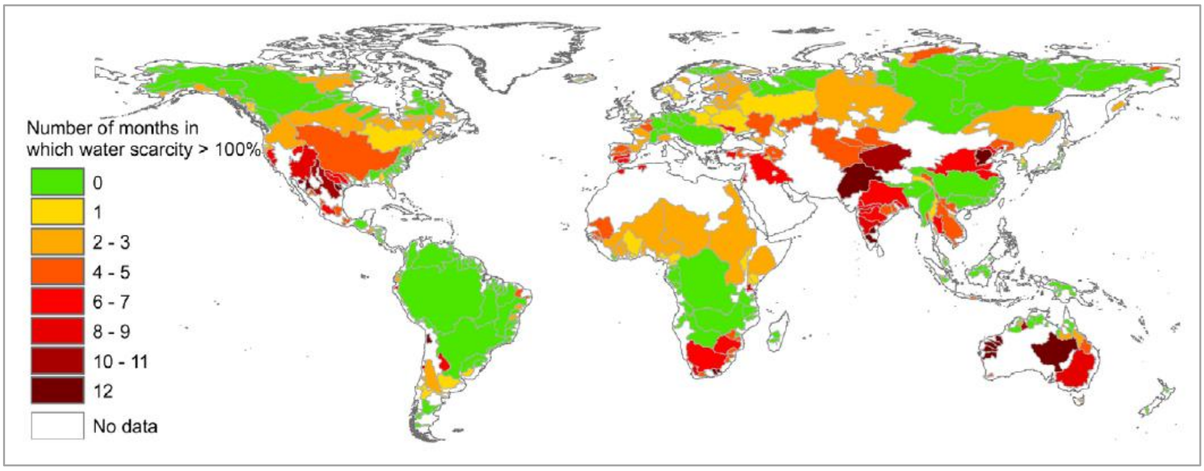

Figure 2-2: Number of months in the year when blue water footprint is greater than blue water availability for the world's major river basins for the period 1996-2005 (Hoekstra et al., 2012).

Evaluating water scarcity in a local context, *Figure 2-1* indicates that in 2005, South Africa was classified as having a moderate water shortage, with the population surviving on under 1700 m^3/capita/year (Kummu et al., 2010). Following the growth trend of water shortage from 1980 to 2005 (when the South African population went from living on more than 1700 m^3/capita/year to having between 1000- and 1700 m^3/capita/year), it is possible that the water shortages may now be classified as chronic and may be in the region of 500 – 1000 m^3/capita/year (Kummu et al., 2010). Similarly, it can be noted from *Figure 2-2* that for seven months of the year, the water consumption exceeds the water availability for most of South Africa (Hoekstra et al., 2012). In particular, the Groot-Kei River Basin in the Eastern Cape experiences eleven months of severe water scarcity. The findings of Kummu et al. (2010) and Hoekstra et al. (2012) indicate that water scarcity is of great concern in South Africa and efforts, such as the implementation of water saving interventions, must be made to alleviate water scarcity.

2.1.2 Water Mismanagement

According to Piper (2014), South Africa was the first country to include the human right to "sufficient food and water" within its constitution that was drafted in 1996. The right to have access to water was symbolic of the end of 47 years of apartheid law, under which water was unequally distributed, with most water being channelled to areas where white people lived (Department of Water Affairs, 2013; Piper, 2014). On the back of this, South Africa has emerged as a leader in having one of the best water legislations in the world (Piper, 2014; Nhamo et al., 2020). However, considering the constitutional right that South Africans have to water and that South Africa has one of the best water legislations in the world, has water access and infrastructure been effectively and efficiently managed?

South Africa has been facing a water crisis that in part, is caused by the failure to meet demand management targets, decaying infrastructure, theft of water resources and deteriorating water quality (Herold, 2010; Kummu et al., 2010; Department of Water Affairs, 2013).

2.1.2.1 Water Demand Management Targets

Both Herold (2010) and Wegelin and Jacobs (2013) asserted that municipalities (local authorities) have not adequately implemented water conservation and water demand management (WC/WDM) within their regions. This is because the Water Services Act,

Act 108 of 1997, requires that all Water Service Providers (which municipalities are) must develop a WC/WDM strategy and business plan, which details their measures to promote WC/WDM (Wegelin & Jacobs, 2013).

In the 2010 State of the Nation Address, President Jacob Zuma stated that measures would be put in place "to reduce our water losses by half by 2014" (Wassung, 2010; McKenzie et al., 2012; Wegelin & Jacobs, 2013). However, at the time of his address, most municipalities did not have a WC/WDM strategy and business plan in place (Wegelin & Jacobs, 2013). This meant that municipalities could not plan, obtain funding and implement projects that ensure the sustainability of water resources in the municipality, and in South African as a whole (Wegelin & Jacobs, 2013). Thus, without WC/WDM strategies in place across the country, it would be difficult to realise this target. Water saving interventions can assist in realising this target as they are implemented not by the water service provider, but by individual consumers.

2.1.2.2 Decaying Infrastructure

A study conducted by McKenzie et al. (2012), quantified the various components of the International Water Association (IWA) Water Balance, within the South African context (as shown in *Figure 2-3*). The study found that of the entire system volume, the level of Non-Revenue Water (NRW) was estimated to be 36.8% and consisted of 31.8% water losses and 5.0% unbilled authorised consumption (McKenzie et al., 2012; Department of Water Affairs, 2013). Of the 31.8% water losses, 6.4% consists of commercial (apparent) losses and 25.4% consists of real/physical losses (McKenzie et al., 2012). While commercial losses are as a result of unauthorized consumption which in essence is water theft, real/physical losses are due to water leaks along the distribution network and this is caused by inadequate maintenance of the distribution network (McKenzie et al., 2012).

Herold (2010) stresses the importance of continuous maintenance to minimize persistent leaks and other repairs needed to curb water losses. However, in 2008, the water demand management expenditure in Gauteng was less than R100 million and was only sufficient to perform maintenance on less than 40% of the municipal water infrastructure (Herold, 2010). On the back of a stagnant South African economy, the government will have no option but to further reduce the budget allocated to several departments, and the budgets for the maintenance of water distribution networks will not be spared. However, by reducing the end user's water consumption, this will reduce water demand, thus reducing real/physical losses along the distribution systems. This can be achieved with the implementation of water saving interventions by the end user, especially by those who are deemed high consumers.

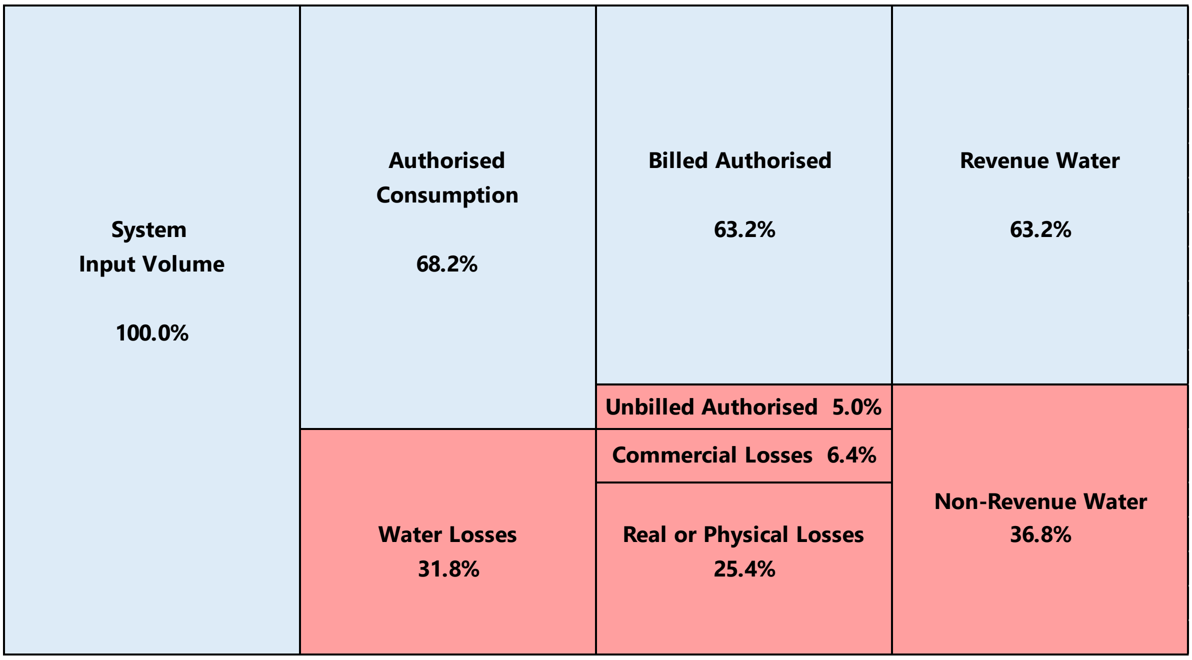

Figure 2-3: The South African water balance (McKenzie et al., 2012).

2.1.2.3 Water Theft

As per the South African water balance determined by McKenzie et al. (2012) (*Figure 2-3*), commercial losses or apparent losses were described as the theft or illegal use of water, as well as customer meter inaccuracies. These losses were determined to be 6.4% (or 275 million m^3/annum) of the total system volume of 4 292 million m^3/annum and have a financial value of approximately R1.25 billion (McKenzie et al., 2012). It is difficult to ascertain what portion of these figures is purely due to water theft because customer meter inaccuracies are prevalent. Water meter inaccuracies are typically due to meters extending beyond their usable life, and in these instances, water meters tend to underestimate consumption resulting in a loss of revenue to the water service provider (Couvelis, 2012). The severity of water theft should be of great concern and measures must be in place to reduce the likelihood of it happening as well as the extent of the effects.

Further to the 275 million m^3/annum in apparent losses, Herold (2010) states that approximately 175 million m^3/annum is being unlawfully abstracted from the Upper Vaal catchment. The sad reality is that the quantity and location of the water theft is well known, however those perpetuating the crime cannot be held accountable because the legal, administrative and abstraction monitoring mechanisms are not in place (Herold, 2010). The water is being stolen from one of the conduits transferring water from Lesotho, for which urban consumers in Gauteng are paying greatly for, but yet nothing can be done to stop the theft (Herold, 2010). This water theft has grave consequences as it results in the Vaal River system being in a deficit of 8% (Herold, 2010).

As can be noted, water theft contributes to water scarcity and must be tackled directly. Water saving interventions would assist in reducing water scarcity, thus reducing the impact that water theft is having on water resources.

2.1.2.4 Water Pollution

After the new South African constitution was drafted, the new economic plan for providing water, was to adopt the World Bank's model of having the public pay for the cost of water and sanitation infrastructure (Piper, 2014). According to Piper (2014), this meant that black people, who made up the bulk of the population, but who previously did not share in the wealth of the country, were expected to pay for very expensive projects such as the Lesotho Highlands Water Project. This resulted in most people not paying for water and sanitation because they merely could not afford it.

However, in the townships of Johannesburg, the water bills were incorporated into the monthly housing rental, and the city of Johannesburg decided to evict non-paying residents (Piper, 2014). Furthermore, evictions over unpaid water bills were occurring across the country and this led to residents having to make use of polluted rivers for drinking water (Piper, 2014). In 2000, there was a cholera outbreak in Kwa-Zulu Natal, and by the time it was contained, 120 000 people had been infected and 265 people succumbed to the illness (Piper, 2014).

Both Herold (2010) and Wassung (2010) have highlighted the high levels of water pollution occurring from acid mine drainage, irrigation, sewage effluent and biological matter. Furthermore, Wassung (2010) has criticised the Department of Water and Sanitation for not spearheading reform in the mining, agriculture and other industrial sectors, which would result in harsher consequences for water pollution. Water pollution is severely impacting water resources such as rivers and catchment areas, and some beaches, thus reducing the quantity of usable freshwater (Herold, 2010; Department of Water Affairs, 2013).

Similarly, to water theft, water pollution reduces the quantity of water available for use, thus contributing to water scarcity. Conversely, the implementation of water saving interventions aids in reducing water scarcity, and ultimately reducing the impact that water pollution is having on water resources.

2.2 Analysing Various Water Saving Interventions

2.2.1 Leak Fixing

Leakages have been identified by several researchers as one of the major contributors to water losses in a Water Distribution System (WDS) (Gupta & Kulat, 2018). Water losses are classified as either real or apparent. Real water losses are physical water losses where water is physically lost; while apparent losses refer to the authorized usage of water that is not billed and thus, not paid for. Apparent losses are often due to inaccurate meter readings, broken meters, unregistered meters, or errors in customer billing (Gupta et al., 2017; Gupta & Kulat, 2018).

Gupta and Kulat (2018) noted that in developing countries leakages in the WDS can account for as much as 50% of the water supplied. The Department of Water Affairs (2013) published data which illustrated that water losses and high night flows experienced in South Africa could be as high as 70% of the water supplied. These significant losses result in water service providers having to pump out more water to meet the demand (Gupta et al., 2017). As a result, additional energy is consumed and to compensate for the increased energy demand, water tariffs charged to customers are increased (Gupta et al., 2017; Gupta & Kulat, 2018).

The implementation of this water saving intervention has the benefit of addressing water losses within the WDS, as well as benefiting the society at large by mitigating adverse impacts on water quality and consumer health (Department of Water Affairs, 2013; Gupta & Kulat, 2018). Leakages can negatively impact the quality of water as a burst or broken pipe can serve as a point of possible contamination as pathogens or debris from the surroundings can enter the water distribution network (Kumar et al., 2010; Gupta & Kulat, 2018).

Leakages can be caused by several factors, namely: old or aging infrastructure, lack of maintenance of pipelines and fittings, corroded steel pipes, network overloading due to increased demand, low quality workmanship and pressure surges (Department of Water Affairs, 2013; Saghi & Aval, 2015). Pressure surges cause significant damage to piping networks and fittings and as such, pressure management is generally discussed in research centred around leak fixing (Saghi & Aval, 2015).

In the study conducted by Booysen et al. (2019) the impact of general maintenance of plumbing fixtures and pipelines actioned at 196 schools within the Western Cape Province was assessed. The results indicated that leak fixing contributed to an overall reduction in the minimum night flow. During the first five (5) days of active leak fixing, the overall reduction in the minimum night flow at the schools was approximately 28% (Booysen et al., 2019).

Leak fixing is often discussed and explored in conjunction with other water saving techniques. Aksela et al. (2009) and Ahopelto and Vahala (2020) stated that leakage control can be managed by district metering, which is the demarcation of a water network to have distinct points of flow and pressure measurement. While district metering aids in the quick identification and repair of leaks, to address the background leakages within a WDS caused by aging infrastructure, pressure reduction and asset management such as the renovation and repair of pipelines is most effective (Mutikanga et al., 2013; Aksela et al., 2009; Ahopelto & Vahala, 2020).

In the study conducted in Finland by Ahopelto and Vahala (2020), a cost-benefit analysis was performed against three water saving interventions, namely, district metered areas, district metered areas with pressure management and pipeline renovation. The study concluded that there was no cost benefit for the utilities that implemented these interventions seeing as the value of the water savings made did not cover the cost of implementing the interventions. This was related to the fact that the utilities did not experience significant water losses within their respective WDS (Ahopelto & Vahala, 2020). This suggests that the implementation of these water saving interventions is only financially beneficial when the water losses experienced are significant. It should be noted that from the results obtained, between the three water saving interventions assessed, district metering performed the best while pressure management came in as a close second.

Britton et al. (2013), noted that households included in the study achieved an overall decrease of 89% in their minimum night flows. This was achieved by using various methods of communication to inform homeowners of their water use and, in some cases, the possibility of leaks. When made aware of the leaks, most respondents acted promptly by either hiring a plumber or repairing the issue themselves (Britton et al., 2013). This shows that when consumers are notified and made aware of possible leaks, consumers are willing to act. Researchers such as Boulos et al. (2008), Giustolisi et al.

(2008), and Cheung et al. (2010) have opted to use network modelling and simulation technologies to assess the efficiency of leak fixing.

Ruiz et al. (2020), assessed whether the adoption of water conservation measures such as leak repairs, reduced shower times, use of dishwashers and washing machines only with full loads and installation of water conserving appliances, could lead to sufficient water savings and relieve stress on water resources caused by excessive demand. This study, which was conducted in several counties in the United States, found that the adoption of the water conservation measures only alleviated water stress in 6% of the U.S. counties (Ruiz et al., 2020). The researchers attributed the low percentage to the fact that the agricultural sector accounts for a large percentage of water use in the identified counties, therefore any residential programmes would be futile in relieving water stress due to the role that the agricultural sector plays in contributing to water stress.

2.2.2 Retrofitting and Water Saving Fixtures

Retrofitting refers to the installation of water saving fixtures, equipment and appliances, in order to make an already existing system or household's water use more efficient and promote water savings (Liu & Ping, 2012). Geller et al. (1983) and Ruiz et al. (2020) have linked water scarcity to the need for water saving interventions in residential household through the direct implementation of water saving initiatives such as retrofitting.

In the American study conducted by Geller et al. (1983), a three-prong approach was adopted which involved: (1) education on water conservation, (2) behavioural assessments on water conservation and (3) installation of water conservation devices in different households. The study found that substantial water savings were only achieved after the installation of the water saving devices and minor savings were achieved from the education and behavioural assessment approaches (Geller et al., 1983).

Barnard et al. (2014) presented a case study of retrofitting within a hotel. The water saving fixtures installed within the hotel rooms were new pressurised shower systems, toilet cisterns with a smaller capacity and dual flush capability, and installing mixer taps in the basins. The water saving fixtures achieved a reduction of 24% in the total water use within the hotel. The study emphasised that there was a need to inform hotel staff and residents on how to use the new fixtures and create an environment that encouraged a behavioural change in water consumption patterns and practices (Barnard et al., 2014). Moglia et al. (2018) and Stavenhagen et al. (2018) substantiated these observations and found that awareness campaigns that promoted the implementation of retrofitting, water saving technologies and appliances were considered more impactful than awareness campaigns that solely promoted water conservation efforts.

Several researchers have focused on water conservation and water savings on the domestic/residential scale. Britton et al. (2013), Watson (2017) as well as Yang et al. (2017) conducted studies on the use of technology to aid residential consumers to conserve water. Both Britton et al. (2013) and Watson (2017) looked at the use of smart metering interventions to reduce household water consumption. While the findings of Britton et al. (2013) showed that the use of smart meters reduced household minimum night flows by 89%, Watson (2017) presented data that illustrated the impact that the social, cultural and economic environment of residents included in the study, have on the amount of water that can be saved from the implementation of smart metering. Yang et al. (2017) developed a model that makes use of the Internet of Things technology to provide a consumer with accurate information on the water consumption of various appliances within the household. This information, together with practical advice on water saving activities, assisted the consumer in reducing their overall water consumption (Yang et al., 2017).

Retrofitting and leak fixing are the leading domestic water saving initiatives that have been presented in literature (Keramitsoglou & Tsagarakis, 2011; Biggs, 2017; Ruiz et al., 2020). Some research studies have assessed the efficiency of these initiatives. Biggs (2017) found that retrofitting a toilet cistern with a hold-flush system saved up to 20% water and installing low-flow aerators on taps and showerheads yielded water savings of close to 65%. In the study conducted by Ruiz et al. (2020), the full adoption of various domestic water savings initiatives such as fixing leaks, behavioural changes in water use (e.g., taking shorter showers) and the installation of household water saving fixtures (low-flow toilets, taps and showerheads), managed to ensure that 6% of U.S counties were no longer classified as water stressed.

2.2.3 Efficient Use of Water

Efficient water use refers to the controlled supply and usage of water. Efficient water use interventions are often divided into pricing and non-pricing techniques (Tortajada et al., 2019). Tortajada et al. (2019) described the implementation of water tariffs as a pricing water saving measure whilst interventions such as awareness campaigns, district metering and the isolation of illegal water connections are considered non-pricing-based interventions. The adoption of both pricing-based and non-pricing-based interventions result in the optimisation of water consumption, and as such efficient water use (Katz et al., 2016; Bruhl & Visser, 2021). Therefore, efficient water use will be discussed in conjunction with other water saving interventions.

When the City of Cape Town experienced severe drought during the period of 2016 to 2018, there was a call for water to be used sparingly and efficiently (Booysen et al. 2019; Bruhl & Visser, 2021). Many water-use and supply restrictions were implemented to prevent "Day Zero" in Cape Town. Bruhl and Visser (2021) researched the effectiveness of the water conservation techniques implemented in the City of Cape Town during the severe drought. The water interventions implemented were increased water tariffs; water restrictions; reduction in water pressure; and awareness campaigns.

The water tariffs were increased to discourage excessive water consumption, thereby decreasing water usage, and increasing water savings. According to Bruhl and Visser (2021), prior to July 2017, the cost of 10.5 kilolitres per month was at most R65. This price increased to R365 by February 2018 for the same quantity of water and signified a substantial increase of approximately 460%. The City of Cape Town implemented various water restrictions as the drought intensified, beginning with Level 2 restrictions which specified on which days municipal water could be used for irrigation and ending with Level 6B restrictions which limited total indoor and outdoor water consumption to 50 litres per person per day. Residents who were found to not be complying with the water restrictions would be fined and/or would have a water management device installed on their property (Bruhl & Visser, 2021).

Furthermore, the use of awareness campaigns also served as an indirect means of controlling the water usage (Booysen et al., 2019; Bruhl & Visser, 2021). The City of Cape Town kept the residents informed of the drought severity and their response measures to ensure that "Day Zero" was not reached. Moreover, the city would penalise consumers by publishing a list of those who were not compliant (consumer were identified using a GIS based system) and would send warning letters to consumers who were using an excessive amount of water. The warning letters were found to be effective in reducing water consumption in the short-term (Bruhl & Visser, 2021).

The results of the study showed that the largest reduction in water usage, approximately 20.1–24.3%, was achieved when the following combination of interventions were employed: (1) people were told that "Day Zero" is inevitable and it is fast approaching, (2) the water pressure was throttled, (3) water tariffs were increased and, (4) when the amount of water per person per day was restricted to 50 litres (Bruhl & Visser, 2021). Similarly, the study by Tortajada et al. (2019) concluded that the non-pricing water saving techniques had a greater impact than the pricing techniques (Bruhl & Visser, 2021).

The study on "Day Zero" in Cape Town shows that the efficient use of water techniques, is largely dependent on the implementation of other water conservation techniques (Booysen et al., 2019; Bruhl & Visser, 2021). To encourage reduced water usage, the residents were prompted by different awareness campaigns, keeping them with the current situation, as well as guiding them on ways they could reduce their water consumption. Where the campaigns fell short, the reduction in water supply and water pressure, forced the residents to become more mindful of their consumption (Bruhl & Visser, 2021).

As stated by Ruiz et al. (2020), the agricultural sector is a large consumer of water and targeted focus on water conservation in this sector can significantly reduce the water stress of an area. The research conducted by Velasco-Munoz et al. (2018) further reiterates that much effort has been devoted toward finding more efficient ways to use water within the agricultural sector. Velasco-Munoz et al. (2018) stated that the efficient use of water in the agricultural industry has become one of the most profound areas of research. Other researchers, such as Mahmood et al. (2015), Tang et al. (2016) and Huang et al. (2020), agree with this and have focused their studies on the agricultural sector.

A study on the adoption level of water saving interventions conducted by Mahmood et al. (2015) analysed various irrigation water saving technologies in use or that could be used by farmers in Faisalabad, Pakistan. The study found that over 91% of farmers adopted one or more forms of water saving techniques. Tang et al. (2016) conducted a similar study to Mahmood et al. (2015) and found that 83% of the farmers in Guanzhong Plain, China, made use of at least one water saving farming technique. Furthermore, the study conducted in China by Huang et al. (2020), focused on the potential water savings that can be achieved through efficient maize farming techniques, and it was determined that the irrigation water consumption can be reduced by 28-46%.

Within households, voluntary controlled water usage was observed most prominently within higher income households (Bruhl & Visser, 2021). Bruhl and Visser (2021), also stated that the higher income households were more motivated to adjust their water consumption patterns as they considered this part and parcel of their civic responsibility. It should be noted that this may also be due to the fact that the higher income households had the financial means to invest in alternative water supply measures such as rainwater harvesting and borehole water. Contrary to this, in the poorer communities, such as in the Cape Flats, most of the reduction in water use was a result of throttling the water pressure supplied so that the water loss within the piping network could be decreased (Bruhl & Visser, 2021).

The efficient usage of water has been shown to be a direct result of the increasing global awareness of the need to preserve water as a resource, and due to the impacts of climate change (Velasco-Munoz et al., 2018). However, much of the research on the efficient use of water has been based on the implementation of this intervention within the agricultural sector or within higher income households or upper end residential building complexes (Velasco-Munoz et al., 2018). Mammadova et al. (2021) and Frankel et al. (2021) are part of the limited number of researchers that have conducted studies relating to the implementation of green water practices within schools or housing complexes.

2.2.4 Pressure Management

Thornton and Lambert (2005:2), defined pressure management as the *"practice of managing water distribution system pressures to the optimum levels of service, ensuring sufficient and efficient supply to consumers"*. Gupta et al. (2017) and Samir et al. (2017) both stated that leakages within a water distribution system are directly dependent on the pressure of the water flow within the system. Consequently, pressure management has been described as one of the most effective ways of reducing physical water losses in a water distribution system (Thornton & Lambert, 2005; Gupta et al., 2017; Samir et al., 2017).

Gomes et al. (2011), Gupta et al. (2017) and Samir et al. (2017) investigated the effect of pressure management in water distribution systems. All three studies found that pressure management by way of the installation of pressure reducing valves (PRVs) was an effective means of reducing leakages within a WDS. In the study conducted by

Samir et al. (2017), PRVs were placed at strategic places throughout a defined District Metered Area (DMA) and the effect was evaluated against different performance indices. The DMA was situated in Alexandria, Egypt. The researchers employed the use of a modelling software programme called Water CAD. Using this programme, the researchers simulated different scenarios within the DMA, the first being the base case in which no PRVs were installed. Thereafter, five (5) scenarios were modelled, which varied the location of the PRVs as well as their sizes.

The efficacy of the installation of the PRVs at various points throughout the DMA as well as the size of the PRV installed was determined by calculating the infrastructure loss index, a scale developed by the International Water Association (IWA). The scale categorises the water loss from A to D, where category A is defined as good, and any further reduction may become economically unfeasible. Category D is bad and implies that the water saving interventions in place are inefficient. The infrastructure loss index (ILI) is calculated by dividing the "current annual real losses" by the "unavoidable annual real losses". The total reduction of the leakage volume was also calculated using the results from the simulated scenarios by subtracting the "scenario leakage volume" from the "base case leakage volume" (Samir et al., 2017). The study concluded that the use of PRVs reduced the leakage rate within that area by 37%. However, the results of the study also highlighted the fact that the size of the PRV used as well as where the PRVs are placed within a distribution network is paramount to their effectiveness. Of the five scenarios modelled, only three scenarios yielded a reduction in the amount of water lost through leakages (Samir et al., 2017).

The research conducted by Gupta et al. (2017) is similar to Samir et al. (2017), in that the effectiveness of PRVs installed within a WDS was shown to be dependent upon the placement of them. In the study by Gupta et al. (2017), the leakage rate within a defined water network was decreased by 20.82% after the strategic placement of the PRVs within the network.

Lambert et al. (2002), unlike the other researchers, stated that the control of the flow within the pipes and thereby the control of pressure surges is the most important aspect of pressure management. Excess pressure or pressure surges are one of the most common causes of pipe bursts. A pressure surge occurs when there is an unbalanced force in a piping network, and they are often caused by a water hammer. A water hammer occurs when water that is in motion is suddenly stopped or is forced to change direction (Lambert et al., 2002; Boulos et al., 2008). Pressure surges are thus more common in WDS where there is intermittent supply or when water is pumped directly into the mains, as opposed to a gravity fed WDS.

The most widely researched non-domestic water saving intervention is pressure management. Lambert et al. (2002) showed that pressure management within WDS has been implemented widely across the world (refer to *Table 2-1*).

Table 2-1: Pressure management strategies implemented in different countries (Lambert et al., 2002).

Country	**References to pressure management**
Malaysia	Install break pressure tanks or pressure reducing valves to control very high pressures. Leakage in the distribution system is proportional to water pressure.
Italy	Identifying water pressures to reduce damages to materials under normal use
Korea	Not specifically mentioned
Finland	Managing pressure is not used to reduce leakage
France	Not specifically mentioned
Poland	Real losses influenced by end-system water pressure
Romania	Development… to control pressure values in the distribution system
Hong Kong	Flow-modulated pressure reducing valves in areas with unduly high pressure
Portugal	Intended flow and pressure telemetered data in EPAL
Spain	Pressure reduction is the preventative measure par excellence
Norway	Leakage very much dependent on pressure. Existing pressure zones; possibility of reducing pressures, introducing new pressure zones, modulated pressure control.
Denmark	Use of pressure zones, pumping heads kept as low as possible
Thailand	Plan for zoning system to check flows and pressures
Australia	Systems generally operate at high pressures. Research into pressure management.
Morocco	Strong pressure
South Africa	Pressure management receiving considerable attention in recent years. Pilot studies in major cities and many completed projects (e.g., 60 smart PRVs in Johannesburg)
Germany	Leakage rates change with pressure much more than would be predicted by the theoretical "square root" relationship. Leakage targets set to customary 3 to 5 bar average supply pressure. Pressure management not normally used for loss reduction
Hungary	Not specifically mentioned
USA	Pressure management not widely practised. Recommended to allow for pressure in performance comparisons, and to further the science of pressure management.
Taiwan	Not specifically mentioned

As can be seen in *Table 2-1*, South Africa has also adopted pressure management techniques, particularly, the installation of PRVs. Pressure management has been thoroughly researched in the South African context in the studies conducted by Mckenzie et al. (2003), McKenzie et al. (2004) and Mckenzie and Wegelin (2005). The first study done by McKenzie et al. (2003) looked at the use of pressure reducing valves and controllers to reduce the water consumption of Khayelitsha township in the Western Cape, while the second study, McKenzie et al. (2004) was an assessment of the work done on the first study. Ultimately, the pressure management interventions achieved a reduction in water consumption of approximately 40%. Further to this, the study conducted in the areas of Sebokeng and Evaton in Gauteng, found that the pressure management interventions adopted yielded a reduction in water consumption of more than 20% (Mckenzie & Wegelin, 2005).

2.2.5 Greywater Reclamation

Greywater is defined as untreated wastewater that originates from general household or domestic activities such as bathing, dishwashing, and laundry (Leas et al., 2014; Smith & Hyde, 2014; Carden et al., 2018). Greywater does not include wastewater from the toilets – this is instead defined as blackwater. Greywater reclamation is thus the reuse of wastewater, be it treated or untreated, for potable or non-potable uses (Leas et al., 2014; Smith & Hyde, 2014; Carden et al., 2018).

Greywater reuse is one of the more popular innovative water conservation techniques and is included amongst other water conservation techniques such as rainwater harvesting, groundwater harvesting, and seawater desalination (Radingoana et al., 2020). The ineffectiveness of the other water conservation methods in developing countries is primarily due to the costs involved, the inaccessibility and limited technological expertise.

In the South African context, while greywater reuse remains the preferred water saving intervention, much of the reluctance to implement such systems has to do with the perception of greywater reuse (Radingoana et al., 2020). As greywater is classified as wastewater, it is often regarded as unclean and unfit for human consumption. A study conducted by Ilemobade et al. (2012), illustrated that most of the participants from the universities of Cape Town, the Witwatersrand and Johannesburg preferred the use of greywater for toilet flushing as opposed to garden irrigation. The reasoning behind their decision was the fear of coming into direct contact with the water and contracting diseases. This was a valid concern because greywater is not a safe substance as it contains pathogens that could cause illness in humans or animals, and it is for this reason that greywater should not be used to irrigate edible crops (Barnes, 2016; Carden, 2016; Carden et al., 2018). Furthermore, children have a very high risk of getting infections from greywater, when it is used for irrigation purposes, thus greywater should not be used in areas where children play (Spain et al., 2014; Barnes, 2016; Carden, 2016).

According to Leas et al. (2014), the health risks surrounding the reuse of greywater is a common concern presented by most research regarding greywater reuse. Alexander and Clark (2016) noted that one of the disadvantages of greywater systems is the perceived likelihood of the recycled water (which is not suitable for consumption) mixing with potable water. Although this is an unlikely occurrence, widespread belief amongst consumers that this is a major risk, has resulted in significant reluctancy in adopting this water saving technique. Radingoana et al. (2020) suggested that the reason people have negative attitudes toward greywater reuse has to do with the limited awareness and knowledge of the topic. The research conducted by Schoeman (2017) and Alexander and Clark (2016), suggests that much of the success of greywater reclamation, is dependent on increased public education and awareness, as well as government participation.

While there is a great willingness amongst persons who were asked whether they would make use of a greywater reuse system, the execution of it remains low in comparison. Of the participants that agreed to the need of a wastewater reuse system, in research completed by Schoeman (2017), only 51% stated that such a system has been implemented either at their homes or at their workplaces. Similarly, Leas et al. (2014) completed a study in the arid regions of the Middle East and North Africa and found that of the 72% of households in the Palestinian West Bank that agreed to implement the use of Greywater Treatment Units and treated greywater, only 6% made use of partially treated greywater.

Some of the obstacles of the establishment of widespread use of treated greywater include the uncertainty surrounding the health of users, and the cost of it (Leas et al., 2014; Spain et al., 2014; Carden, 2016). Alexander and Clark (2016) provided an in-depth review of the benefits and challenges of greywater reuse in the United States Environmental Protection Agency (EPA), Region 5. This region includes the areas of Indiana, Illinois, Ohio, Michigan, Minnesota, Wisconsin and 35 Tribes. According to Alexander and Clark (2016) there are three main motivations behind the reuse of greywater, namely: urban-rural migration, the "*water-energy-nexus*" and the increasing awareness of environmental and public health. The identification of these three main motivations is in line with the information presented in the research conducted by Nolde (2014), as well as Smith and Hyde (2014).

Alexander and Clark (2016) presented a case study on the residential complex, Solaire, in Manhattan. The building houses an internal wastewater treatment facility. The wastewater from the complex is treated and recycled back for use within the housing complex to flush the toilets, to replenish the water for the air conditioning system, and to irrigate the park. Solaire was able to realise a water saving of at least 50% of their potable water, and in comparison, to similar buildings within its locality, it discharges roughly 63% less water into the sewer network per apartment. These savings, however, were realised through the implementation of both the wastewater treatment and recycle system, and smart plumbing fixtures (Alexander & Clark, 2016).

It is important to note that the water reuse practiced in Solaire is not a true reflection of typical greywater systems. Typical greywater systems do not include a treatment facility for the water (Geary et al., 2005). Nonetheless, the principle of re-using wastewater is still shown to be a worthwhile water saving intervention (Smith & Hyde, 2014; Alexander & Clark, 2016; Carden, 2016; Carden et al., 2018).

The case studies presented in the research done by Alexander and Clark (2016) highlighted the importance of government intervention for the successful implementation of large-scale greywater reclamation. Without government input, greywater reclamation would be reserved for those who either know about it and know how it works or why it should be practiced, and for those who are able to afford such systems (Alexander & Clark, 2016).

Schoeman (2017) conducted a survey by way of an online questionnaire. The study focused within South Africa and the questionnaire was circulated randomly. It should however be noted that this study does not specify the demographics of the respondents as well as how many people participated in the survey. Therefore, the results are not representative of the general South African population. Nevertheless, the results are still worth exploring. Most of the participants indicated that, both as a homeowner and at their respective companies, there is a need to adopt and implement wastewater reuse or recycling systems (Schoeman, 2017). However, the main concerns regarding the implementation of greywater reuse identified by the participants of the survey were the limited knowledge and cost of such systems. As shown by Alexander and Clark (2016), the non-implementation of large-scale greywater reclamation systems, stem from the lack of knowledge and understanding of the intervention as well as a lack of financial support – translating to public awareness and government or private investment, respectively.

Greywater reuse has also been investigated in Nigeria by Adewumi and Oguntuase (2016). The research conducted was prompted by the need to address the wastewater management systems in Nigeria. The study ultimately provides recommendations for the implementation of a wastewater reuse program in the country, because at the time that the article was published in 2016, wastewater reuse in the country was primitive and still very theoretical.

2.2.6 Awareness Campaigns

An awareness campaign is a non-price-based water saving intervention, that is implemented with the goal of transferring information to groups within a society, to raise awareness about the social, economic, and environmental benefits of water conservation practices and technology as well as the immediate and long-term ramifications of inefficient water use (Texas Water Development Board, 2010; Torres & Carlsson, 2016; UN Environment, 2017; Bruhl & Visser, 2021). The aim of this water saving technique is to promote a change in social norms and behaviour related to water consumption and shift public perception in a manner that favours the importance of water conservation and water resource sustainability (Texas Water Development Board, 2010; Torres & Carlsson, 2016; Benedict & Hussein, 2019; Tortajada et al., 2019).

For an awareness campaign to be effective, there are various critical aspects that must be considered prior to its implementation. These aspects include the following:

1. *The goals of the awareness campaign*: Having a set goal that the results can be measured against is related to determining the campaign's effectiveness (Texas Water Development Board, 2010; UN Environment, 2017; Benedict & Hussein, 2019; Booysen et al., 2019).
2. *The target audience and relevant stakeholders*: An understanding of the target audience's culture, current water consumption patterns, behavioural norms, and beliefs, play a significant role in the development and implementation of an effective campaign (Geller et al., 1983; Texas Water Development Board, 2010; Torres & Carlsson, 2016).
3. *Protocols of communication*. Based on the analysis of the target audience, the appropriate method of communication i.e., pamphlets, television and radio adverts, text messages, social media, community workshops, newsletters, etc., must be utilised to ensure the information is transferred efficiently to the

desired target group (Geller et al., 1983; Texas Water Development Board, 2010; Torres & Carlsson, 2016; Benedict & Hussein, 2019).

By accurately identifying the target group and using the appropriate methods of information distribution and educational tools, knowledge can be transferred to individuals who, under normal circumstances, would not have access to this information due to social and economic inequalities (Torres & Carlsson, 2016; Bruhl & Visser, 2021). Increasing accessibility to information increases the likelihood of widespread public participation (Geller et al., 1983; Texas Water Development Board, 2010; Bruhl & Visser, 2021).

Benedict and Hussein (2019) conducted a study on a water awareness campaign implemented in Jordan and observed that the religion of the target audience as well as their commitment to state security and nationalism, was considered when implementing the campaign. Mosques were used as a distribution point for information and emphasis was put on water insecurity being both a threat to the environment and the security of the state. Similarly, Torres and Carlsson (2016), observed that in a society where there is greater social cohesion, comparing water conservation efforts of one household to another, altered social norms and resulted in water savings. The awareness campaign focused on sharing information regarding the water conservation efforts of various households in the target group and assigned gradings based on their efforts. A 6.8% reduction in water consumption within the targeted group was observed, while households that were not targeted still reduced their consumption by 5.8% (Torres & Carlsson, 2016). This illustrates that awareness campaigns that are tailored to a specific target audience, yield favourable changes in water consumption practices which increase water savings.

While Benedict and Hussein (2019) concluded that the use of awareness campaigns that are tailored to a specific target group would result in long term and meaningful behavioural change in water consumption practices; Syme et al. (as citied in Bruhl & Visser, 2021), stated that the long-term impact of awareness campaigns on water consumption behaviour was doubtful. Furthermore, a study conducted by Geller et al. (1983) found that despite the use of educational tools that provided residential consumers with information on water conservation as well as behavioural reports, the results proved that this information had minimal influence on reducing actual water consumption.

The implementation of awareness campaigns can mitigate the need for capital intensive water saving interventions (Bruhl & Visser, 2021). This aspect is attractive for developing nations in which the need for water conservation and water savings is paramount but there is insufficient capital available for infrastructure development that supports this need (Benedict & Hussein, 2019; Booysen et al., 2019). Additionally, awareness campaigns curb the need for water saving interventions that could lead to political or public uproar such as water shedding, water pressure throttling, etc. (UN Environment, 2017; Bruhl & Visser, 2021). The potential uproar that water saving interventions can cause is illustrated by the observations made by Benedict and Hussein (2019), who noted that when water supply was restricted or cut off, citizens rebelled by damaging and stealing infrastructure.

Research has shown that the effectiveness of awareness campaigns as a water savings intervention is difficult to determine (and in some cases remains unclear) as this intervention is regularly implemented in combination with other interventions i.e., retrofitting, leak fixing, pressure management, etc. (Katz et al., 2016; Torres & Carlsson, 2016; UN Environment, 2017). Owing to this challenge, very few studies which focus on the effectiveness of awareness campaigns have been done (Katz et al., 2016; Bruhl & Visser, 2021). Stavenhagen et al., (2018) noted that awareness campaigns that promoted the use of water savings technology or water efficient appliances, had a greater impact on water savings than public awareness campaigns that simply promoted the importance of water resource conservation, and changes in water consumption practices and behaviours.

Another study conducted by Keramitsoglou and Tsagarakis (2011) looked at the awareness of water saving amongst students and their parents, and how this can influence the use of water saving technology or the adoption of water saving initiatives. The study found that parents and their children were more willing to adopt water saving initiatives that required minimal effort from them, however, the children would not abandon certain water wasting habits like long showering times.

Multiple researchers have noted the difficulty of assessing the effectiveness of awareness campaigns as a water saving intervention, as it is often implemented in collaboration with other interventions. The studies discussed in this section cover campaigns that were geared towards decreasing residential water consumption and do not cover efforts to decrease water consumption in institutional facilities.

2.3 Shared Savings Contracts

2.3.1 What are they?

Shared savings contracts are a type of energy savings performance contract (Andrews, 2004; Van Der Like, 2009; Roos, 2010; Basar, 2013; Oregon Department of Energy, 2016; Jacobs et al., 2020). The premise of an energy savings performance contract (ESPC) is that a project owner enters into an agreement with an energy savings company (ESCO), where the ESCO must investigate, plan, and implement energy conservation measures at a facility for the purpose of achieving energy savings (Andrews, 2004; Roos, 2010; Jacobs et al., 2020). According to Andrews (2004), the energy conservation measures implemented can involve savings in both energy and water, or only energy or only water savings. Thus, for the purposes of this review, the term “energy” will be used interchangeably to refer to energy (electricity) and water, unless otherwise stated.

Basar (2013) discussed some types of ESPCs and distinguished between a shared savings contract and a guaranteed savings contract. In a shared savings contract (*Figure 2-4*), the ESCO is responsible for funding the project costs and any external funding obtained is an agreement between the creditor and the ESCO, i.e., the client/project owner does not get involved (Basar, 2013). However, the client/project owner will pay the ESCO for the value of savings owed to them, and this should be sufficient to offset the loan from the creditor and provide profits to the ESCO (Basar, 2013). Conversely, with a guaranteed savings contract (*Figure 2-5*), the project funding is obtained by the client/project owner and the repayments of the loan amount is paid using the value of the savings achieved, which must be guaranteed by the ESCO (Basar, 2013). The responsibility thus is with the ESCO to ensure that the project funding is being utilised efficiently to ensure that high savings can be obtained.

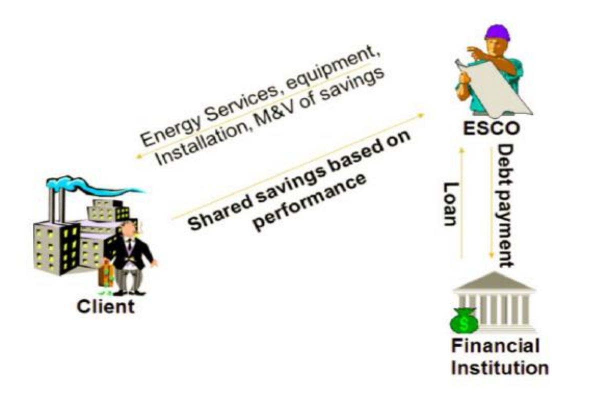

Figure 2-4: Shared Savings Energy Performance Contract Financial Model (Basar, 2013).

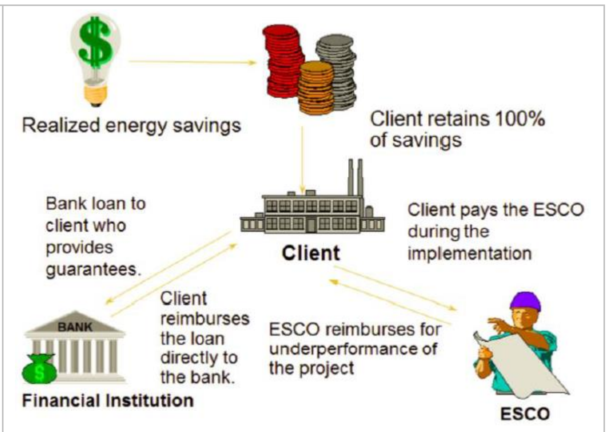

Figure 2-5: Guaranteed Contract Energy Performance Contract Financial Model (Basar, 2013).

2.3.2 How do they work?

Andrews (2004), Roos (2010) and Basar (2013) all agree that what makes a shared savings contract unique and unlike most contracts between a project owner and a typical contractor/service provider, is that much of the risk of non-performance on the project lies with the contractor/service provider (in this case the ESCO) and not with the project owner. It is this uniqueness that makes the shared savings model appealing to project owners, who in most cases would not be able to otherwise fund and execute such projects (Andrews, 2004). According to the Oregon Department of Energy (2016), shared savings contracts reduces the management effort of the project owner/client because one contractor can be appointed to perform all the tasks detailed in *Figure 2-6*. The contractor is responsible for the design, installation, commissioning and the supervision of the improvements (Oregon Department of Energy, 2016). Even though the contractor may utilize a team of consultants and subcontractors, they are still accountable for the success of the project and it is this single point of accountability that makes shared savings projects easier to manage than the typical construction project (Oregon Department of Energy, 2016).

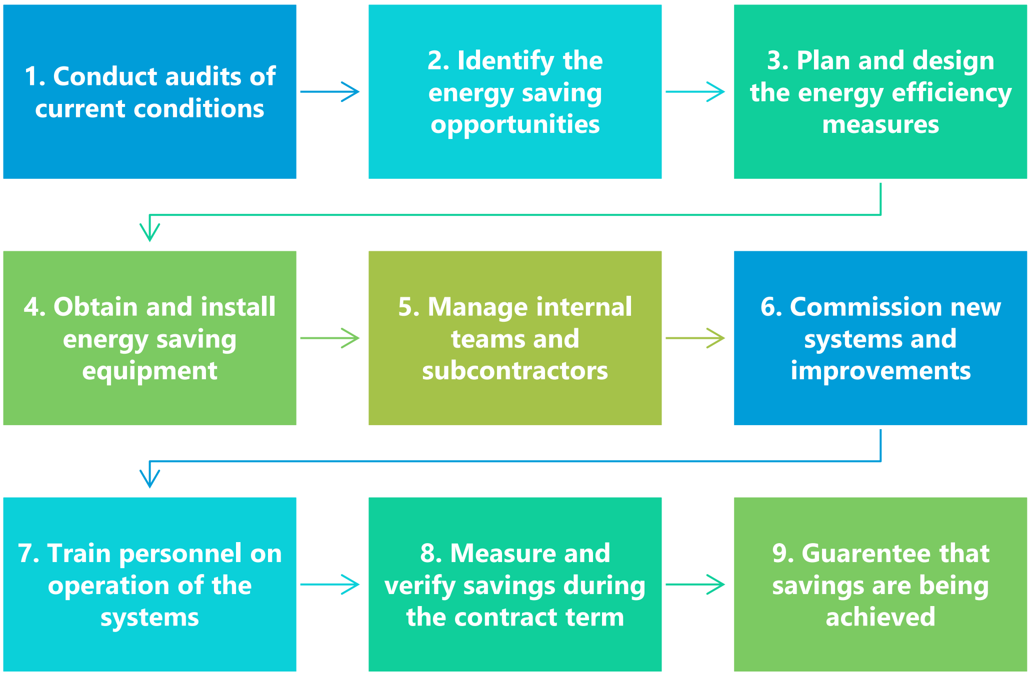

Figure 2-6: Services required from a contractor in a shared savings contract (Oregon Department of Energy, 2016).

For all ESPCs, including shared savings contracts, it is important to understand how savings will be determined. According to Van Der Like (2009), to determine the savings that can be guaranteed for a guaranteed savings ESPC, the ESCO conducts a detailed energy audit which is the basis for calculating the guarantee and drafting a project plan. The audit results are also used for the measurement and verification plan, which details how the savings will be calculated to ensure that they are achieved (Van Der Like, 2009). Jacobs et al. (2020), however, states that for a shared savings ESPC, the savings are measured against a baseline which is determined using the historical consumption of the project site. For energy savings, this would be the average historical energy consumption (e.g., the amount of kWh), while for water savings, this would be the average historical water consumption (e.g., the amount of m^3) both determined over a set historical period.

The savings achieved would be the difference between current consumption, following the installation of energy saving equipment, and the baseline consumption (Jacobs et al., 2020). However, for the guaranteed savings ESPC, if the savings are not met, the ESCO pays the project owner the difference between the guarantee and the current consumption (Van Der Like, 2009; Roos, 2010). The decision can be made between the client and the ESCO to keep the baseline the same for the contract period or to adjust it should unforeseen circumstances change the current consumptive patterns of the project site (Jacobs et al., 2020). Furthermore, the Oregon Department of Energy (2016) and Jacobs et al. (2020) agree that the value of savings must be calculated using the energy units saved multiplied by the energy unit tariff. Oregon Department of Energy (2016) state that it is best practice to have a knowledgeable independent auditor that will review the measurement and verification plan, to minimize the client's risk.

Basar (2013) states that the project owner will pay either the same or a lower energy price during the duration of the ESPC. However, following the end of the contract or after the project has been paid off, the project owner takes full ownership of the project and all profits from the savings realised thereafter, belong to the project owner (Roos, 2010; Basar, 2013).

2.3.3 Status Quo, Advantages and Disadvantages

Shared savings contracts and other forms of ESPCs are not common around the world and there are several barriers that prevent their utilisation. According to Morino et al. (2010) and Basar (2013), financial institutions and project owners/clients do not have much trust in ESCOs, mainly because there is a lack of uniformity of the contracts. The mistrust stems from issues such as complex ESCO proposals which make it difficult to draft a standard contract, insufficient competition in the sector, inexperienced ESCOs, absence of standard guidelines of measuring savings, the assurance of project savings, and a lack of examples of best practice (Morino et al., 2010; Basar, 2013). Furthermore, the financial crisis and economic downturn affecting several countries, have made it difficult for ESCOs to acquire funding from financial institutions particularly in Europe (Morino et al., 2010).

Aside from the barriers stipulated, there are some structural, legislative and economic changes that are increasing the demand for energy savings and are making it favourable for ESCOs to operate (Morino et al., 2010). According to Van Der Like (2009), the growing awareness of the built environment's impact on the environment, economy and health has increased the demand for green buildings projects, some of which are being funded by a type of ESPC called paid-from-savings. The paid-from-savings financial strategy is a way to make existing buildings more green by using the savings generated from building systems upgrades, to pay for the cost of the greening project within a specified pay-back period (Van Der Like, 2009). Morino et al. (2010) is in agreement with Van Der Like (2009) in that the renovation and upgrading requirements in the building space have led to several projects being undertaken by ESCOs.

In terms of legislative changes, several "European Directives" are in support of energy efficient measures being implemented across Europe (Basar, 2013). These directives include the *Energy End-Use Efficiency and Energy Services (2006/32/EC)*, *European Performance of Buildings Directive (2010/31/EU)* and the *Energy Efficiency Directive (2010/27/EU)* (Basar, 2013). Several regulations, policies and sustainable energy action plans have been developed in the European union as a result of an increased awareness for the environment and climate change issues (Morino et al., 2010). Additionally, international programs which support collaboration, technical help and economical backing for efficiency in energy and savings investments have been established, such as the *Clinton Climate Initiative for Cities 104* (Morino et al., 2010).

According to Morino et al. (2010) and Basar (2013), energy markets have become more liberal and this has created a favourable economic environment for ESCOs to operate in. Likewise, increased opportunities for value-added services have arisen through the liberalisation of the electricity and gas sectors (Morino et al., 2010; Basar, 2013). Added to this is the rise in energy taxes across several European countries, and these are ensuring feasible payback periods for energy saving projects and increasing the demand for ESCO services (Morino et al., 2010).

Shared savings contracts have several advantages and disadvantages, depending on the perspective of the project owner/client or the ESCO.

i. An advantage to the project owner is that most of the risk lies with the ESCO (Andrews, 2004; Roos, 2010; Basar, 2013), therefore the ESCO is incentivised to ensure accurate savings measurements, high quality workmanship, preventative maintenance, and ongoing monitoring throughout the contract period (Oregon Department of Energy, 2016).
ii. An advantage to the project owner is having the ESCO be the single point of accountability, as this makes the contract much easier to manage (Oregon Department of Energy, 2016).
iii. An advantage to the ESCO is having the project run smoothly due to reduced red tape that is common of typical construction projects (Oregon Department of Energy, 2016).
iv. An advantage to the ESCO is the leeway of ensuring that as much savings as possible can be attained, thus increasing their share of the value of the savings, should there not be a limit on this within the contract.
v. An advantage to the ESCO is that shared savings contracts tend to be multi-year agreements that can ensure revenue over a longer period than conventional contracts (Vitasek et al., 2013).
vi. A disadvantage to the ESCO is that in some regions, energy and water tariffs are low and are prone to fluctuation, leading to unprofitable projects and unpredictable savings forecasts, respectively (Basar, 2013).

vii. A disadvantage to the ESCO is that due to the unavailability of reliable energy and water consumption data, the determination of baselines and savings forecasts can be difficult (Basar, 2013).

viii. A disadvantage to the project owner is that they may feel that the ESCO is benefitting much more from the shared savings contract than they are, and according to (Vitasek et al., 2013), this may lead to one of three actions.

   1. The project owner will issue a new tender at the end of the contract to ensure competition.
   2. The project owner may decrease the ESCOs scope by including additional suppliers during the shared savings contract, thus ensuring added competition.
   3. The project owner may request that the ESCO provides their costs and profit margins relating to the shared savings contract, in attempt to negotiate the value of savings being paid to the ESCO.

Ultimately, both the project owner and the ESCO, while being aware of the advantages and disadvantages that relate to them, can ensure that the shared savings contract is structured in a manner that protects and secures everyone’s interests.

2.3.4 Shared Savings Contract Studies

Most research studies have been largely based on general ESPCs and very few have focused on shared savings contracts. In a paper by Van Der Like (2009), five projects that involved the implementation of renovations/upgrades to existing building facilities, were discussed. The purpose of all five projects was the same, i.e., to renovate, upgrade and install new systems to existing buildings in an attempt to make them green buildings and for the them to achieve Leadership in Energy and Environmental Design (LEED) certification (Van Der Like, 2009).

The Adobe Systems made use of a paid-from-savings financial strategy to self fund the greening initiatives implemented at a cost of $1.7 million. The greening initiatives focused on using energy efficient cooling and heating systems, installing energy efficient lighting, water efficient water fixtures, installing a drip-irrigation system, planting drought tolerant plants and diverting solid waste. The reductions for electricity, water and solid waste, were 39%, 38% and 98%, respectively. This resulted in $1.5 million in annual savings, which was a return of investment of 91%, and the project cost was paid back in 1.1 years. Although this project did not make use of a performance contract linked to an ESCO, it highlighted the efficiency and effectiveness of the greening initiatives implemented as indicated in *Table 2-2*.

The remaining four projects all utilised a guaranteed savings ESPC with an ESCO (refer to *Table 2-2*). The California Environmental Protection Agency (EPA) and the Dallas Convention Center both self-funded their project costs to the values of $3.5 million and $16 million, respectively. On the other hand, the National Geographic Society obtained a revenue bond to fund their $6.5 million project, while it was not clear whether the $24 million project cost for the Colorado State Capitol was self-funded or was obtained through a loan. The Colorado State Capitol entered into a 19-year long ESPC with an ESCO, who guaranteed $1.1 million in annual savings. Similarly, the Dallas Convention Center entered into a 10-year long ESPC with their ESCO who guaranteed $2 million in annual savings. Only a portion of the projects for both California EPA and National Geographic Society were completed by their appointed ESCOs and thus, only a portion of the $1.6 million and $406 000 respective savings were guaranteed by the ESCOs.

It was interesting to note that the four buildings implemented very similar greening measures and they all focused on electricity/energy and water efficiency, with one building (National Geographic Society) having tackled waste efficiency. However, the savings achieved varied greatly. The California EPA achieved high savings in energy (60%) and water (50% external and 20% internal), and this was evident in the high annual savings and short pay-back period, which made them the most successful of the four ESPC projects. The energy savings for both Colorado State Capitol (34%) and Dallas Convention Center (35%) were somewhat the same, however the Dallas

Convention Center had additional savings in water of 18%, and the guaranteed savings of $2 million from their ESCO were almost double that of the Colorado State Capitol guaranteed savings of $1.1 million. The National Geographic Society achieved low savings in energy (8-11%) and water (18%) but high savings in waste costs (70%). This translated to annual savings of $406 000, which was the lowest of the four projects and is evident in the long pay-back period of 16 years.

In summary, green building projects with ESPCs may have varying project costs however the range of possible green measures that can be implemented may be similar. What will deem the project successful is the savings that can be achieved and how these savings translate into annual monetary savings. The project cost when divided by the annual monetary savings will give the pay-back period in years, and the shorter the pay-back period, the less risky a project is (Jan, 2019).

Table 2-2: Green building projects (Van Der Like, 2009).

Project Particulars	**Project Name**				
	Adobe Systems Headquarters	**California Environmental Protection Agency (EPA)**	**Colorado State Capitol**	**Dallas Convention Center**	**National Geographic Society Headquarters**
Financial Strategy	Paid-from-savings where client self-funded the project.	A combination of self funding and a guaranteed savings ESPC with an ESCO.	A 19-year guaranteed savings ESPC with an ESCO.	Paid-from-savings where client provided the funds needed by the ESCO for the 10-year guaranteed savings ESPC.	A combination of revenue bond and a guaranteed savings ESPC with an ESCO.
Project Cost	$1.7 million	$3.5 million	$24 million	$16 million	$6.5 million
Measures Implemented	-Retrofitting of fans and lighting systems. -Installation of flow restrictors, low flow shower heads, waterless urinals and drip-irrigation system.	-Installation of efficient HVAC and lighting systems, solar panels and energy efficient lights. -Installation of low-flow toilets, waterless urinals	-Modifying the chilled water system, replacing the cooling tower, and the installation of energy efficient chillers, irrigation	-Replacement of old chillers and old bulbs, installation of solar panels and power capacitors. -Installation of low-flush toilets and energy	-Replacement of chillers and boilers, installation of window film, white roof and energy efficient lighting.

Project Particulars	Project Name				
	Adobe Systems Headquarters	**California Environmental Protection Agency (EPA)**	**Colorado State Capitol**	**Dallas Convention Center**	**National Geographic Society Headquarters**
		and water-efficient fixtures.	controls and low-flow toilets.	efficient cooling tower.	-Installation of water efficient flush valves.
Savings Achieved	Reductions in electricity consumption (39%), water consumption (38%) and diverted solid waste (98%).	Reductions in energy consumption (60%), external water consumption (50%) and internal water consumption (20%).	Reduction in energy consumption by 34%.	Reductions in energy consumption (35%) and water consumption (18%).	Reductions in energy consumption (8-11%), water consumption (18%) and waste costs (70%).
Annual Savings	$1.5 million	$1.6 million	$1.1 million guaranteed by ESCO	$2 million guaranteed by ESCO	$406 000
Payback Period	1.1 years	2.2 years	21.8 years	8 years	16 years

In a study conducted by Andrews (2004), an overall assessment of the energy saving performance contracts (ESPCs) that federal agencies in the United States have awarded, was provided. It was found that out of 340 ESPC contracts that were awarded, the value of the private sector investments was approximately $1.6 billion, as opposed to the $3.17 billion in appropriation funds that were allocated by the US Government to improvements aimed at energy reduction between 1985 and 2001 (Andrews, 2004). Another important finding was that of the 340 ESPC contracts, none of the ESCOs failed to achieve savings. Furthermore, federal ESPC projects attained 30% more energy savings when compared to initiatives undertaken by municipal/state governments, hospitals, schools, and universities. Additionally, an analysis of 214 of the 340 ESPC projects, found that the savings achieved translate to approximately $550 million in economic benefit to the American taxpayers. Andrews (2004) also found that the average length of the federal ESPC terms was 14 years, but they were authorized for up to 25 years.

As part of the study, Andrews (2004) also compared ESPCs to Appropriation-funded energy conservation measures. For each financial strategy, the study compared the cost of energy conservation measures, the average project duration, the project financing, and the project life-cycle costs. The findings were:

i. There was no significant difference in the cost of the energy conservation measures completed under ESPCs or under direct appropriations.
ii. The average project duration for ESPCs was 27 months while the average project duration for appropriations-funded projects was 63 months. The project duration included the procurement phase as well as the design and construction phase.
iii. In an ESPC, the principal amount and interest accrued on funds loaned for the project by the ESCO, were recovered over the life cycle of the ESPC. Similarly, under the appropriations-funded project, any funds borrowed by the contractor formed part of the project costs. However, the duration of financing and thus the cost of financing was much less for appropriations-funded projects than for ESPCs.
iv. It was determined that appropriations-funded projects had lower life-cycle costs only for project durations that were between 28 and 68 months, and only if the upfront survey costs were below 18% of the design and construction costs. However, it was determined that appropriations-funded projects would lose their competitiveness with ESPCs, should the annual energy savings decrease by 2% or more from the projected savings.

The research study by Mckenzie and Wegelin (2005) was a shared savings contract that was packaged into what the author's referred to as a Public-Private Partnership (PPP), where the ESCO funded all the pressure management interventions that were implemented and could claim up to 20% of the value of the water saved. The key role players in the PPP included the client, the ESCO, the funding agent and an independent auditor. The independent auditor was responsible for the verification of the savings which provided the basis on which the ESCO was paid. The PPP thus aligned with best practice norms of ESPCs as stipulated by Oregon Department of Energy (2016).

The purpose of the project was to reduce the water wastage and leakage of two areas (Sebokeng and Evaton) in South Africa through the implementation of pressure management. Prior to the implementation of pressure management, it was determined that the two areas have extremely high minimum night flows (MNF) that were recorded to be 75%, while the MNF for a well managed system is typically in the region of 10% to 15%. Mckenzie and Wegelin (2005) acknowledged that it was not realistic to strive to reduce the MNF to that of a well managed system, but that this merely indicated the great potential there was to achieve savings.

Mckenzie and Wegelin (2005) identified pressure management as the intervention that would be the cheapest to implement while having the greatest single impact on the reduction in water wastage and leakage. They did, however, acknowledge that other forms of water demand management could be considered thereafter. The implementation of pressure management involved cutting into the two existing water mains (1000mm diameter and 675mm diameter) and installing a network of smaller pipes (*Figure 2-7*). Four of the smaller pipes had pressure reducing valves (PRVs) and associated meters, strainers and gate valves installed on them. The PRVs controlled the pressures into the two areas by reducing water pressures during off peak periods and increasing pressures during peak demand periods. This pressure management system reduced both leakages in the system and the occurrence of burst pipes.

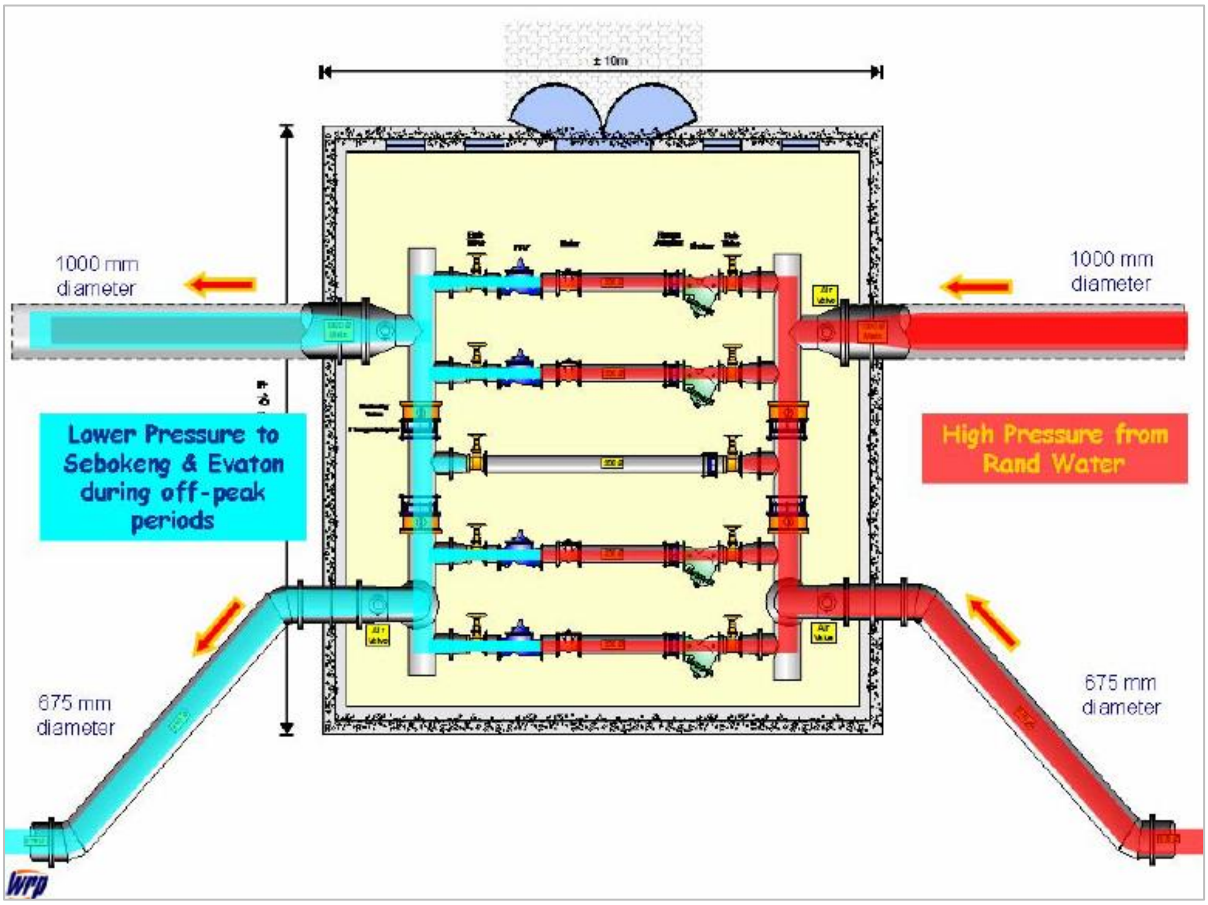

Figure 2-7: Pressure management installation for Sebokeng/Evaton (Mckenzie & Wegelin, 2005).

The study found that the implementation of pressure management successfully reduced water wastage (MNF) from 3 000 m^3/h to 2 000 m^3/h, providing estimated savings of 8.5 million m^3/annum (*Figure 2-8*). The project cost was approximately R5 million (US$0.7 million) and the savings achieved were estimated to be R20 million (US$3 million) per annum. The pay-back period was approximately 2.5 months, thus supporting the notion that pressure management would be the most cost effective WDM intervention that could have been implemented.

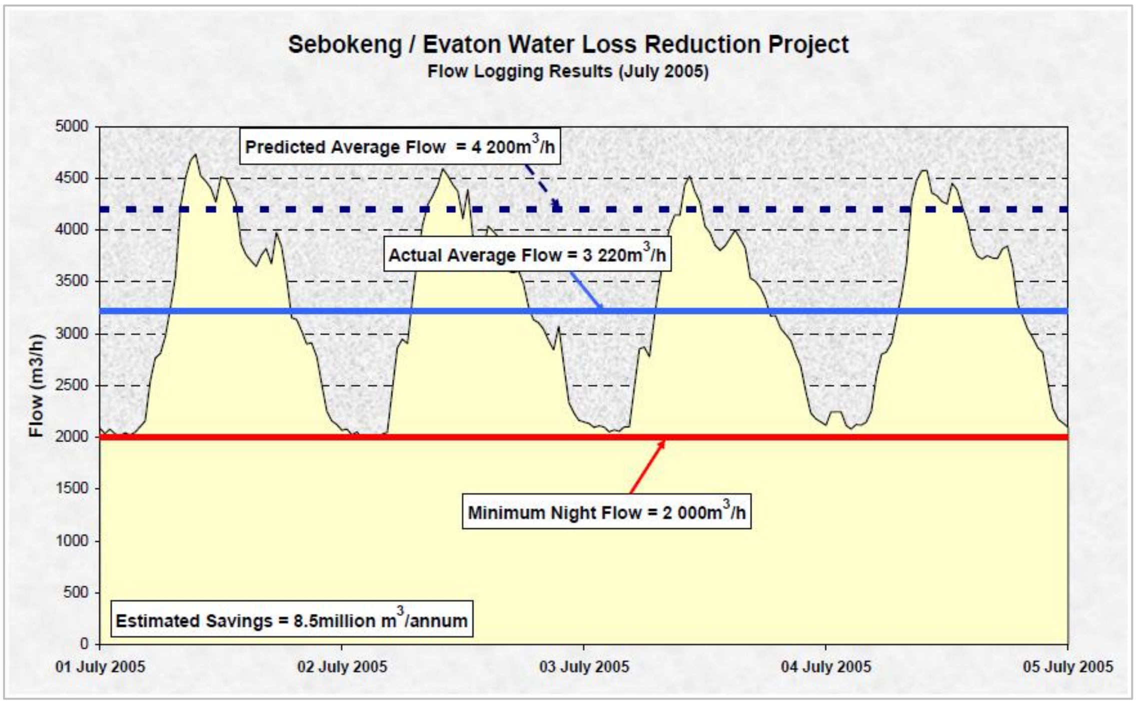

Figure 2-8: Savings achieved in Sebokeng/Evaton (Mckenzie & Wegelin, 2005).

2.4 Summary

The findings of Kummu et al. (2010) and Hoekstra et al. (2012) indicate that water scarcity is of great concern in South Africa and efforts, such as the implementation of water saving interventions, must be made to alleviate water scarcity. Furthermore, Herold (2010) has highlighted the issues plaguing water resources in South Africa which include the theft of water and decaying infrastructure, the impact of which can be reduced through the implementation of water saving interventions.

Several studies have been conducted on water saving initiatives on a domestic/residential scale and in the agricultural sector. Studies such as those conducted by Geller et al. (1983), Biggs (2017) and Ruiz et al. (2020), have provided various water saving measures that can be adopted by residential consumers, with some studies also highlighting the efficiency of the various measures. Retrofitting and leak fixing are the leading domestic water saving initiatives that have been presented in literature (Keramitsoglou & Tsagarakis, 2011; Biggs, 2017; Ruiz et al.,2020). It should be noted that alternative water supply initiatives such as rainwater harvesting, borehole water and dual quality water systems were not thoroughly discussed in this literature review. The focus of the literature review was on water saving initiatives and not on alternative water supply initiatives.

Some of the interventions were implemented in combination such as treated greywater reuse and retrofitting shown in the study conducted by Alexander and Clark (2016), pressure management and efficient water use shown in the study conducted by Bruhl and Visser (2021) and, leak fixing and retrofitting as shown in the study conducted by Ruiz et al. (2020). On the other hand, some interventions such as awareness campaigns, were most effective when implemented in combination (Barnard et al., 2014; Katz et al., 2016; Stavenhagen et al., 2018; Bruhl & Visser, 2021).

Very few studies assessed the broad range of interventions, that when implemented would maximize water savings. This was an identified gap that justified this study. Furthermore, it was noted that the shared savings contracts (energy savings performance contracts) presented in literature, are typically either energy savings contracts or a combination of energy and water savings. The study by Mckenzie and Wegelin (2005), was the one study found that was a shared water savings contract that implemented pressure management as the sole water saving intervention.

Following the review of studies that have been undertaken, the gaps identified, for which this study seeks to fill are:

1. Water scarcity and water mismanagement are of great concern in South Africa and the implementation of water saving interventions has been identified as an alternative means of reducing the impact of these issues.
2. Little research has been done on an institutional scale to demonstrate the wide range of water saving initiatives that can be implemented as well as the efficiency of these water savings initiatives.
3. Little research has been done on shared water savings contracts and of the studies available, the number of interventions implemented have been minimal.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research Method and Design

The study was based on the water saving interventions that were conducted at 164 institutional facilities in three provinces within South Africa. The service provider participated in a shared water savings contract (SWSC) and was allocated facilities in three provinces. The author was given approval to use the water saving interventions data gathered in the SWSC for this study.

The age of the facilities ranged from 5 years old to as old as 110 years; however, 90% of the facilities were older than 15 years. Most of the facilities had aging water infrastructure, and in many instances, the infrastructure was original to the facility and had never been replaced. For most of the facilities, the water pipes would have not been changed from the time the facility was built, due to the pipes being located either behind thick concrete walls or underground. The older buildings had galvanised steel pipes within the buildings and lead asbestos pipes underground. Most of the lead asbestos pipes were removed over the years and replaced with PVC pipes. Approximately 85% of the facilities had not undergone any large-scale renovations to their water infrastructure from the time they were built, and most of the infrastructure upgrades were because of reactive maintenance performed on an as-and-when basis.

The facilities comprised of the following:

- Judicial Buildings
- Military/Naval Bases
- Police Stations
- Prisons

The water saving interventions were all performed by one service provider under the confines of a shared water savings contract (SWSC). The mandate given to the service provider by the client, was to reduce the monthly billed water consumption of each facility by a minimum of 25% within a period of 3 years, through the implementation of water saving interventions. Thereafter, the savings had to be maintained for the remainder of the duration of the SWSC. To benchmark the water savings achieved at each facility, the service provider developed a baseline consumption. The baselines were determined with the use of three years of consistent water consumption (obtained from the municipal water bills), no older than five years prior to the initiation of the SWSC. Using the three years of consistent water consumption data, an average daily water consumption was obtained, and this was the baseline consumption for the facility. The baselines were therefore specific to a facility as it was based on the historic consumption of that facility. Baselines could be amended during the SWSC if the client determined that the consumption of a facility had changed, due to factors such as behavioural change in water consumption, water restrictions imposed by the municipality/water utility and decommissioning of parts of a facility.

For each facility, an assessment was conducted to determine which water saving interventions would yield savings and these interventions were implemented. A total of eight interventions were implemented across the facilities. The interventions and description of each intervention are provided in *Table 3-1*. Some facilities may have had only one intervention implemented while other facilities had various interventions implemented, thus some interventions were more prevalent than others. However, the water saving interventions were consistent and were implemented across all facilities where applicable.

Table 3-1: Descriptions of the interventions that were implemented.

No.	Intervention	Description
1	Leak Fixing	Identifying and fixing leaking plumbing fixtures and repairing of burst pipes.
2	Retrofitting	The replacement of existing plumbing fixtures with water efficient fixtures.
3	Pressure Management	The management of water pressure by ensuring that pressures are sufficient during peak and non-peak demand periods.
4	Borehole Installation	The drilling and equipping of a new borehole to supplement water supply to a facility.

No.	Intervention	Description
5	Borehole Refurbishment	The replacement of components to return a borehole to working condition, to supplement water supply to a facility.
6	Controlled Supply and Usage	The management of water supply by regulating the quantity of water supplied or used by water consumers.
7	Awareness Campaigns	Educating water consumers at the facilities on the negative impact of leakages and water wastage.
8	Isolation of Illegal Water Connections	The location and removal of water supply connections leading from the facility to external consumers.

It should be noted that borehole installation and borehole refurbishment are not water saving interventions, but initiatives that supplement water supply. However, the requirement of the SWSC was for the service provider to reduce the monthly billed water consumption, and it was identified that this could be achieved using borehole water (which does not form part of billed consumption). Although the use of borehole water increased the electricity consumption of the facility, the client did not oppose the implementation of this initiative.

3.2 Data Gathering

3.2.1 Data Collection and Filtering

The data was collected from the service provider involved in implementing the water saving interventions at 164 facilities. The service provider began work on various sites from September 2016, following the approval of several baseline consumptions for some facilities. Water saving interventions could only commence on a facility once the baseline consumption was approved. The water saving interventions did not commence at the same time at all the facilities, because the service provider had limited resources and was limited to the time required for baselines to be approved by the client. However, once the water saving interventions commenced at a facility, the following process was followed:

i. The service provider created an internal database to track the savings for each facility.

ii. On a monthly basis, the service provider would obtain the water bill for each facility on which the water saving interventions were implemented. The water bill stated the volume of water consumed at the facility, the current meter reading, the previous meter reading and the number of days between meter readings.

iii. Data capturers employed by the service provider would manually capture the information from the water bill onto the internal database. It is acknowledged that the manual capturing of data increases the probability of data inaccuracies due to human error, and this is a limitation of the study.

iv. The approved baseline consumption for the facility was also captured onto the internal database.

v. The savings were determined by comparing the volume of water consumed at the facility for the month, with the approved baseline consumption.

vi. As more facility baselines were approved and water saving interventions implemented, the internal database was populated, up to the point where the database consisted of monthly data for 164 facilities (all with varying durations).

The client, as the custodian of the facility, would be sent the water bill by the relevant municipality or water utility. As part of the terms of the SWSC, the client was responsible for providing the service provider with the facility bills. However, due to the client's capacity constraints, permission was given to the service provider to obtain the water bills directly from the municipality or water utility. Savings could only be determined from the water bills. In the months for which the service provider could not obtain a water bill for any of the facilities, the facility information on the internal database could not be updated and the savings invoice could not be generated. The service provider generated savings invoices for all the facilities within the first week of every month; therefore, if they were unable to obtain any water bills within that first week, the facility savings would be omitted for the month. However, because the water meter readings on the water bill were cumulative, the service provider could account for the savings once the next water bill was obtained.

The water bills for the facilities were used to measure and verify the savings being achieved at the facilities. The SWSC did not include the appointment of an independent auditor to verify the savings achieved, as was done in the study by Mckenzie and Wegelin (2005). However, because the water bills were obtained from an independent third party, the client and the service provider were comfortable with them being used to determine savings.

The 164 facilities on which water saving interventions were implemented formed the population; thus, it was necessary to obtain a representative sample that would encompass the data set. The criteria for data filtering needed to be defined because the facilities did not have water saving data for the same period in the period of study. The criteria for filtering were:

i. Facilities that had less than 12 months of water saving data were removed from the data set.
ii. Facilities that had data missing for more than two months in a 12-month cycle were removed from the data set.

This process helped ensure that the facilities that would be selected to form the sample, would all have sufficient data. Following the filtering process, a total of 131 facilities were left and this made up the new population.

3.2.2 Sampling Method and Sample Size

The study aimed to obtain results that would be representative of the whole population. For this Probability Sampling was applied, so that every member of the population had a chance of being selected (Acharya et al., 2013). Various probability sampling techniques were evaluated, and it was determined that the Stratified Sampling Method would be appropriate for this study (Westfall, 2009). This sampling method involves dividing the population into sub-groups (referred to as *strata*) that are based on specific characteristics such as age, gender, location, etc. (Thompson, 2012). Random Sampling or Systematic Sampling is then used to select the data points from each stratum. Random sampling ensures that every data point has an equal probability of being selected, while systematic sampling involves assigning numbers to data points and selecting the numbers at regular intervals (McCombes, 2019). The key benefit of using Stratified Sampling is that it allows for representation of the diverse characteristics of the data in the analysis, by ensuring that every stratum is accurately represented (Acharya et al., 2013).

For this study, it was decided that the sub-groups (strata) would be the three provinces in which the facilities were located. Due to the need to maintain the confidentiality of the service provider, these provinces will be referred to as Province A, Province B and Province C. It should be noted that the strata could have been the types of institutions (judicial buildings, military/naval bases, police stations, and prisons), and the number of the facilities per province is provided in *Table 3-2* below. However, the types of facilities are not equally represented in the provinces. It was determined that the provinces should be the strata, as this choice would allow for comparisons of how water saving interventions are addressed in the various provinces, as well as on the various facilities. Adding to this, the types of institutions were not equally represented in the population, and this would have made the selection of the sample challenging. To obtain the data points from the strata, Random Sampling was used to ensure that each facility had an equal chance of being selected.

Table 3-2: The number of the different types of facilities within the three provinces.

Provinces	**Type of Facility**				**Total**
	Judicial Buildings	**Military/Naval Bases**	**Police Stations**	**Prisons**	
Province A	10	6	7	13	36
Province B	4	13	13	11	41
Province C	12	23	29	23	87
Total	26	42	49	47	164

In determining the sample size, i.e., how many data points were required in total, consideration was given to three factors: *level of precision*, *confidence level* and *degree of variability* (Israel, 1992). The *level of precision*, also known as the *sampling error or* *margin of error*, refers to the range in which the sample mean can differ from the population mean (Qualtrics, 2021). A level of precision of 10% (or 0.1) was chosen for this study as it is deemed to be a more conservative choice as opposed to 5% or 7%. The *confidence level or risk level* refers to what percentage of the sample will have a mean that falls within the selected level of precision (Muthen & Muthen, 2002). A 90% confidence level was selected in line with the 10% level of precision. The *degree of variability*, also known as the *standard deviation*, is a measure of how clustered the data is around the mean (Qualtrics, 2021). According to Israel (1992) and Qualtrics (2021), a standard deviation of 50% or 0.5, is the most conservative as it provides the maximum variability in a population and would yield a large sample size.

The sample size is determined using Equation 3.1 below, which is the modified Cochran Formula for small populations (Bartlett II et al., 2001; Forbes et al., 2011; Glen, 2021). The level of precision (0.1) and the degree of variability (0.5) are the *e* and *p* variables in Equation 3.1, respectively. The confidence level is not applied directly into Equation 3.1 but is used to determine the *z* variable. It was possible to make use of the z variable (or z-score) because the data follows the normal distribution. For the selected confidence level of 90%, the z variable (z-score) is 1.65 (Forbes et al., 2011; Glen, 2021).

$$Sample\ size\ (n_O) = \frac{\frac{z^2\,p\,(1-p)}{e^2}}{1 + (\frac{z^2\,p\,(1-p)}{e^2 N})} \tag{3.1}$$

Where:

n_o = sample size

z = z-score

p = the degree of variability or standard deviation

e = level of precision or margin of error

N = population size

Using the chosen level of precision, confidence level and degree of variability, the sample size for the population of 131 facilities, was calculated as 44.79. This sample size comprised of less than 35% of the population and this was deemed low. It is noted that if the sample is too big, the study can become complex, expensive, and time-consuming to run. Although the results are more accurate, the benefits may not outweigh the costs. It is also noted that the current population of 131 facilities is low, and statisticians would recommend that all the institutions be studied. However, the formula is a guide to the final selection of sample size and limitations of time and resources led to the selection of 60 data points out of the 131 facilities.

It should be noted that the 131 facilities are not equally distributed amongst the three provinces. The Stratified Sampling method allows for the sampling fraction for each stratum to be taken in the same proportion as the stratum has in the population. This means that the fraction that the province contributed to the total number of facilities would be the same fraction that the province should be represented in the sample size. However, as shown in *Table 3-3* below, Province C contributed more than half of the facilities while Provinces A and B contributed a similar number of facilities. Taking this into consideration, it was decided that to ensure equal representation of the provinces, the sample size would be divided equally between the three provinces. However, after the filtering process, there were only 19 facilities in Province B that could be selected. The remaining 40 facilities were randomly selected from Province A and Province C. The random selection was conducted by writing the facility names on a piece of paper and drawing the names out of a bowl.

Table 3-3: The distribution of facilities and the sample size amongst the strata (provinces).

Item	**Provinces (Strata)**			**Total**
	A	**B**	**C**	
No. of Facilities in Population	41	38	85	**164**
No. of Facilities after Filtering	34	19	78	**131**
No. of Facilities in Sample	20	19	20	**59**

3.2.3 Data Consolidation

The service provider applied the following procedure of planning, executing, and monitoring for the all the facilities:

1. Determine the facility's baseline volume using 3-years historical billed consumption for the site. The baseline was then submitted to the client and formal approval was provided. In cases where 3-years historical consumption was not available, the client approved the use of 6 months of measured consumption.
2. A Global System for Mobile Communications (GSM) data logger was installed on either the facility's water meter or a check water meter that the service provider would install. The reason for this was some of the facilities had water meters that could not accommodate the installation of a GSM data logger; thus, a compatible water meter needed to be installed in addition to the existing water meter.
3. The GSM data logger was used to record the flow rate passing through the water meter and the data was transmitted to a cloud-based platform that could be accessed remotely. The purpose of this was two-fold:
    a. The GSM data logger allowed the service provider to monitor remote facilities at any time of the day.
    b. The loggers provided an early warning system of any abnormalities in the expected flow rate, with high flow rates being associated with heavy leaks, on occasions where there was no other plausible reason.
4. The frequency of data transmission from the GSM data loggers was set by the service provider, with the most frequent being every 15 minutes. However, this would affect the battery life of the logger, thus, most loggers were set to transmit data twice a day. Separate to the set upload frequency, alarms could be set on the data logger for the service provider to be notified via SMS if the flow rate was recorded above a set threshold.

5. The service provider proceeded to undertake a condition assessment of the facility to determine which water saving interventions needed to be implemented, and in some instances, the sequence in which the interventions needed to be implemented.
6. The water saving interventions were then implemented. Depending on the interventions, some were completed within a month while other interventions were implemented over a longer period before their effect on the water consumption was realised. The costs of implementing the water savings were met by the service provider.
7. Once the first intervention was completed on a facility, the service provider proceeded to determine the water savings that the intervention yielded.
8. The service provider obtained the water bill from the municipality or water utility, which provided the facility's water consumption for the period of billing. This billed water consumption was compared to the baseline water consumption, and water savings were achieved only when the billed water consumption was less than the baseline water consumption.
9. Some municipalities charged for sewer water discharge that was linked to the facility's water consumption. For these facilities, the sewer baseline was a percentage of the baseline volume and was charged on a sewer water tariff. Thus, savings could also be achieved on the sewer water discharge.
10. The service provider then proceeded to quantify the monetary value of the water savings for both the water consumed and sewer water discharged. This was determined using the potable water tariff and the sewer water tariff at the time of analysis. These tariffs were set by the municipality and were not constant throughout the duration of the shared water savings contract.
11. The service provider then claimed a percentage of the savings realised from the client based on the agreed split outlined in the shared water savings contract.
12. The analysis of savings was performed for every period for which a municipal water bill could be obtained. In most instances, the period was monthly, and

this analysis could be performed from the first month of savings until the contract end date.

13. The service provider ensured that as many viable water saving interventions were implemented at every facility to increase the water savings. The service provider also ensured that water savings were maintained by monitoring the facilities and reacting to any infrastructure issues that would decrease water savings.

Using the above procedure, the service provider developed a database for each facility that tracked the water savings. It was this database that was used to collect data for the facilities that were selected to form part of the sample population in this study. It should be noted that all aspects pertaining to costs were not included in this study, because the costs of interventions were not tracked. Thus, the non-cost items that made up the facility databases are defined in *Table 3-4*, as well as the items that made up the variables that were used for analysis.

The period of study was from 01 September 2016 to 30 June 2020. It was decided, however, to confine the data collection period to the period between 01 January 2019 and 30 June 2020, and 12-months of data was collected for all the facilities within this period. The decision to collect 12-months of data within the data collection period, was to ensure that seasonal variations were accounted for within the study, to ensure homogeneity of the data, and to account for the impact that the Covid-19 pandemic would have had on the facility consumption.

Table 3-4: The items that formed the facility databases.

Item	Description	Variable Number	Variable Type
Facility Name	The facility where the water saving interventions were implemented and the point of water consumption.	Variable 1	Grouping
Province Name	The province where the facility is located.	Variable 2	Grouping
Month	The different months within the data collection period.	Variable 3	Grouping

Item	Description	Variable Number	Variable Type
Year	The different years within the data collection period.	Variable 4	Grouping
Date captured	Date when the water bill was received from the municipality and the report created.	N/A	N/A
Approved Baseline Volume	Baseline consumption for the facility that was based on the facility's historical water consumption. (Refer to Variable 5)	Variable 5	Continuous
Date of Baseline Approval	Date when the baseline was set for the first time or when the revised baseline was approved.	N/A	N/A
Billed facility water consumption – m^3/period	Water consumption from the municipal account based on the difference between the current and previous water meter readings. (Refer to Variable 6)	Variable 6	Continuous
Billed facility water consumption – duration (days)	Number of days between the period of water meter readings. (Refer to Variable 7)	Variable 7	Continuous
Billed facility water consumption – m^3/day	Refer to comments for Variable 8.	Variable 8	Continuous
Baseline water consumption – m^3/period	Refer to comments for Variable 9.	Variable 9	Continuous
Savings due to interventions – m^3/period	Refer to comments for Variable 10.	Variable 10	Continuous
Intervention Types	The eight types of interventions that could have been implemented at a facility.	Variable 11	Grouping
Number of Interventions	The number of interventions applied at a facility.	Variable 12	Grouping
Combinations	The combination of interventions applied at a facility.	Variable 13	Grouping

A total of 12-months of data for each facility was extracted from the database for each of the variables. A detailed explanation (where applicable) of some of the variables used for analysis is provided:

Variable 5: Approved Baseline Consumption – m^3/day

- The baseline consumption for the facility that was based on 3-years of historical consumption or 6-months of measured consumption for the facility.
- This would have been the expected consumption per day without any interventions.

Variable 6: Billed facility water consumption – m^3*/period*

- This was the water consumption from the municipal account, based on the difference between the current and previous water meter readings.
- The dates of meter readings differed for each month and in some instances, the water consumption accumulated depending on the period between meter readings.

Variable 7: Billed facility water consumption – duration (days)

- Number of days between the period of water meter readings.
- The number of days were not consistent with either the days of the month or a fixed duration, and in some instances, the number of days was accumulated or shorter than the days in the month.

Variable 8: Billed facility water consumption – m^3*/day*

- This was a continuous variable that was determined using Equation 3.2 below.

$$Billed\ facility\ water\ consumption\left(\frac{m^3}{day}\right) = \frac{Billed\ facility\ water\ consumption\left(\frac{m^3}{period}\right)}{Billed\ facility\ water\ consumption\ (days)} \quad (3.2)$$

Variable 9: Baseline water consumption – m^3*/period*

- This was a continuous variable that was determined using Equation 3.3 below.

$$\begin{aligned} Baseline\ water\ consumption\left(\frac{m^3}{period}\right) \\ &= Approved\ baseline\ consumption\left(\frac{m^3}{day}\right) \\ &\times\ Billed\ facility\ water\ consumption\ (days) \quad (3.3) \end{aligned}$$

Variable 10: Savings due to interventions – m^3*/period*

- This was a continuous variable that was determined using Equation 3.4.

- If the calculation yielded a negative value, then the billed consumption was more than what was expected (baseline).
- Therefore, no savings were achieved for that period.

$$\begin{aligned} &Savings\ due\ to\ interventions\left(\frac{m^3}{period}\right) \\ &\quad = Baseline\ water\ consumption\left(\frac{m^3}{period}\right) \\ &\quad - Billed\ facility\ water\ consumption\left(\frac{m^3}{period}\right) \qquad (3.4) \end{aligned}$$

3.3 Data Analysis

The decision for the type of data analysis to use was informed by the data. A possible form of data analysis would have been a time-series analysis that observes the values that a variable takes at different times (Statistics Solutions, 2021). Time series analysis recognises that data points taken over a period may have an inner composition such as autocorrelation, trend, or seasonal variation, that should be considered (Nist Sematech, 2013). The time units could be daily, weekly, monthly, or annual observations. However, according to Box and Tiao (1975), a minimum of 50 observations are required to make use of this form of analysis, and in most cases the observations must be consecutive. Time series analysis was not appropriate for this study, because 50 consecutive observations could not be achieved given the following:

- The study period was approximately four years.
- The water saving interventions did not commence at the same time at all the facilities.
- The water savings were based on municipal water bills that could only be provided monthly.
- Most facilities did not obtain municipal water bills for every month from the inception of the water savings to the end of the study period.

It was then decided to use means and standard deviations to characterise the variables and hypothesis testing using the student t-test and analysis of variance. The Statistical

Package for the Social Science (SPSS) data analysis software, otherwise known as IBM SPSS Statistics (Norusis, 2011) was selected for the analysis. This software is widely used to conduct descriptive analysis and hypothesis testing (Field, 2013).

3.3.1 Hypotheses Testing

The hypothesis to be tested were derived from the objectives and are detailed below.

Objective 1: To assess whether the water saving interventions that have been applied have significantly saved water.

Null Hypothesis (H0): Water saving interventions save water at above 25% of the baseline.

Alternative Hypothesis (H1): Water saving interventions save water below 25% of the baseline.

Objective 2: To determine the combinations of water saving interventions which maximize water savings.

An analysis of the combination of interventions that were implemented at the various facilities will be conducted and thereafter, the following hypotheses will be tested:

Null Hypothesis (H0): There is no water savings differences with the intervention combinations.

Alternative Hypothesis (H1): There is water savings differences with the intervention combinations.

Null Hypothesis (H0): There is no water savings differences with the number of interventions deployed at the facilities.

Alternative Hypothesis (H1): There is water savings differences with the number of interventions deployed at the facilities.

Objective 3: To determine the consistency of water saving interventions across the provinces.

Null Hypothesis (H0): There is no water savings differences between provinces.

Alternative Hypothesis (H1): There is water savings differences between provinces.

Null Hypothesis (H0): There is no water savings differences between the intervention types.

Alternative Hypothesis (H1): There is water savings differences between the different intervention types.

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Overall Effectiveness of Water Saving Interventions

As detailed in *Table 3-3*, the final sample for data analysis consisted of 59 facilities. The split of facilities between Province A, Province B and Province C was 20, 19 and 20, respectively. The approved baseline consumption for each facility formed the pre-intervention consumption prior to the implementation of any water saving interventions. *Table 4-1* indicates the total approved baseline consumptions per province. It is noted that Province C had the highest approved baseline consumption of 4.13 million m^3, followed closely by Province A with 4.05 million m^3 and Province B had the lowest approved baseline consumption with 2.33 million m^3.

Table 4-1: Approved baseline consumption per province over 12 months.

Province	Approved Baseline Consumption (m^3/annum)	Percentage
Province A	4 052 328	38.5%
Province B	2 335 605	22.2%
Province C	4 131 707	39.3%
Total	**10 519 640**	**100%**

The billed facility consumption formed the post-intervention consumption after the water saving interventions were implemented. The total billed facility water consumption for all 59 facilities was 4.26 million m^3 over 12 months (*Table 4-2*). Of the three provinces, Province A had the highest billed facility water consumption with 48% (2.04 million m^3), followed by Province C with 35% (1.48 million m^3), while Province B had the smallest billed facility water consumption at 17% (0.728 million m^3).

Table 4-2: Billed facility water consumption per province over 12 months.

Province	Billed Facility Water Consumption (m^3/annum)	Percentage
Province A	2 044 529	48%
Province B	727 829	17%
Province C	1 483 385	35%
Total	**4 255 743**	**100%**

The statistical parameters of the billed facility water consumption were determined for the dataset of the 59 facilities, and these were summarized in *Table 4-3*. The overall average billed facility water consumption from 708 observations was 6 002 m^3 per month with a standard deviation of 10 356 m^3/month. Province A and Province B had facilities with the lowest minimum monthly billed facility water consumption of 15 m^3/month and 9 m^3/month, respectively. The minimum billed facility water consumption was due to the low occupation in certain institutions such as small judicial buildings and small police stations. Conversely, a facility in Province A had the highest monthly billed facility water consumption of 75 800 m^3/month, which was in line with Province A having the highest overall total of billed facility water consumption.

Table 4-3: Descriptive statistics of the billed facility water consumption per province.

Statistical Parameter	Province A	Province B	Province C	Overall
Billed facility water consumption (m^3/annum)	2 044 529	727 829	1 483 385	**4 255 743**
Number of observations	240	228	240	**708**
Average (m^3/month)	8 519	3 178	6 181	**6 002**
Minimum (m^3/month)	15	9	230	**9**
Maximum (m^3/month)	75 800	17 407	41 095	**75 800**
Standard Deviation (m^3/month)	15 518	3 985	6 904	**10 356**

The savings due to interventions were determined as the difference between the approved baseline consumption and the billed facility consumption. The statistical parameters of the savings due to interventions were determined for the 59 facilities, and these are summarized in *Table 4-4*. On average, the facilities in all the provinces decreased their monthly consumption by 8 835 m^3/month. The facilities in Province C had the highest monthly average saving of 11 035 m^3/month with high standard deviations of 19 547 m^3/month, followed by the facilities in Province A at 8 366 m^3/month with standard deviations of 11 860 m^3/month. Province B had the lowest average monthly savings of all provinces at 7 021 m^3/month and standard deviations of 9 328 m^3/month.

Table 4-4: Descriptive statistics of the savings due to the interventions per province.

Statistical Parameter	Province A	Province B	Province C	Overall
Savings due to interventions (m^3/annum)	2 007 799	1 607 776	2 648 322	**6 263 897**
Number of observations	240	228	240	**708**
Average (m^3/month)	8 366	7 021	11 035	**8 835**
Minimum (m^3/month)	52	6	(235)	**(235)**
Maximum (m^3/month)	59 743	43 927	98 670	**98 670**
Standard Deviation (m^3/month)	11 860	9 328	19 547	**14 397**

Furthermore, the approved baseline consumptions, the billed facility consumptions, and the savings due to the interventions were analyzed, and are presented in tabular format (*Table 4-5)* and graphically (*Figure 4-1)*. In total, the provinces consumed 40% of the approved baseline consumption over the 12-month period of study, which meant that the water saving interventions yielded 60% water savings. Facilities in Province A, which had the highest consumption of the three provinces, had a baseline of 4 052 328 m^3/annum and consumed 50% of the approved baseline consumption over 12 months. Facilities in Province C consumed 36% of the approved baseline consumption and facilities in Province B consumed only 31% of the approved baseline consumption. Thus, the facilities in Province B, while having the lowest approved baseline consumption, achieved the greatest overall savings of 69%.

Table 4-5: Summary of consumption and savings for the three provinces.

Province	**Approved baseline consumption**		**Billed facility consumption**		**Savings due to interventions**	
	Total (m^3/annum)	% of baseline	Total (m^3/annum)	% of baseline	Total (m^3/annum)	% of baseline
Province A	4 052 328	100%	2 044 529	50%	2 007 799	50%
Province B	2 335 605	100%	727 829	31%	1 607 776	69%
Province C	4 131 707	100%	1 483 385	36%	2 648 322	64%
Grand Total	**10 519 640**	**100%**	**4 255 743**	**40%**	**6 263 897**	**60%**

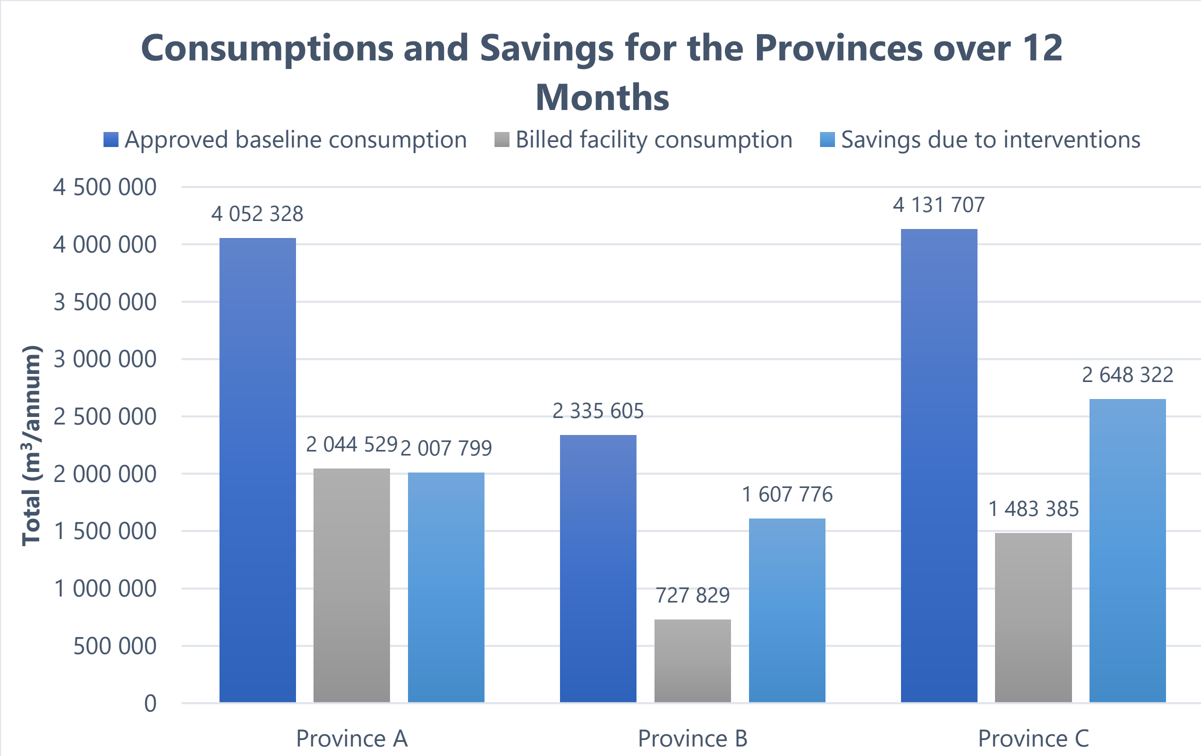

Figure 4-1: Consumptions and savings for the provinces over 12 months.

4.2 Implemented Water Saving Interventions

As discussed in *Section 2.2*, retrofitting and leak fixing were found to be the leading domestic water saving initiatives that have been presented in literature (Keramitsoglou & Tsagarakis, 2011; Biggs, 2017; Ruiz et al., 2020). The results of the study correlate with the literature by showing that of the 8 water saving interventions implemented, retrofitting was performed at all 59 facilities and 90% of the facilities implemented leak fixing (*Figure 4-2*). Pressure management was the third widely used water saving intervention and it was implemented by 43% of the facilities, followed by awareness campaigns at 17% (10 facilities). The interventions that were barely used were controlled supply and usage (7%), borehole installations (10%) and isolation of illegal water connections (12%).

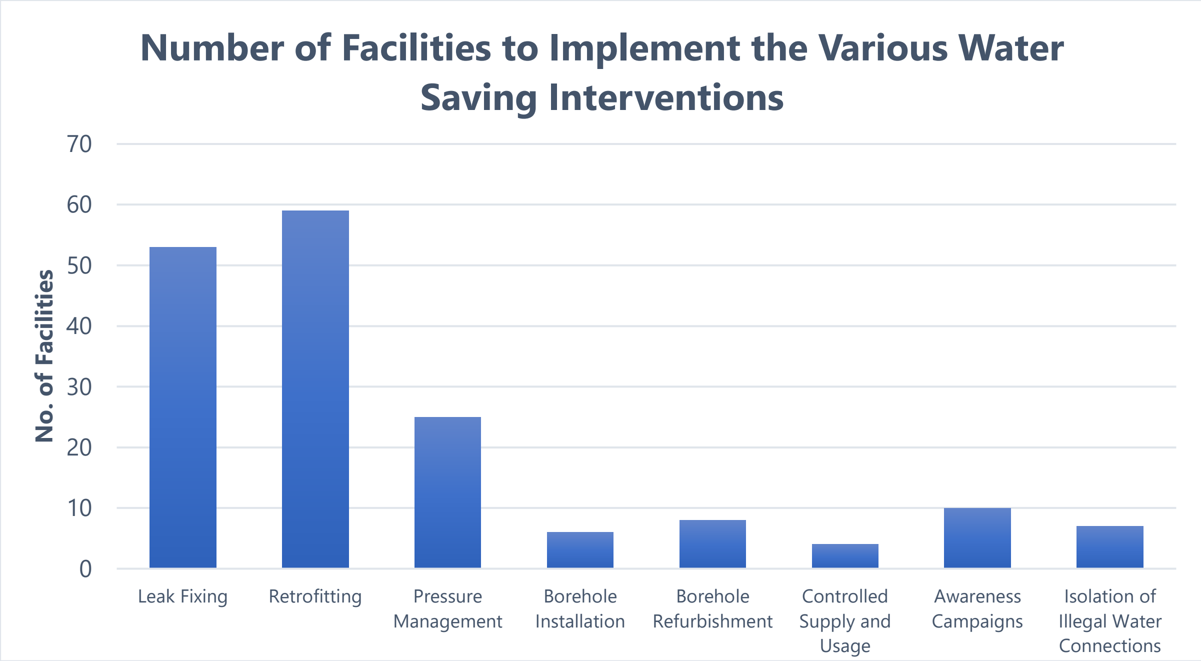

Figure 4-2: The number of facilities implementing the various water saving interventions.

As previously mentioned in *Section 3.2.3*, the water saving interventions implemented at each facility were specific to the conditions of that facility. An assessment was conducted to determine which water saving interventions would yield savings and these interventions were implemented. Amongst the three provinces, 42% of the facilities implemented 2 interventions, while 29% implemented 3 interventions and a total of 19% implemented 4 interventions (*Table 4-6*). In Province A and Province B both had 11 institutions that implemented 2 interventions to save water and none of the facilities in both provinces implemented 6 interventions. On the other hand, Province C had one facility that implemented 6 interventions, however, 50% of the facilities implemented at least 3 interventions. There was only one institution in Province A that implemented only one water saving intervention.

Table 4-6: The number of interventions implemented at various facilities within the provinces.

No. of Interventions	No. of Facilities to Implement Interventions				
	Province A	Province B	Province C	Total	%
1	1			1	2%
2	11	11	3	25	42%
3	2	5	10	17	29%
4	5	1	5	11	19%
5	1	2	1	4	7%
6			1	1	2%
Total	**20**	**19**	**20**	**59**	**100%**

As *Table 4-6* suggests, more than one intervention can be implemented at any facility, to enable significant water savings as per the reports from the assessors. *Table 4-7* indicates which were the most prevalent water saving interventions implemented by the facilities. As indicated, 24 of the 25 facilities with 2 interventions had implemented leak fixing and retrofitting in combination. Of the 17 facilities with 3 interventions, 12 had implemented leak fixing, retrofitting and pressure management. Additionally, of the 11 facilities with a combination of four different interventions, 3 of the 11 implemented awareness campaigns in addition to leak fixing, retrofitting and pressure management, while 2 of the 11 included the control of supply and usage together with leak fixing, retrofitting and pressure management. The remaining 17 facilities implemented unique combinations relevant to their facility conditions, and what was deemed as the most suitable interventions to maximize water savings.

Table 4-7: The number of combinations of interventions implemented by facilities.

Combinations of Interventions	No. of Facilities to implement
Leak fixing & retrofitting	24
Leak fixing, retrofitting & pressure management	12
Leak fixing, retrofitting, pressure management & awareness campaigns	3
Leak fixing, retrofitting, pressure management & controlled supply and usage	2

Combinations of Interventions	No. of Facilities to implement
Leak fixing, retrofitting, pressure management, borehole installation, awareness campaigns & isolation of illegal water connections	1

4.3 Significance of Water Savings

The first research objective was to assess whether the water saving interventions that have been applied had significantly saved water. The hypothesis test conducted was used to determine whether the mean water savings were 25% above the mean baseline consumption at a 10% confidence level. The 25% reduction in billed facility consumption was a requirement of the shared water savings contract, as stated in Section 3.1.

Null Hypothesis (H0): Mean water saving interventions save water below 25% of the baseline.

Alternative Hypothesis (H1): Mean water saving Interventions save water on or above 25% of the mean baseline.

A one sample test of means compares the mean of a sample to a pre-specified value and tests for a deviation from that value. In this case, the predetermined mean was 25% of the baseline. Each province was tested against its corresponding baseline and the results are provided in *Table 4-8*. According to the one sample t-test, the overall mean of water savings for all the facilities in the three provinces (8 835 m^3/month), was significantly above 25% of the baseline (4 303 m^3/month). The alternative hypothesis was accepted at 10% level of significance. Individually, Provinces A, B and C, also prove to be significantly above 25% of the baseline. In conclusion, the water saving interventions that have been implemented, have significantly saved water.

Table 4-8: t-Test: One sample test of the mean.

Parameter	Overall	Province A	Province B	Province C
Mean (m^3/month)	8 835	8 366	7 021	11 035
Variance	207 261 712	140 660 935	87 014 547	382 076 402

Parameter	Overall	Province A	Province B	Province C
Observations	709	240	229	240
Hypothesized Mean Difference (m^3/month)	3 709	4 221	2 550	4 304
Degrees of Freedom (df)	708	239	228	239
t Stat	-11.000	-11.000	-5.000	-5.000
P (T<=t) one-tail	0,000	0,000	0,000	0,000
t Critical one-tail	1,283	1,285	1,285	1,285
P (T<=t) two-tail	0,000	0,000	0,000	0,000
t Critical two-tail	1,647	1,651	1,652	1,651
Decision	**Reject H0**	**Reject H0**	**Reject H0**	**Reject H0**

4.4 Effectiveness of Combinations of Water Saving Interventions in the Provinces

The second research objective was to determine the effectiveness of various combinations of water saving interventions. To achieve this objective, the combinations of interventions implemented were analyzed. Each water saving intervention was assigned a combination code from A to H, as detailed in *Table 4-9*. For facilities where more than one intervention was implemented, the codes were concatenated, e.g., a facility that implemented both leak fixing and retrofitting will have the code AB. The codes were used for combination analysis only.

Table 4-9: Combination codes for the water saving interventions.

Code	Intervention
A	Leak Fixing
B	Retrofitting
C	Pressure Management
D	Borehole Installation
E	Borehole Refurbishment
F	Controlled Supply and Usage
G	Awareness Campaigns
H	Isolation of Illegal Water Connections

The results of the combination analysis are provided in *Table 4-10*. Of the 59 facilities, 17 facilities implemented unique combinations. There was only one institution that implemented one intervention (B – Retrofitting) and managed to save 79% of their consumption. The saving can be a result of accurate inspection aligned with the correct choice of intervention.

Leak fixing in combination with retrofitting was implemented by 24 of the 59 facilities, yielding a total of 1 369 831 m^3 and an average annual consumption 57 076 m^3 for the 24 facilities. The combination yielded an average saving of 53% where the combination was not mixed with any other interventions, and the combination had the highest percentage of savings of the facilities where only 2 combinations of interventions were implemented. Leak fixing was utilized by 53 of the 59 facilities, while retrofitting was implemented by all the facilities. The combination of leak fixing, retrofitting and pressure management (ABC) was the most widely used amongst the facilities with 3 interventions, and was the second most implemented combination of all the combinations (12). Combination ABC yielded savings of 71% which was the second-best savings percentage of the facilities that implemented 3 interventions. Leak repair, retrofitting and borehole refurbishment (ABE) yielded the highest water savings (92%) amongst all the combinations.

Three of the 11 facilities with 4 combinations of interventions implemented the combination leak fixing, retrofitting, pressure management and awareness campaigns (ABCG). This combination, while being the most implemented, did not yield the most savings amongst the group of 4 combinations. Facilities with combination ABCG had a total billed facility consumption of 335 351 m^3, which yielded an average annual consumption of 111 784 m^3 for the 3 facilities. It was also noted that the facility that implemented combination ABGH had an extremely low consumption when compared to the other facilities that implemented 4 combinations; however, this combination yielded one of the higher savings of 65%.

Table 4-10: Savings achieved from the combination of water saving interventions.

No. of Interventions	Combinations	No. of Facilities	Approved Baseline per period (m^3)	Billed Consumption per period (m^3)	Savings due to Interventions per period (m^3)	% Saved of the Approved Baseline
1	B	1	3 096	659	2 437	79%
2	AB	24	2 895 367	1 369 831	1 525 536	53%
	BC	1	100 607	92 768	7 839	8%
3	ABC	12	3 375 715	990 788	2 384 927	71%
	ABE	1	102 767	8 123	94 644	92%
	ABF	1	195 915	87 493	108 422	55%
	ABG	1	27 385	19 756	7 629	28%
	BCE	1	180 107	66 835	113 272	63%
	BEH	1	97 219	56 702	40 517	42%
4	ABCD	1	126 801	39 116	87 685	69%
	ABCE	1	302 775	90 796	211 979	70%
	ABCF	2	513 434	273 607	239 827	47%
	ABCG	3	605 684	335 351	270 333	45%
	ABDE	1	695 871	193 347	502 524	72%
	ABEF	1	588 060	322 690	265 370	45%
	ABGH	1	1 823	638	1 185	65%
	BCGH	1	32 214	19 457	12 757	40%
5	ABCDE	1	264 492	139 487	125 005	47%
	ABCGH	1	17 846	10 967	6 879	39%
	ABDGH	1	102 884	45 800	57 084	55%
	BDEGH	1	242 580	63 933	178 647	74%
6	ABCDGH	1	46 998	27 599	19 399	41%

There were 4 facilities which implemented 5 different combinations of interventions. Three of the four implemented leak fixing, retrofitting, awareness campaigns and isolation of illegal water connections. The facility that saved the most water (74%) amongst those that implemented 5 combinations, implemented borehole installation and borehole refurbishment in addition to retrofitting, awareness campaigns and isolation of illegal water connections. The highest number of combinations found was 6 and only one facility implemented six combinations. It should be noted that this facility was not one of the highest consumers of water and the savings achieved of 41% were on the lower end of savings achieved as seen in *Figure 4-3*.

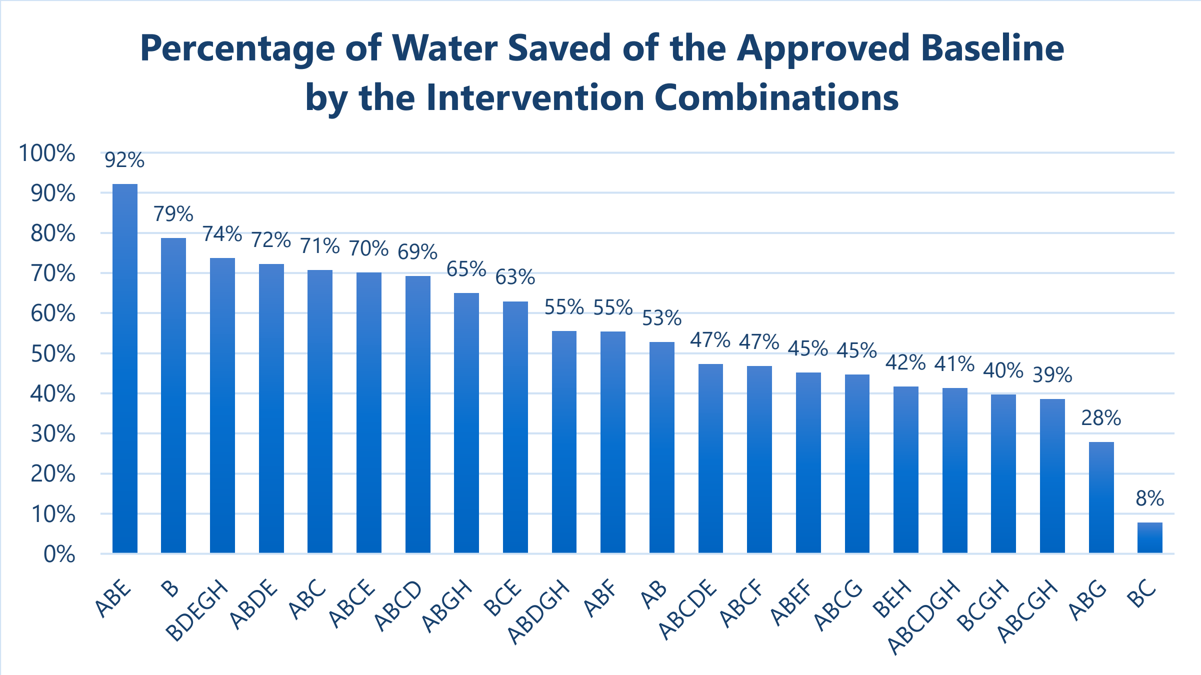

Figure 4-3: Water savings achieved by the intervention combinations.

One Way Analysis of Variance was used to test the second hypothesis; which is that different intervention combinations yield different water savings at 10% level of significance.

H0: There is no water savings differences within the intervention combinations.

H1: There is water savings differences within the intervention combinations.

The results of the One Way Analysis of Variance are presented in *Table 4-11*. With the p-value less that the 10% level of significance, H0 (null hypothesis) was rejected, and it was accepted that there was significant water saving differences within the interventions combinations.

Table 4-11: One Way Analysis of Variance - savings by intervention combinations.

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Combination Groups	310 210	21	14 772	24.571	<0.000	1.438
Within Groups	164 730	274	601 206			
Total	474 950	295				

The third hypothesis tested was to determine if there were water saving differences with the number of interventions deployed at the facilities.

H0: There is no water savings differences with the number of interventions deployed at the facilities.

H1: There is water savings differences with the number of interventions deployed at the facilities.

As noted in *Table 4-12*, the p value of 0,00 was less than the 10% level of significance. Thus, H0 was rejected stating that there was no water saving differences with the number of interventions deployed at the facilities, and the alternative hypothesis was accepted. This meant that there were differences in water savings achieved, and that the number of interventions implemented affected the water savings.

Table 4-12: One Way Analysis of Variance - savings by number of interventions.

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	197 720	5	39 544	14.887	<0.000	1.896
Within Groups	318 750	120	2 656			
Total	516 470	125				

As can be noted in *Figure 4-4*, the results indicated that the implementation of 3 water saving interventions yielded the most savings and thus was a turning point on the graph. The implementation of 3 interventions yielded average savings of approximately 13 000 m^3/period or 33% of the total average savings. The next best number of interventions was 4, which yielded average savings of approximately 12 000 m^3/period or 30% of the total average savings. This may indicate that the implementation of more than 3 interventions will not yield more savings and could possibly be uneconomical. However, it would be recommended that more sites be studied for a longer period, and that the costs of implementing and maintaining the individual interventions be included in such an analysis.

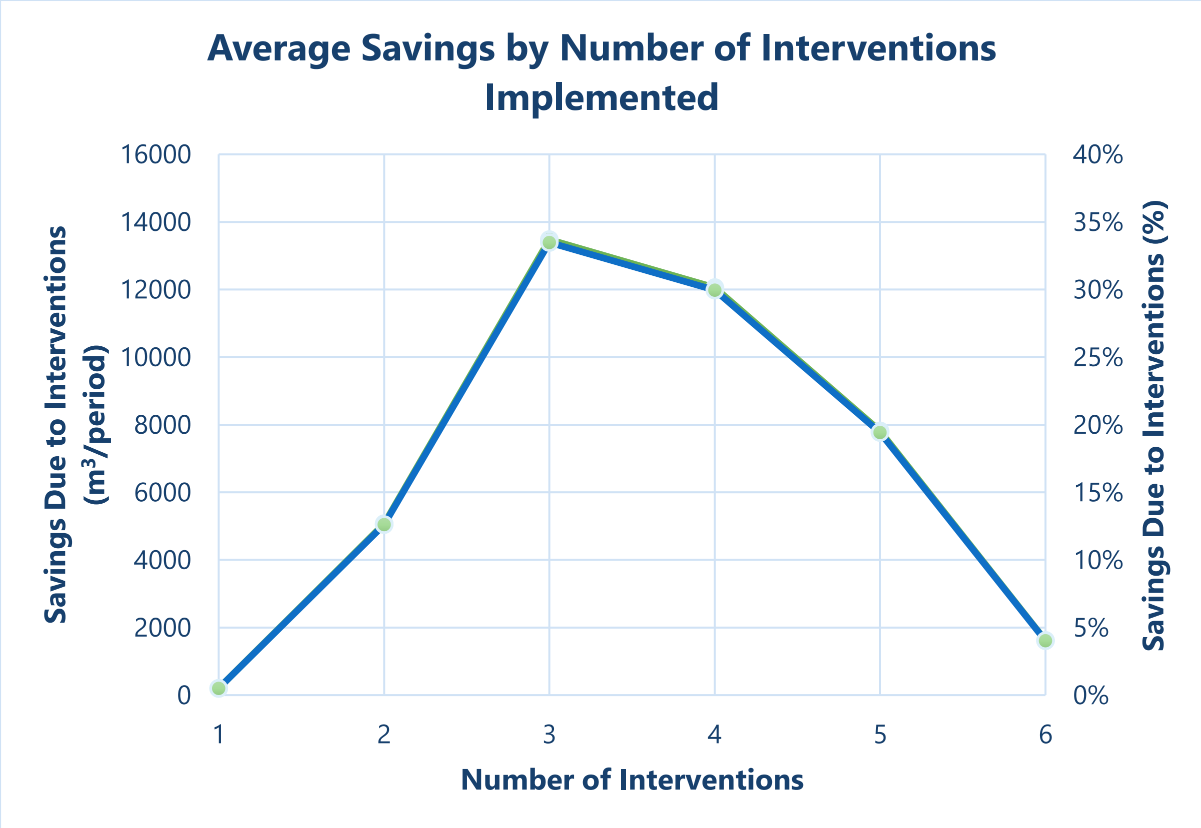

Figure 4-4: Savings achieved by number of interventions.

The third research objective was to determine the consistency of water saving interventions across the provinces.

H0: There is no water savings differences between provinces.

H1: There is water savings differences between provinces.

Post Hoc Tests were conducted to determine whether there were significant differences between the number of interventions implemented by facilities in the different provinces. This was determined using the p-values calculated from the mean differences between the number of interventions implemented (*Table 4-13*). A p-value of less than 0.05 indicated that there were significant differences between the number of interventions implemented. The results showed that there were significant differences between the implementation of 1 intervention as opposed to 3 interventions, between implementing 2 interventions as opposed to implementing 3 or 4 interventions and between implementing 3 interventions as opposed to implementing 6 interventions.

This analysis confirmed that interventions can be implemented in combinations to save water; however, there are some combinations that can yield better savings than others. It was also evident that variations in water savings were obtained by different combinations, regardless of the number of combinations implemented.

Table 4-13: Post Hoc Comparisons of the effect of the Number of Interventions.

Post Hoc Comparisons - Number of Interventions					
***No.**		**Mean Difference**	**SE**	**t**	****P-value**
1	2	-4874,317	4081,197	-1,194	0,84
	3	-13274,422	4118,489	-3,223	**0,017**
	4	-11854,947	4180,425	-2,836	0,053
	5	-7618,512	4484,389	-1,699	0,533
	6	-1413,5	5660,322	-0,25	1
2	3	-8400,104	1256,532	-6,685	**<0,001**
	4	-6980,63	1446,676	-4,825	**<0,001**
	5	-2744,195	2174,088	-1,262	0,805
	6	3460,817	4081,197	0,848	0,958
3	4	1419,475	1548,761	0,917	0,942
	5	5655,909	2243,312	2,521	0,119
	6	11860,922	4118,489	2,88	**0,047**
4	5	4236,435	2355,089	1,799	0,467
	6	10441,447	4180,425	2,498	0,126
5	6	6205,012	4484,389	1,384	0,737
Notes: ***Number of interventions** ****P-value adjusted for comparing a family of 6**					

The last hypothesis was to determine the consistency of the effectiveness of interventions across the provinces, and whether the interventions would work the same if implemented at similar facilities.

H0: There is no water savings differences between the intervention types.

H1: There is water savings differences between the different intervention types.

To achieve this, a Two Way Analysis of Variance using Fisher's exact test was carried out, to test if there were significant water saving differences per intervention between the provinces at a 10% confidence interval.

Retrofitting was implemented by all the facilities, and thus, could not be assessed for significant differences in savings between provinces that implemented it and those that did not. None of the facilities in Province C implemented the Controlled Supply and Usage intervention and for this reason Province C could not be included in the analysis for Controlled Supply and Usage. Due to the two limitations, the Two Way Analysis of Variance using Fisher's test of all interventions encountered singularities. Thus, as an option, the Two Way Analysis of Variance was done independently between provinces and interventions that did not lead to singularity.

The p-values of the Two Way Analysis of Variance between the interventions and provinces are provided in *Table 4-14*. It was evident from the analysis that there were significant differences between facilities that have installed the interventions and those that have not across the provinces, at 0,01 level of significance and for pressure management at 0,05 level of significance. There were significant differences between facilities with pressure management, borehole installation and borehole refurbishment, and those that did not install the interventions at 0,01 level of significance.

Table 4-14: Two Way Analysis of Variance between provinces and interventions.

ANOVA - Savings due to interventions (m³/period)						
Cases	**Interventions P-Values**					
	Leak Fixing	Pressure Management	Borehole Installation	Borehole Refurbishment	Awareness Campaigns	Isolation of Illegal Water Connections
Province	0,146	0,440	0,003	<0,001	0,050	0,099
Intervention	0,022	<0,001	0,002	<0,001	0,147	0,132
Province ✻ intervention	<0,001	0,063	<0,001	<0,001	<0,001	<0,001

Figure 4-5 provides graphical representation of the savings of six intervention types which were included in the combination of interventions that yielded savings in each of the provinces. The results provided in Graphs A to F will be analyzed for each province.

Province A

Leak fixing (Graph A), when implemented in combination with other interventions, was remarkably effective and saved 8 795 m^3/annum or 98%, as opposed to 203 m^3/annum or 2% when it was not implemented in combination with other interventions. On the other hand, pressure management (Graph B) saved 11 117 m^3/annum (59%) when implemented but combinations that did not include it still managed to save 7 678 m^3/annum (41%). As shown in Graphs C and D, borehole installation and borehole refurbishment had very distinct effects in Province A when included in the intervention combinations. When implemented, borehole installation saved 23 317 m^3/annum (78%) as opposed to savings of 6 705 m^3/annum (22%) when it was not implemented. Similarly, borehole refurbishment saved 31 996m^3/annum (85%) when implemented in combination with other interventions, as opposed to 5 740 m^3/annum (15%) when this intervention was not implemented. Conversely, awareness campaigns (Graph E) and isolation of illegal water connections (Graph F) were the least effective when they were installed in combination with other interventions in Province A, both saving only 2 428 m^3/annum or 21%. In summary, the facilities in Province A yielded the most savings from intervention combinations that included leak fixing, pressure management, borehole installation and borehole refurbishment.

Province B

As can be noted in Graph A, leak fixing for Province B was only 33% (6 388 m^3/annum) effective when implemented in combination with other interventions, as opposed to 67% (12 692 m^3/annum) when it was not implemented. The savings achieved when pressure management was implemented or not implemented in combination with other interventions were similar (Graph B), i.e., 8 187 m^3/annum (55%) and 6 607

m^3/annum (45%). As shown in Graphs C and D, borehole installation and borehole refurbishment had a similar impact when implemented in combination with other interventions, saving 13 202 m^3/annum (68%) and 12 264 m^3/annum (70%), respectively. Coincidently, awareness campaigns (Graph E) and isolation of illegal water connections (Graph F) had the same impact when implemented or not implemented in combination with other interventions. These interventions each saved 16 241 m^3/annum or 71%, while the savings achieved by other intervention combinations were 6 556 m^3/annum or 29%. In summary, the facilities in Province B yielded the most savings from intervention combinations that included borehole installation, borehole refurbishment, awareness campaigns and isolation of illegal water connections.

Province C

Like in Province A, leak fixing was highly effective in Province C when implemented in combination with other interventions, saving an average of 12 682 m^3/annum or 88% (Graph A). As shown in Graph B, pressure management was also highly effective in Province C when implemented in combination with other interventions, saving an average of 12 787 m^3/annum or 76% as compared to 4 026 m^3/annum (24%) when not implemented. Conversely, borehole installation (Graph C) and borehole refurbishment (Graph D) did not have a big impact when implemented in combination with other interventions, as they only saved 4 462 m^3/annum (27%) and 3 376 m^3/annum (23%), respectively. Awareness campaigns (Graph E), when implemented with other interventions, had a low impact on savings and yielded average savings of 3 774 m^3/annum or 20%, as opposed to when it was not implemented (14 944 m^3/annum or 80%). The least effective intervention combinations for Province C, were those that included isolation of illegal water connections as shown in Graph F. This intervention yielded savings of only 1 657 m^3/annum (11%), as opposed to when this intervention was not implemented in combination with other interventions (13 379 m^3/annum or 89%). In summary, the facilities in Province C yielded the most savings from intervention combinations that included leak fixing and pressure management.

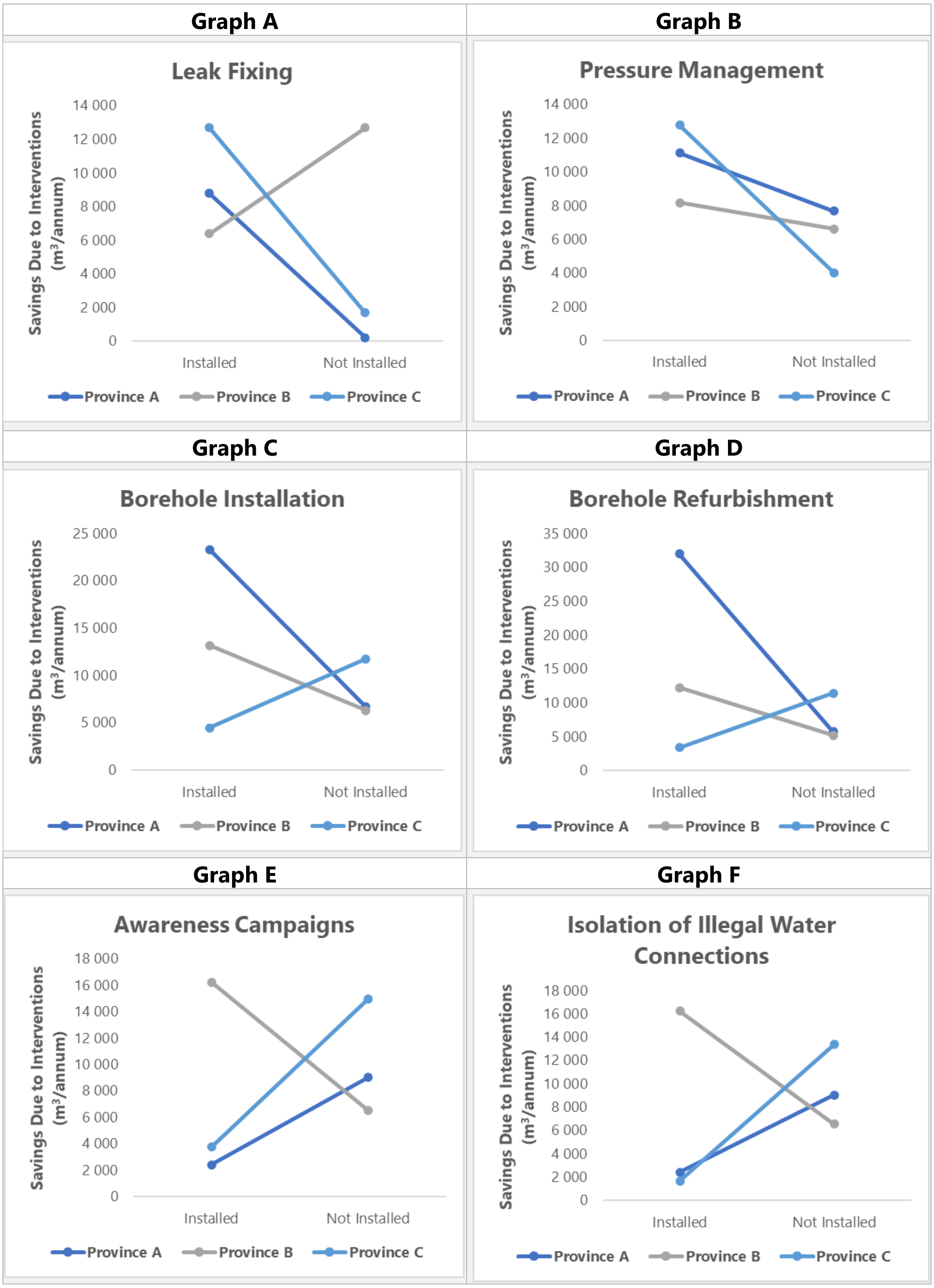

Figure 4-5: The savings due to interventions implemented in the provinces.

4.5 Effectiveness of Water Savings at the Various Facilities

Table 4-15 below indicates the split of the various facility types amongst the provinces. It can be noted that the most representative split is in Province A where the facilities make up 20 – 35% of the total of 20. The least representative split is in Province C where the number of each facility type ranges between 5% and 45%. In total, most of the facilities were military/naval bases (19) and prisons (19), followed by police stations (12), while judicial buildings made up the least with 9 facilities.

Table 4-15: The number of facilities in the three provinces.

Facility	Provinces			Total
	A	B	C	
Judicial Buildings	4 (20%)	3 (16%)	2 (10%)	9
Military/Naval Bases	7 (35%)	4 (21%)	8 (40%)	19
Police Stations	4 (20%)	7 (37%)	1 (5%)	12
Prisons	5 (25%)	5 (26%)	9 (45%)	19
Total	**20**	**19**	**20**	**59**

Like *Table 4-1* that provides the approved baseline consumptions in the various provinces, the pre-intervention (baseline) consumptions were noted for facilities, and these are presented in *Table 4-16*. The military/naval bases and the prisons had similar approved baseline consumptions (46.2% and 46.1%, respectively) and made up 92.3% of the consumption, which is much higher than the percentage that these facilities comprise of the total facilities (i.e., 62.7%). Judicial buildings and police stations had an extremely low combined approved baseline consumptions of 811 147 m^3/annum or 7.7% of the total approved baseline consumptions.

Table 4-16: Approved baseline consumption per facility over 12 months.

Facility	Approved Baseline Consumption (m^3/annum)	Percentage
Judicial Buildings	369 143	3.5%
Military/Naval Bases	4 860 526	46.2%
Police Stations	442 004	4.2%
Prisons	4 847 967	46.1%
Total	**10 519 640**	**100%**

The billed facility consumption formed the post-intervention consumption after the water saving interventions were implemented. The total billed facility water consumption for the facilities was 4.26 million m^3 over 12 months (*Table 4-17*). The results show that the billed facility consumption is exceedingly high for the prisons at 62% (2.6 m^3/annum) even though they make up 19 of the 59 facilities. Military/Naval Bases have the second highest billed facility consumption at 32%, followed by police stations (3%) and judicial buildings (2%).

Table 4-17: Billed facility water consumption per facility over 12 months.

Facility	Billed Facility Water Consumption (m^3/annum)	Percentage
Judicial Buildings	103 528	2.4%
Military/Naval Bases	1 376 504	32.3%
Police Stations	134 556	3.2%
Prisons	2 641 155	62.1%
Total	**4 255 743**	**100%**

The statistical parameters of the billed facility water consumption per facility are summarized in *Table 4-18*. It was noted that the number of observations for military/naval bases and prisons were the same (228); however, the average monthly billed facility consumption for prisons (11 635 m^3/month) was almost double that of the military/naval bases (5 985 m^3/month). Judicial buildings and police stations had extremely low average billed facility water consumption of 959 m^3/month and 934 m^3/month, respectively, when compared to the average billed facility consumptions of military/naval bases and prisons. This meant that great savings were achieved at these facilities. The lowest billed facility water consumption of 9 m^3/month was found to be at a police station, while the highest billed facility water consumption of 75 800 m^3/month was found to be at a prison.

Table 4-18: Descriptive statistics of the billed facility water consumption per facility.

Statistical Parameter	**Judicial Building**	**Military/ Naval Base**	**Police Station**	**Prisons**	**Overall**
Billed facility water consumption (m^3/annum)	103 528	1 376 504	134 556	2 641 155	**4 288 743**
Number of observations	108	228	144	228	**708**
Average (m^3/month)	959	5 985	934	11 635	**6 002**
Minimum (m^3/month)	15	134	9	230	**9**
Maximum (m^3/month)	5 587	25 700	7 372	75 800	**75 800**
Standard Deviation (m^3/month)	1 403	5 060	1 186	15 742	**10 356**

The savings due to interventions were determined as the difference between the approved baseline consumption and the billed facility consumption. The statistical parameters of the savings due to interventions were determined by facility type, and these are summarized in *Table 4-19*. The results show that the most savings were achieved at military bases with a total of 3 484 022 m^3/annum and an average of 15 148 m^3/month. These savings were followed by those achieved at prisons, which yielded a total of 2 206 812 m^3/annum and an average of 9 722 m^3/month. It was interesting to note that the average savings for judicial buildings (2 459 m^3/month) and police stations (2 135 m^3/month) were high and not too far from those for prisons (9 722 m^3/month). This was to be expected due to the extremely low billed facility water consumption. Interestingly, it was at a military/naval base where the highest monthly saving of 98 670 m^3/month was noted, and where the lowest savings of 12 m^3/month was noted. It can also be noted from *Table 4-19* that one prison failed to achieve savings in a particular month, where the billed facility consumption exceeded the approved baseline consumption by 235 m^3/month.

Table 4-19: Descriptive statistics of the savings due to the interventions per facility.

Statistical Parameter	Judicial Building	Military/ Naval Base	Police Station	Prisons	Overall
Savings due to interventions (m^3/annum)	265 615	3 484 022	307 448	2 206 812	**6 263 897**
Number of observations	108	228	144	228	**708**
Average (m^3/month)	2 459	15 148	2 135	9 722	**8 835**
Minimum (m^3/month)	51	12	34	(235)	**(235)**
Maximum (m^3/month)	17 261	98 670	23 105	59 743	**98 670**
Standard Deviation (m^3/month)	4 588	20 161	3 257	11 462	**14 397**

Lastly, the approved baseline consumptions, the billed facility consumptions, and the savings due to the interventions were analyzed, and are presented in tabular format (*Table 4-20)* and graphically (*Figure 4-6)*. The results show that even though judicial buildings comprised of the lowest percentage of approved baseline consumption (3.5%), the highest percentage savings were achieved at judicial buildings (72%). These savings were followed closely by military/naval bases which saved 71.7% or 3.48 million m^3/annum, from their approved baseline consumption of 4.86 million m^3/annum. The percentage savings for police stations were also high at 69.6% and were in the range of those achieved by judicial buildings and military/naval bases. Conversely, prisons which had the second highest approved baseline consumption of 4.85 million m^3/month, saved less than half (45.5%) of this consumption. This greatly impacted the overall percentage of savings achieved by all the facilities, which was found to be 60%.

Table 4-20: Summary of consumption and savings for the facilities.

Facility	Approved baseline consumption		Billed facility consumption		Savings due to interventions	
	Total (m^3/annum)	% of baseline	Total (m^3/annum)	% of baseline	Total (m^3/annum)	% of baseline
Judicial Buildings	369 143	100%	103 528	28.0%	265 615	72.0%
Military/ Naval Base	4 860 526	100%	1 376 504	28.3%	3 484 022	71.7%
Police Stations	442 004	100%	134 556	30.4%	307 448	69.6%
Prisons	4 847 967	100%	2 641 155	54.5%	2 206 812	45.5%
Grand Total	**10 519 640**	**100%**	**4 255 743**	**40%**	**6 263 897**	**60%**

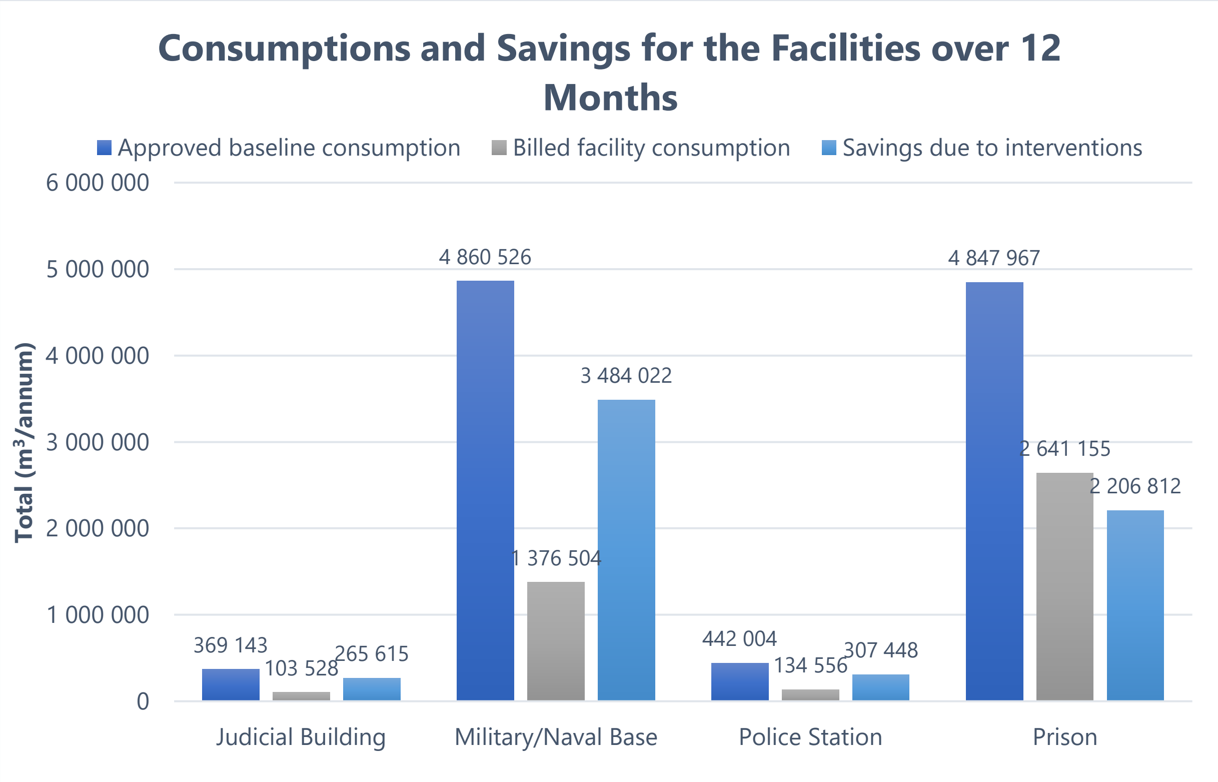

Figure 4-6: Consumptions and savings for the facilities over 12 months.

4.6 Effectiveness of Combinations of Water Saving Interventions at Facilities

Following the analysis of consumptions and savings amongst the facilities, it was important to assess the interventions that yielded the savings. *Table 4-21* indicates the number of interventions implemented at the various facilities. It can be noted that 6 of the 9 judicial buildings (67%) implemented 2 interventions. On the other hand, there was at least one military base that implemented between 2 and 6 interventions, while the number of interventions implemented at 92% of the police stations was 2. Most prisons (37%) implemented 3 interventions, which was closely followed by the 32% that implemented 4 interventions. Overall, 42% of facilities had only 2 interventions implemented.

Table 4-21: The number of interventions implemented at various facilities.

No. of Interventions	No. of Facilities to Implement Interventions					
	Judicial Building	Military Base	Police Station	Prison	Total	%
1			1		1	2%
2	6	5	11	3	25	42%
3	2	8		7	17	29%
4	1	4		6	11	19%
5		1		3	4	7%
6		1			1	2%
Total	**9**	**19**	**12**	**19**	**59**	**100%**

An analysis of the intervention combinations implemented at the various facilities was undertaken. The results found that the 6 military/naval bases that implemented the combination of leak fixing, retrofitting and pressure management (ABC), saved the most water of all the intervention combinations with 1.77 million m^3/annum (*Table 4-22*) and an average of 294 862 m^3/annum per military/naval base. The second highest water savings were achieved at one prison that implemented the combination of ABDE (leak fixing, retrofitting, borehole installation and borehole refurbishment), where a total of 502 524 m^3/annum or 72% was saved. For the police stations, 11 of the 12 facilities implemented the combination of leak fixing and retrofitting and 45% of institutions also implemented the same combination. These police stations saved a total of 305 011 m^3/annum (27 728 m^3/annum per facility). The results also indicated that 14 unique intervention combinations were implemented at various prisons, with the most implemented (4) of these combinations being ABC which yielded savings of

400 764 m^3/annum. The lowest savings of 1 185 m^3/annum was obtained at a judicial building that implemented leak fixing, retrofitting, awareness campaigns and isolation of illegal water connections (ABGH) however these savings translated to 65% savings for the facility.

One military base saved a total of 19 399 m^3/annum from the implementation of 6 different types of interventions. This, however, was the second lowest savings of all the military/naval bases and saved 41% of the approved baseline consumption. Significantly, the results showed that judicial buildings and police stations did not yield the highest savings amongst all the facilities, however, this was to be expected as they comprised of only 3.5% and 4.2%, respectively of the approved baseline consumption.

In conclusion, the stratified sampling method yielded a fair representation of the different types of facilities in relation to the approved baseline consumptions. The military/naval bases and prisons were equally represented with 19 facilities, followed by judicial buildings and police stations with 9 facilities and 12 facilities, respectively across the three provinces. It is clear from the descriptive analysis that the military/naval bases and the prisons were the largest consumers of water (due to their sizes and occupations). On average the prisons tended to consume more than the military/naval bases, however, the military/naval bases saved more water than the prisons. Most of the military/naval bases were found in Province C, followed by Province A while Province B had the lowest number of military/naval bases. There were more police stations in Province B than in Province A and Province C only had one police station of its 20 facilities. In terms of the combination analysis, military/naval bases, and prisons with 3 and 4 combinations of interventions were the biggest savers of water. The combination of interventions that yielded the highest savings (2.38 million m^3/annum or 38%) across all the facilities was the combination of leak fixing, retrofitting and pressure management.

Table 4-22: Savings achieved from the combination of water saving interventions at various facilities.

*NOI	Combinations	Judicial Building		Military/Naval Base		Police Station		Prison		% Saved of Baseline
		**Savings	***No	**Savings	***No	**Savings	***No	**Savings	***No	
1	B					2 437	1			79%
2	AB	49 440	6	982 182	5	305 011	11	188 903	2	53%
	BC							7 839	1	8%
3	ABC	214 990	2	1 769 173	6			400 764	4	71%
	ABE			94 644	1					92%
	ABF			108 422	1					55%
	ABG							7 629	1	28%
	BCE							113 272	1	63%
	BEH							40 517	1	42%
4	ABCD			87 685	1					69%
	ABCE							211 979	1	70%
	ABCF			239 827	2					47%
	ABCG			175 811	1			94 522	2	45%
	ABDE							502 524	1	72%
	ABEF							265 370	1	45%
	ABGH	1 185	1							65%
	BCGH							12 757	1	40%
5	ABCDE							125 005	1	47%
	ABCGH			6 879	1					39%
	ABDGH							57 084	1	55%
	BDEGH							178 647	1	74%
6	ABCDGH			19 399	1					41%
Total Savings (m^3/annum)		265 615		3 484 022		307 448		2 206 812		
% Saved of the Baseline		72.0%		71.7%		69.6%		45.5%		

Note:
***Number of interventions**
****Savings due to interventions (m^3/annum)**
*****Number of facilities**

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

At any given point in time within the water cycle, the volume of water available is approximately 1.36 billion km^3; however, only 0.013% or 176 800 km^3 exists as surface water for most of the world's population to utilise (Shiklomanov, 1993; Bureau of Reclamation California-Great Basin 2020). Adding to this extremity is the notion that the water cycle is a finite and closed system, meaning that the quantity of water available at any point in the cycle is approximately the same and that no further volumes of water can be removed from or added to the system (Dooge, 1968). Furthermore, issues such as rapid population growth, increased industrialisation, and climate change are threatening the security of already limited water resources. Thus, the problem posed is how to safeguard water resources on the back of these threats.

South Africa is classified as semi-arid because the country receives an average rainfall of less than 500mm a year (Mwendera, 2016). Adding to the physical scarcity of water in South Africa is the poor management of water. Although South Africa has one of the best water legislations in the world (Piper, 2014; Nhamo et al., 2020), according to Herold (2010), water access and water infrastructure have not been effectively managed. Herold (2010) further explains that the poor management of water has been caused by the failure to meet demand management targets, decaying infrastructure, theft from water resources and deteriorating water quality. It has been identified that the implementation of water saving interventions by end consumers can assist in reducing the impact of water scarcity and water mismanagement.

There are various kinds of water saving interventions and these include leak fixing, retrofitting, pressure management, efficient use of water, greywater reclamation and awareness campaigns. Most research has focused on leak fixing and retrofitting, particularly on a domestic scale, rather than on an industrial or commercial scale (Keramitsoglou & Tsagarakis, 2011; Biggs, 2017; Ruiz et al., 2020). Pressure management, when implemented in some studies, was effective in achieving water savings (Mckenzie & Wegelin, 2005; Gomes et al., 2011; Gupta et al., 2017; Samir et al., 2017), and this is one of the interventions that was not implemented on a domestic scale, but rather on a district scale to reduce the water wastage of an entire area. Some of the interventions were implemented in combination such as treated greywater reuse and retrofitting shown in the study conducted by Alexander and Clark (2016) pressure management and efficient water use shown in the study conducted by Bruhl and Visser (2021) and, leak fixing and retrofitting as shown in the study conducted by Ruiz et al. (2020). On the other hand, some interventions such as awareness campaigns, were most effective when implemented in combination with other interventions (Barnard et al., 2014; Katz et al., 2016; Stavenhagen et al., 2018; Bruhl & Visser, 2021).

However, very few studies assessed the broad range of interventions, that when implemented would maximize water savings. This was an identified gap that justified this study. Furthermore, it was noted that shared savings contracts (energy savings performance contracts), are typically either energy savings contracts or a combination of energy and water savings. The study by Mckenzie and Wegelin (2005), was the one study found that was a shared water savings contract (SWSC) that implemented pressure management as the sole water saving intervention.

In view of the issues of water scarcity and water mismanagement that exist in South Africa, a SWSC was initiated with the sole purpose of reducing water consumption at institutional facilities within three provinces. The service provider had the mandate of implementing various water saving interventions that were intended to maximise the water savings at 164 facilities. The facilities consisted of judicial buildings, military/naval bases, police stations and prisons. This study sought to assess the effectiveness of the water saving interventions implemented under the SWSC, with a focus on:

i. Assessing whether the water saving interventions applied have significantly saved water,
ii. Determining how the combination of water saving interventions impacts on the effectiveness of water savings, and

iii. Determining the consistency of water saving interventions across the facilities.

5.1 Summary of Findings

5.1.1 Significance of Water Savings Achieved

Eight different types of water saving interventions were implemented at the 164 facilities, either in isolation or in combination with other interventions. This study obtained a representative sample of 59 facilities, split across Provinces A, B and C, and 12-months of water consumption data was obtained and analysed. The study found that retrofitting was implemented at all 59 facilities, followed by leak fixing at 53 facilities and pressure management at 25 facilities. The least implemented water saving intervention was controlled supply and usage (efficient use of water), which was implemented at only 4 facilities, (*Figure 4-2*). As noted in *Table 4-6*, 42% of the facilities (25) implemented 2 water saving interventions to achieve savings, followed by 29% of the facilities (17) that implemented 3 interventions and 19% of the facilities (11) that implemented 4 interventions.

The total approved baseline consumption (pre-intervention consumption) was 10.52 million m^3/annum split across Provinces A, B and C in percentages of 38.5%, 22.2% and 39.3%, respectively. Following the implementation of the water saving interventions, the overall billed facility consumption (post-intervention consumption) was reduced by 60% to 4.26 million m^3/annum (*Table 4-5*). Of the savings due to interventions implemented, Province C had the highest overall water savings with 2.65 million m^3/annum; however, Province B saved the largest percentage of the baseline at 69%. The results thus show that the savings have been significant because the average savings of 8 835 m^3/month across the facilities was much higher than 25% of the average baseline consumption of 4 303 m^3/month across the facilities.

5.1.2 Intervention Combinations that Maximised Water Savings

A total of 22 unique intervention combinations were implemented at the various facilities. The most popular combination to be implemented was leak fixing and retrofitting, which was implemented at 24 of the 59 facilities and yielded 53% savings.

The second most popular combination to be implemented at 12 of the 59 facilities, was leak fixing, retrofitting and pressure management, and this combination managed to save 71% water savings. Overall, 19 of the 22 combinations of water saving interventions achieved more than 40% water savings, and this comprised of 56 of the 59 facilities (*Table 4-10* and *Figure 4-3*).

The intervention combination that achieved the highest savings (92%) was the combination of leak fixing, retrofitting and borehole refurbishment, while the second highest savings of 79% was achieved at a facility that implemented retrofitting only. However, because both these savings were achieved at singular facilities, there is insufficient data to lead to the conclusion that these combinations maximise water savings. Thus, referring to the two most popularly implemented combinations, it is more accurate to state the combination of leak fixing, retrofitting and pressure management maximised water savings. This was supported by the results shown in *Figure 4-4*, that showed that the highest average water savings (33%) are achieved with the implementation of 3 water saving interventions.

5.1.3 Consistency of Water Saving Interventions

As part of the study, it was important to determine the consistency of the effectiveness of interventions across the provinces and whether the interventions would yield the same results if implemented at similar facilities. It was evident from the analysis that there were significant differences in water savings between facilities that have installed the interventions and those that have not across the provinces. From the graphs provided in *Figure 4-5*, it was evident that some interventions when combined with other interventions, were more effective in saving water than others.

The facilities in Province A yielded the most savings from intervention combinations that included leak fixing, pressure management, borehole installation and borehole refurbishment. On the other hand, the facilities in Province B yielded the most savings from intervention combinations that included borehole installation, borehole refurbishment, awareness campaigns and isolation of illegal water connections. Like

Province A, the facilities in Province C yielded the most savings from intervention combinations that included leak fixing and pressure management. It should be noted that because retrofitting was implemented at every facility in the sample, it was not possible to conduct an analysis to determine the savings obtained at facilities where it was not implemented.

5.1.4 Water Savings by Facility Type

The split of facilities within the sample of 59 facilities was 9 judicial buildings, 19 military/naval bases, 12 police stations and 19 prisons. *Table 4-20* shows that, although judicial buildings contributed the lowest number of facilities in the sample and had the lowest approved baseline consumption (3.5%), judicial buildings had the highest percentage savings of 72%. Second to this were the 71.7% water savings achieved at military/naval bases, which were remarkably high considering that the combined pre-intervention consumption on these facilities was the highest at 4.86 million m^3/ annum or 46.2% of the total. Conversely, although prisons contributed the joint most facilities in the sample and had the second highest approved baseline consumption (46.1%), they had the lowest percentage savings (45.5%).

An analysis of the intervention combinations implemented at the various facilities was undertaken. The results found that the 6 military/naval bases that implemented the combination of leak fixing, retrofitting and pressure management saved the most water of all the intervention combinations with 1.77 million m^3/annum (*Table 4-22*). The second highest water savings (502 524 m^3/annum) were achieved at one prison that implemented the combination of leak fixing, retrofitting, borehole installation and borehole refurbishment. The fewest interventions were implemented at a police station that implemented retrofitting and managed to save 79% of the approved baseline consumption. On the other hand, the most interventions were implemented at a military/naval base, where the combination of leak fixing, retrofitting, pressure management, borehole installation, awareness campaigns and isolation of illegal water connections, saved 19 399 m^3/annum or 41%.

5.2 Concluding Remarks

In conclusion, the study objectives have been achieved and have satisfied the research aim of evaluating the effectiveness of water savings interventions under a shared water savings contract. The study outcomes obtained are of practical importance to any entity looking to enter a large-scale shared water savings contract. Of notable importance, the following outcomes can be noted:

- Water saving interventions can yield significant water savings and the savings are independent of the magnitude of the pre-intervention consumptions of the facilities.
- It should not be assumed that facilities that have high pre-intervention consumptions will have a big scope for water saving interventions and thus will yield high water savings.
- The different types of water saving interventions can be implemented in isolation or in combination with other interventions, and the facility conditions need to inform which interventions are likely to be most effective.
- Leak fixing and retrofitting are popular interventions to implement (as can be seen in this study as well as in literature). However, the savings achieved from the implementation of these interventions vary significantly.
- There is no consistency with the interventions that are implemented at similar facilities, further revealing the need to base the interventions to implement on the facility conditions.

5.3 Recommendations for Future Research

Before recommendations can be made, it is important to state the limitations that were known prior to the commencement of this study, or limitations that were encountered during this study.

i. The study was limited to 59 facilities that were spread across three provinces in South Africa.
ii. The study period was limited to 12 months.
iii. The study was limited to the use of 6-months measured consumption to produce a baseline for sites that did not have 3-years historical billed consumption. It is acknowledged that the 6-month period would not account for the seasonal variation of water consumption.
iv. The study was limited to the use of data capturers to manually capture the information from the water bill onto the internal database. It is acknowledged that the manual capturing of data increases the probability of data inaccuracies due to human error.
v. The study could not track consumption and savings as each intervention was implemented and thus could not assign actual savings to individual interventions.
vi. The study was not able to include the impact on a facility's electricity consumption following the installation and use of a borehole as an alternative water supply initiative.
vii. The study was not able to consider the costs of implementing and maintaining the various water saving interventions.
viii. The study did not review minimum night flows. It is acknowledged that this would have provided a comparison between the efficiency of interventions and the reduction in water consumption due to behavioural change.
ix. The study did not include the effects of other alternative water supply initiatives other than the use of borehole water.

Provided below is a list of recommendations for future research.

1. The sample size of facilities was small and further studies should consider using a larger sample.
2. The study period was limited to 12 months, and it is recommended that more facilities are studied for a longer period.
3. The study was limited to facilities in three provinces and further research should look at assessing water saving interventions across South Africa.
4. Further studies could obtain enough data to perform a time-series analysis which would consider seasonal variations in consumption over time.
5. Further studies should make use of alternative methods of data capturing that minimizes the risk of data inaccuracies due to human error.
6. For facilities where multiple interventions were implemented, it was not possible to track changes in consumption and savings, as each intervention was implemented. Thus, it was not possible to assign actual savings to individual interventions, and it is recommended that this be addressed in further studies.
7. The study was not able to consider the effect that the installation and use of boreholes at the facilities had on the electricity consumption of the facility, and this would be recommended for future studies to investigate.
8. The study was not able to consider the costs of implementing and maintaining the various water saving interventions, and further studies could incorporate this.
9. Future research should consider a review of minimum night flows as this could provide a comparison between the efficiency of interventions and the reduction in water consumption due to behavioural change.
10. Future research should consider the effects of other alternative water supply initiatives.
11. Future research should consider assessing the implementation of water saving interventions at non-institutional facilities.

12. Future research should consider the development of an evaluation tool or model that can be used to evaluate the effectiveness of water saving interventions.

CHAPTER 6: REFERENCES

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