

Urban Waste Water Governance in South Africa: A Case Study of Stellenbosch

R. Malisa, E. Schwella, K. I. Theletsane

Abstract—Due to climate change, population growth and rapid urbanization, the demand for water in South Africa is inevitably surpassing supply. To address similar challenges globally, there has been a paradigm shift from conventional urban waste water management “government” to a “governance” paradigm. From the governance paradigm, Integrated Urban Water Management (IUWM) principle emerged. This principle emphasizes efficient urban waste water treatment and production of high-quality recyclable effluent. In so doing mimicking natural water systems, in their processes of recycling water efficiently, and averting depletion of natural water resources. The objective of this study was to investigate drivers of shifting the current urban waste water management approach from a “government” paradigm towards “governance”. The study was conducted through Interactive Management soft systems research methodology which follows a qualitative research design. A case study methodology was employed, guided by realism research philosophy. Qualitative data gathered were analyzed through interpretative structural modelling using Concept Star for Professionals Decision-Making tools (CSPDM) version 3.64. The constructed model deduced that the main drivers in shifting the Stellenbosch municipal urban waste water management towards IUWM “governance” principles are mainly social elements characterized by overambitious expectations of the public on municipal water service delivery, mis-interpretation of the constitution on access to adequate clean water and sanitation as a human right and perceptions on recycling water by different communities. Inadequate public participation also emerged as a strong driver. However, disruptive events such as draught may play a positive role in raising an awareness on the value of water, resulting in a shift on the perceptions on recycled water. Once the social elements are addressed, the alignment of governance and administration elements towards IUWM are achievable. Hence, the point of departure for the desired paradigm shift is the change of water service authorities and serviced communities’ perceptions and behaviors towards shifting urban waste water management approaches from “government” to “governance” paradigm.

Keywords—Integrated urban water management, urban water system, waste water governance, waste water treatment works.

I. INTRODUCTION

RESULTING from climate change, population growth and rapid urbanization, global water demand is inevitably surpassing water supply. For this reason, water management has become a global subject, with stakeholders across disciplines and societies participating in designing water

management principles. Post-World War II technological development was the driver of industrial advancement of the previous century, thus elevating scientific knowledge to unsurpassed levels. Water was an indispensable resource for these developments and has subsequently become the victim of technological achievements and successes. The devastating effect of the fruits of modern civilized nations on natural water resources and the environment in general has turned out to be the most fundamental problem facing the planet’s continued existence. It was in 1977 that the global village realized that the looming global water crisis could threaten human existence. Consequently, a world water conference, hosted by the United Nations, was held in Mar del Plata to address the increasing complexity of managing water resources amid increasing demand and shrinking supplies [53]. During the conference, Integrated Water Resources Management (IWRM) principle [21], which had been in practice for over 50 years, was refined [35]. The IWRM principle focused on the river basin and regional levels. Parallel to the IWRM principle, the IUWM principle emerged. This principle seeks to coordinate all water services, sources and stakeholders in an UWS [8].

The IUWM principle is well researched and continues to be, however, its application is currently widespread in the global North [3]. Pilot projects in Kinshasa, the Democratic Republic of the Congo, Zimbabwe (specifically the Municipality of Marondera) and the Seychelles have alluded to multiple challenges in the implementation of IUWM in sub-Saharan Africa. Whereas [41], in the water partnership program reporting on the City of Windhoek, Namibia held a different view [41]. Postulated that Windhoek was the first city in the world to implement the IUWM concept successfully. Necessitating investigation into the implementation IUWM principles in the sub-Saharan Africa.

Currently, there are ever-increasing water demands surpassing the available natural water supplies in South Africa, particularly in the Western Cape Province. This reality necessitates a paradigm shift in the region’s urban waste water management approach. Stellenbosch Municipality, the water service authority of Stellenbosch located in the Western Cape, is the case study. Investigation of drivers towards shifting Stellenbosch Municipality’s current urban waste water

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management paradigm from the “government” towards the “governance” paradigm through the implementation of IUWM principles was conducted.

The paper is structured as follows: Section II delineates the Stellenbosch municipal water management paradigm and motivation of the study. Section III outlines the research question and objectives of the study. Section IV details the research methodology and methods of the study. The background of Stellenbosch town managed by the municipality, including a brief history of the town’s development, population growth projections and economic contributions are covered in Section V. Brief overviews of the South African water laws, policies and administration pertaining to urban waste water management are also considered in Section V. The current water cycle of the Stellenbosch municipality, ranging from sources of fresh water supplies, water usage by sector to the state of water infrastructure, is covered in Section VI. The results garnered in this study are outlined and discussed in Section VII. Recommendations and conclusions to the study constitute Section VIII.

II. STELLENBOSCH MUNICIPAL URBAN WATER MANAGEMENT PARADIGM

Documented research [32] reveals that Stellenbosch Municipality employs the conventional engineering water management approach, which is linear and fragmented. This is a practice where water is managed by utility through a central control and channeled through separate infrastructure systems comprising drinking water, waste water and storm water. The process entails extraction and utilization of raw water from natural water sources that is treated and distributed through a network for consumption within the municipality’s jurisdiction. In Stellenbosch Municipality, there is a separate water network system servicing the Kayamandi and informal settlements of Nkaneni which are low- income areas [39]. In these areas, access to water and sanitation is predominantly by means of communal taps and ablution facilities. Raw sewage in these settlements is deposited into the storm water system through the sanitation bucket system. In more affluent areas, waste water is collected and conveyed through well-maintained sewerage lines to a central Wastewater Treatment Works (WWTW). The treated effluent is channeled into the Eerste River [16]. In summary, Stellenbosch municipality follows a “government” urban water management paradigm. In this paradigm, the government, through the municipality, continues to take full responsibility for urban waste water management. This practice follows a top-down, command and control management approach, characterized by technocratic solutions [42] premised on a philosophical position that building larger waste water treatment works, larger dams and larger water reservoirs is the main solution to meet the water demands of citizens. In Stellenbosch Municipality’s jurisdiction, this approach has resulted in major water projects such as the extension and upgrades of the Stellenbosch Wastewater Treatment Works (WWTW) to improve the waste water management of the town. To the knowledge of the authors, there are no meaningful water management interventions to improve urban waste water

management in the poorer and poorest areas.

Globally, the “government” water management paradigm was perceived as inadequate to address the complex growing current and future complex multiple challenges confronting water demand and supply needs of an urban setting [22]. This led to the emergence of the “governance” paradigm characterized by bottom-up approaches and power decentralization with emphasis on stakeholder engagement and public participation guided by technocratic contributions. It is the governance paradigm which has birthed the current global water management principles, such as the IUWM principle. The governance practice further translates into every citizen being equally responsible for water management.

A. Motivation for the Study

The motivation for this study stemmed from a concern about the water management paradigm employed by the Stellenbosch Municipality described in Section II. There is escalating pressure in the water sector, particularly in the Western Cape Province in South Africa, to improve the water management paradigm. The challenges confronting the regional water sector necessitates a new scientific approach to solve the complex challenges. These challenges are exacerbated by the current severe drought resulting from climate change [52]. Since future rainfall patterns are unpredictable, the only solution appears to be a change in the water management paradigm, which can secure the UWS, always ensuring adequate, all-purpose water supplies.

The IUWM principle, which is the central scientific focus of this study, was explored from an urban waste water management angle. This principle mimics natural water systems in that water is efficiently recycled preventing depletion of natural water resources. In mimicking the natural system, the IUWM principle seeks to close the urban water cycle loop by viewing the UWS as a complete water cycle.

In practice, the IUWM principle follows several key principles, which include minimal effluent discharge into water-receiving bodies from WWTW and integration of storage, distribution and treatment of UWS. The principle is further underpinned by the production of high volumes of high-quality effluent from the WWTW suitable for recycling, with quality specifications matching the intended reuse purposes [2]. The advantage of the IUWM management paradigm emanates from its capacity to meet the water needs of urban dwellers, whilst simultaneously exerting a positive effect on the ecological reserve.

III. RESEARCH QUESTION AND OBJECTIVES

A. Research Question

What are the drivers in shifting Stellenbosch Municipality’s current urban waste water management towards the IUWM paradigm?

B. Objectives of the Study

To answer the research question, the objectives of this study were as follows:

- To explore the challenges of urban waste water

management experienced by Stellenbosch Municipality pertaining to water laws, policies and administration.

- To evaluate the impact of the above-mentioned water institutions on the performance of WWTWs.
- To investigate potential limiting factors that could hinder Stellenbosch Municipality in shifting its urban waste water management towards the IUWM paradigm.
- To determine the drivers and strategy towards implementation of the IUWM principle in Stellenbosch Municipality.

IV. METHODOLOGY

The research approach adopted was guided by realism which enabled the researchers to employ research methods capable of unraveling the real issues in the Stellenbosch urban waste water management system. These methods were further capable of producing transformative knowledge needed for the implementation of the research findings towards improving the urban waste water system. The research methodology is outlined in the following subsections.

A. Research Methodology

The qualitative transformative research paradigm guided the study [50]. Selection of this research paradigm for the present study emanated from perceptions that social realities are multilayered and dynamic, although historically established, and that these realities characterize urban waste water management in Stellenbosch. A transformative research paradigm also perceives knowledge as truth if it can be translated into practical means of transforming people's lives. This is the case with this study which aims to improve urban waste water management, which is in turn intended to impact significantly on the livelihoods of the communities under study. The theoretical component served as a tool to guide the gathering of information from high-level water practitioners. The information gathered could in turn be translated into practice and then become knowledge [50]. In this context, true knowledge stemmed from urban waste water practitioners through a brainstorming session whose objective was to identify challenges and ways to resolve the challenges in urban waste water management within the case study. The transformation research paradigm insists on knowledge garnered in research to be implementable and should produce positive transformation of the communities under study, which is the main objective of this study. This research is also based on assumptions that in a society there are multiple realities, which are shaped by social, political, cultural and economic groupings [7], whose influence is significant in shaping how urban waste water is managed. Case study research methodology was accordingly employed, given the complexity of managing urban waste water in changing environments comprising highly diverse societies.

1. Case Study

Reasons for employing case study research methodology included the possibility of an in-depth empirical inquiry relating to an existing phenomenon, i.e. urban waste water management.

Furthermore, context, in this case, has an influence on how urban waste water is managed [47]. Although a multiple case studies methodology could be utilized, this study employed a single case study design which focused only on Stellenbosch Municipality a water service authority servicing Stellenbosch. Fig. 1 delineates a single case design.

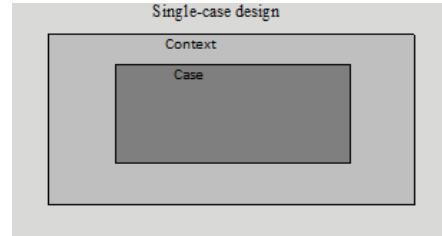


Fig. 1 Basic design for a holistic, single unit of analysis case study.
Adapted from [49]

The use of a case study enabled an in-depth holistic understanding of a complex single unit of analysis, namely the management of urban waste water within its real-world context, i.e. Stellenbosch Municipality [4], [13]. Employment of case study research methodology in this study is further strengthened by perceptions that examining the context and other complex conditions related to a specific case is integral to a comprehensive understanding of the single unit of analysis. The outcome may contribute to the development of a robust urban waste water management framework for Stellenbosch Municipality [31], [48]. In addition, case study data are likely to emerge from multiple sources. This is a desirable research outcome as it strengthens the validity of the research findings [47]. Research methods and data analysis of the research are considered in the following subsections.

B. Research Methods

The aim of this study was to extract in-depth knowledge about the subject matter from urban waste water practitioners. Qualitative research methodology [14] was employed for data collection by means of a focus group. Purposive sampling of participants enabled selection of urban waste water practitioners capable of substantive contributions to the research objectives. Participants were selected according to their designation, expertise, experience and position in Stellenbosch Municipality and the region. The process of data collection involved Interactive Management (IM) soft systems methodology [19], i.e. a research methodology well designed for managing complex systems such as urban waste water management [43], [44], through extraction of solutions from participants who fully understand the realities of the phenomenon.

C. Data Analysis

Interpretive structural modeling data analysis was conducted through Concept Star Professional Decision-Making tools, version 3.64. The tools enabled identification of drivers and the strategy of implementing the desired IUWM principle in Stellenbosch Municipality. Table I describes the participants constituting the interactive management group of the study.

TABLE I
THE PARTICIPANTS IN THE FOCUS GROUP

Stakeholder Group	Description	Designation targeted for this research	Number of participants
South African Department of Environmental Affairs official	Environmental practitioner	The official contributed towards environmental laws and policies in relation to urban waste water management.	One
Chief executive officer of a South African State-owned water enterprise	Public water practitioner	The chief executive officer gave guidance on water and sanitation laws and policies and administration in the country.	One
Professor at the Council for Scientific and Industrial Research	Chief scientist, specializing in waste water (urban, mine and industrial effluents)	The professor gave insights into what has transpired in the water research field on urban waste water management relating to the case study.	One
Private sector urban waste water practitioners	1. Technical director of waste water engineering firm 2. Civil engineer from France 3. Managing director of waste water at international consulting firm	The practitioners contributed towards WWTW infrastructural development relating to the case study.	Three
Municipal officials	1. Director of engineering services in the case study 2. Municipal manager from the Netherlands	The practitioners contributed to urban waste water administration on the case study. The municipal manager from the Netherlands gave an international perspective on urban waste water management.	Two
Former city councilor (Stellenbosch)	Politician	The former city councilor contributed to urban waste water management in the delimited area from a political perspective.	One
Academia	Professor of Public Administration	The professor contributed to governance pertaining to urban waste water relating to the case study.	One
Community members	Members from previously disadvantaged communities	Community members contributed to the perceptions and actual urban waste water management landscape in their areas.	Two

V. BACKGROUND OF STELLENBOSCH: THE CASE STUDY

Stellenbosch Municipality services the town of Stellenbosch which is 52.7 km from the city of Cape Town. Sixty-six percent of Stellenbosch's municipal water supplies come from the city of Cape Town [32], which is currently under immense pressure to meet the water demands of all metropolitan areas under its jurisdiction [52].

A. Historical Perspective

Settlement of Colonists in Stellenbosch

Stellenbosch was founded in October 1679 by Simon van der Stel, the then Governor of the Cape of Good Hope, an outpost of the Dutch East India Company. The outpost was tasked with replenishing Dutch merchant ships rounding the southern tip of the African continent. Van der Stel accordingly encouraged colonists to settle on the banks of the Eerste River [54].

Reference [15] encapsulates the vision of Simon van der Stel on the morning of 29 October 1679 with tender empathy: "It is two hundred and forty years since Simon van der Stel rode into the smiling valley which is girt about with mountains and watered by the Eerste River on its way to the sea from the slopes above Jan de Junker's Hoek. The land must have been as white with Ornithogalum and as pink with heath and monsonias on that spring morning. The river must have clattered as joyously over the round stones and tussocks of reed as it does to-day. But there were no white houses, no great oaks, no vineyards, no flush of peach blossom and no Theological Seminary. It was a wild land upon which he looked when, filled with love for the country and desire for its expansion a desire not shared by the company he founded the town of Stellenbosch and called it by his own name, in his first year of office, 1679." It is now almost a century later since Fairbridges so eloquently described the sensation of Simon van der Stel 335 years ago [15] and Stellenbosch has grown from humble beginnings to a town renowned for its scenic beauty, university, architecture and

wine estates. Between 1684 and 1750 large tracts of land in Stellenbosch were allocated to "Vryburgers" these were farmers that were in the service of the Dutch East India Company but were given freedom to farm for themselves. They settled and farmed the land to produce goods for the Company to supply the ever-increasing fleet of ships en route to the East and back to the West [55]. These farms are still part of the agricultural activities of the Stellenbosch and Franschoek surrounds today. The farms were worked in part by 8 500 slaves originating from West Africa, East Africa, Batavia, Suriname, Java and India [54] Fig. 2 shows a map of Stellenbosch, Fig. 3 depicts Stellenbosch vineyards scenery and Table II delineates the background data of Stellenbosch town.

TABLE II
STELLENBOSCH BACKGROUND DATA. SOURCE [51].

Description	Data
Permanent Population	177 590
Population density	35.8 km ²
Area	831 km ²
Coast line	23.8 km
Temperature ranges:	
Summers are dry and warm to hot.	40°C
Winters are cool, rainy and windy at times.	16 °C average
Province	Western Cape
Country	South Africa

B. Current Stellenbosch Local Government Institutional Arrangements

Stellenbosch Municipality, which is the water service authority of Stellenbosch, falls under grade B category of municipalities. As promulgated in terms of Section 155(6) of the South African Constitution, a municipality consists of a political structure, an administration and the community of the municipality [28]. The mayor is the political head of the municipality responsible for the annual budget and performs certain delegated administrative functions. The municipal council has the right to govern the affairs of the local

government, to exercise the municipality's legislative and executive authority and to finance the affairs of the community

by imposing rates and charging fees for services. In addition, the municipality has the right to impose surcharges on services.

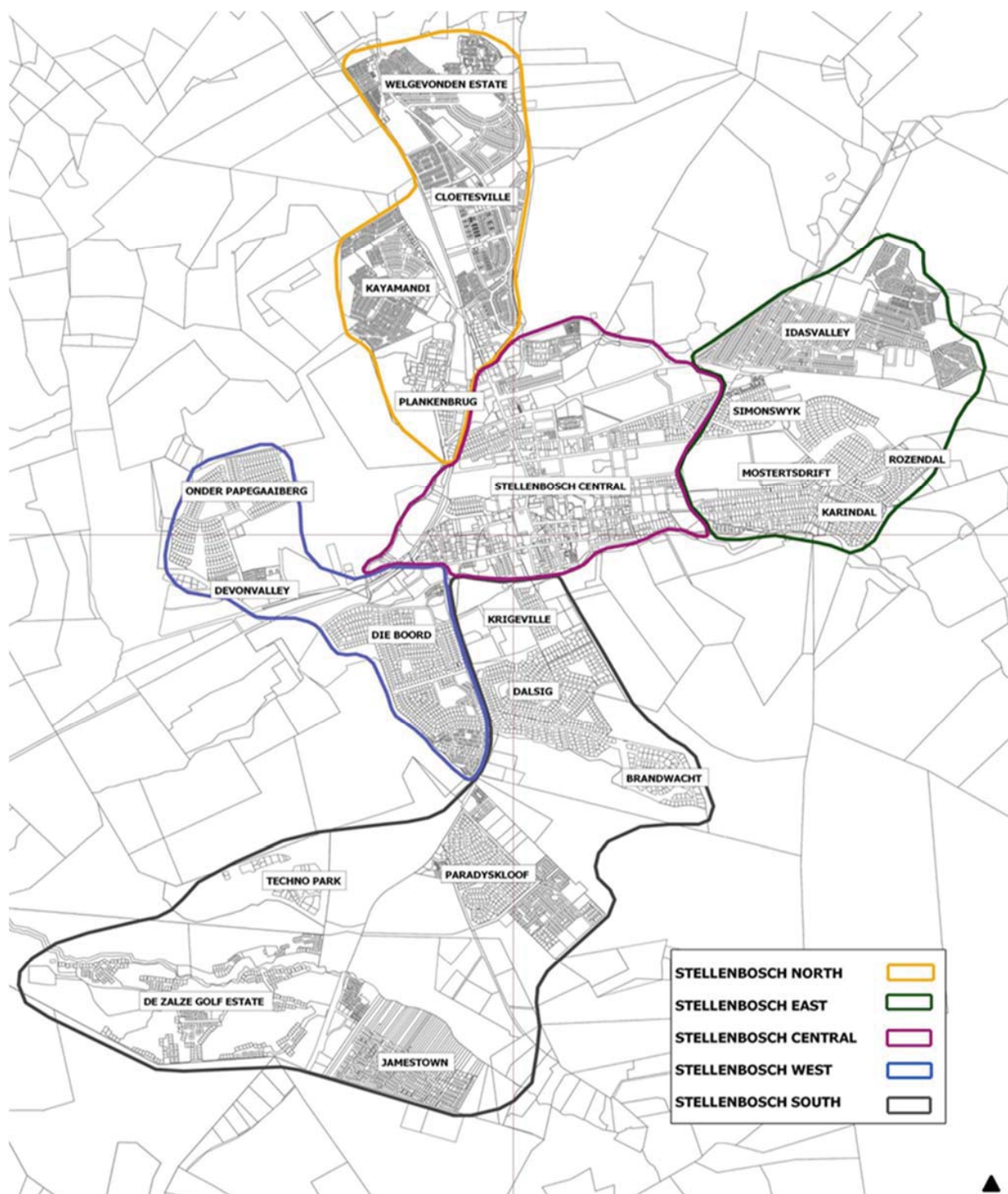


Fig. 2 Map of Stellenbosch [40]



Fig. 3 Landscape of Stellenbosch Vineyards [6]

The mayor plays a pivotal role in the management of the UWS, considering that the process of drafting, approving and executing the municipal budget is the mayor's prerogative. Funds allocated to water services are articulated in the budget. Currently, the operational budget of Stellenbosch Municipality stands at R2.2 billion, which includes the capital budget of R519.6 million [33]. The annual budget is serviced by national government allocations, rates, service charges and borrowing. The fiscal year is from July to June. In addition, the capital budget is financed from own revenue, grants and borrowings. It is within the mayor's discretion to determine what funds should be allocated towards the improvement or introduction of novel water management projects such as urban waste water recycling. Funding is the first success criterion of any project to be initiated and succeed.

In terms of Chapter 5, Section 23 each municipality must adopt an integrated development plan (IDP) for five years at the first sitting of a new council. The IDP must conform to the annual budget and capital projects. Capital expenditure should be prioritized according to the IDP. The IDP is essentially a planning document and, in terms of the law, should be adopted annually together with the budget. This poses a significant challenge to planning and implementation of novel water management projects such as urban waste water recycling as projects of this nature require more than five years to reach maturity.

Furthermore, the mayor is responsible for administrative compliance. Council appoints a municipal manager, usually for five years. The municipal manager is the accounting officer in terms of the Municipal Management Finance Act [No 29 of 1999]. The council also appoints directors as heads of the respective departments. The directors serve a five-year term in office. It is incumbent on council to adopt policies to guide the administration in executing their duties. Policies are reviewed annually at the adoption of the budget. In the context of water management, administrative arrangements of this nature magnify the uncertainty of introducing novel urban waste water management approaches.

C. Urban Waste Water: Institutional Arrangements in Stellenbosch Municipality

Policies

In South Africa, there are three major sanitation policies in operation, namely:

The White Paper on Water Supply and Sanitation (1994);
The White Paper on a National Water Policy for South Africa (1997); and

The White Paper on Basic Household Sanitation (2001).

The above policies guide all sanitation activities in South Africa and the implementation of the Strategic Framework for Water Services (2003). The White Paper on Water Supply and Sanitation (1994) was legalized by the [45]. The Act regulates:

The rights of access to basic sanitation;

The setting of national standards and norms for sanitation;

Water services development plans;

The regulatory framework for sanitation institutions and water services intermediaries;

The monitoring of sanitation and intervention by the Minister or by the relevant Province;

Financial assistance to water services institutions;

Certain general powers of the Minister; gathering of information in a national information system; the distribution of that information; and

The repeal of certain laws. [10]

However, the national sanitation policy is quite broad and there have been concerns around implementation problems. Urban waste water recycling is not articulated in the current policies or in the National Water Act No 36 of 1998. However, it is imperative that at this juncture a water and waste water policy unique to South Africa due to the past injustices of the apartheid system be mentioned in this article. The policy is referred to as the Indigent Policy [56] formulated to offer free water and sanitation services to registered indigent users classified as the poorest of the poor. In terms of the Indigent Policy, households connected to the municipal water and waste water services infrastructure are to receive a subsidy for the basic water supply charged at R61.87 for 6 Kℓ per month per household. The dilemma regarding this policy within Stellenbosch Municipality is that water consumed by the estimated 7 400 households in Kayamandi and Nkaneni via free-standing taps and ablution facilities is unknown. These are settlements which are growing rapidly and are part of Stellenbosch town.

There are provisions of urban waste water management in the National Water Act No 36 of 1998 (NWA) which repealed and replaced the Water Act 54 of 1956. The NWA abolished riparian rights and vesting all water powers and responsibility in the state to ensure that water is "protected, used, and developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons, currently and in future generations" [9]. The (NWA) No 36 of 1998 operates in tandem with the National Water Services Act 108 of 1997.

The Constitution of the Republic of South Africa (Act No. 108 of 1996), particularly Chapter 2: Bill of Rights provides for the right of all people in South Africa to dignity, including the rights to a well-conserved environment which is inhabitable by present and future generations. This is done through laws and policies that articulate the measures on pollution and ecological degradation control with an aim to secure ecological sustainable development, while enhancing the economic development of

South African citizens [26]. The NWA makes provision for proper management of urban waste water but does not make provision for urban waste water reuse or recycling. The Municipal Systems Act No 32 of 2000 only enables local government to execute its mandate of providing adequate clean water and sanitation services.

D. Socio-Political Context

In 1948 the national party tabled the apartheid policy at a meeting held in Stellenbosch, thus securing the town's place in the political and social injustices of the past. The town is known "as the cradle of the apartheid doctrine" based on racial discrimination and the separation of the four main population groups, namely Whites, Indians, Coloreds and Blacks. This distinction between the four groups, enshrined in the apartheid constitution, encompassed all aspects of life, resulting in criminal offenses to live together and to marry someone outside the confines of one's own racial group. The dividing line determined where you should do business, in what line you should queue, where you should swim, how you should conduct business and where you are legally allowed to stay. The entire public sector was a social engineering mechanism to administer the apartheid doctrine. Pre 1948, Stellenbosch had a racially integrated social structure. Post 1948, Stellenbosch residents were forcefully removed to separate residential areas. The two pieces of legislation which the present researchers regard as inhumane, relating to racial urban segregation, were the 1923 Natives (Urban Areas) Act which created a conducive environment for racial urban segregation although it was not compulsory. The 1950 Group Areas Act was brutal as many communities were displaced according to race and lost their properties [12]. A major concern of the above-mentioned practices was the development of basic services infrastructures. The apartheid government prioritized basic services infrastructural development to be in white areas.

The apartheid system was abolished in 1994. A new constitution was enacted based on universal franchise and liberal values. Despite the new political dispensation, Stellenbosch, like most other cities and towns, retained racially divided profiles. White residential areas are individually well serviced, while the majority of black residents live on the outskirts of the town with no or only rudimentary basic municipal services [29]. Despite constitutional amendments at the dawn of democracy mandating the government to ensure that every citizen has access to clean water and adequate sanitation as well as a safe environment [27], racial urban segregation continues to be deeply entrenched in Stellenbosch. The Sustainability Institute in their Stellenbosch Spatial Development Framework draft divided Stellenbosch into the following divisions:

- Stellenbosch North: Welgevonden Estate, Cloeteville, Kayamandi and Plankenburg;
- Stellenbosch East: Idas Valley, Simonswyk, Mostertsdraif, Rozendal & Karindal;
- Stellenbosch Central: Central Stellenbosch, Dorp Street and Stellenbosch University;
- Stellenbosch West: Onder Papegaaiberg, Devon Valley

and Die Boord; and

- Stellenbosch South: Krigeville, Dalsig, Brandwacht, Paradyskloof, Technopark, De Zalze and Jamestown [39].

The above-mentioned divisions of the town resemble a deep urban racial segregation which was instituted since the apartheid era. The geographic composition influences decision-making around infrastructure development and provision of basic services. The northern part of the town constitutes black areas comprising informal and formal mixed dwellings. The population size of the black community is growing rapidly and is poorly documented. Spatial development with regard to the population and the town itself has a significant impact on urban waste water management including initiatives on introducing novel urban water management approaches, because population distribution consequently impacts on water and waste water infrastructure development. The size and growth rate of a population determine whether the town can provide adequate clean water and waste water services within its jurisdiction. Hence, the following subsections further detail problems around Stellenbosch population projections and patterns despite its significant economic contribution in the region.

E. Population Growth Projections

According to Statistics South Africa, the Stellenbosch permanent population has grown from 118 709 to 155 733 during the period 2001 to 2011 and is currently estimated to be 177 590 [11]. Different researchers have projected different population growth rates. Regarding African population, the complexity in determining accurate statistics of Africans living in Stellenbosch stems from 80% of the population being housed in informal houses, i.e. shacks, which is a legacy of the apartheid era, and a high African population growth. This complicates the census-taking process to accurately count the African population, yielding a negative impact on waste water infrastructure development of the town [38]. However, for the intents and purposes of this study, a growth rate of 2.7% per annum is quoted from the Stellenbosch Sustainability Institute report of 2012. With the African population growing at a rate estimated to be 40% per annum [39], partly due to rural-urban migration and influx of foreign nationals [39]; [36], a major concern is that the African population which is the fastest-growing population group continues to be marginalized in terms of basic service delivery, including the provision of adequate clean water and sanitation. The residents utilize communal water taps which are poorly managed. Communal ablution blocks have been erected randomly and are estimated at ten families sharing one toilet. These blocks are far from individual households, forcing residence to resort to open fields and bucket systems with contents being discarded into the storm water system. As a result, raw sewage gravitates into the nearby Plankenburg River which drains into the Eerste River [30]; [24]. The basic reality of the town of Stellenbosch is that first and a third world exist in very close proximity. This further complicates the governance of the town and management of the UWS.

The absence of accurate population statistics is further exacerbated by temporary residents in the form of influx of

seasonal farm workers and high numbers of tourists during the warmer months, as well as the significant student population. The combination of these three groups of temporary residents contributes to a transient pressure on the availability of clean

water and management of the waste water system, posing challenges to water infrastructure planners and developers. Fig. 4 depicts the population growth projections of Stellenbosch in comparison to other municipalities in the region.

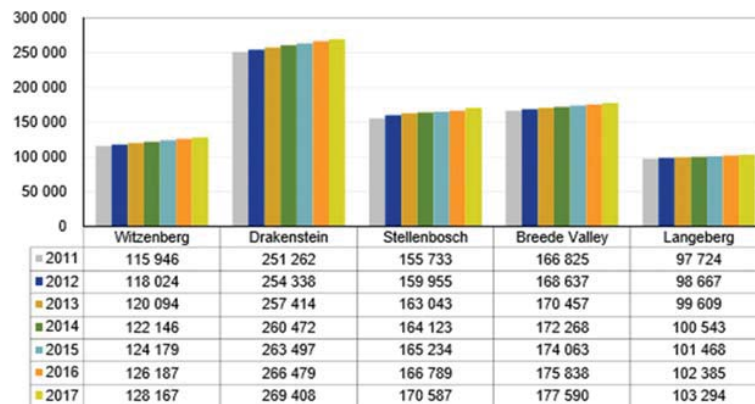


Fig. 4 Population growth projections including Stellenbosch [50]

The significant differences among these projections are that other municipalities within the region do not have the three groups of temporary residents of Stellenbosch Municipality. However, in as much as urbanization emerges as a major contributor to water management challenges, researchers argue that there are numerous advantages stemming from urbanization, provided that the towns or cities are well managed and can create the necessary infrastructure. Advantages include enhanced economic and social development and modernized lifestyles offering high female participation in the labor market. Other researchers have cited high life expectancy, well-being and high literacy [20]; [5]. Since economic development is perceived to be among the advantages of urbanization, the following subsection delineates Stellenbosch's regional economic contributions.

F. Economic Contributions

The most prevalent economic indicator of Stellenbosch is its high economic growth potential depicted in Fig. 5. Stellenbosch has the second largest economy in the Cape Winelands District. The town is the highest contributor to real gross domestic product in rand (GDPR) in growth and size in the region of 17.1% [23]. Its gross domestic product per capita in 2011 was estimated to be R61 733 per annum.

The flip side of the remarkable economic contribution is high socio-economic needs reflected by its Gini coefficient estimated to be 0.6 in 2011 [34]. The high socio-economic needs imply that a high percentage of the population is poor and cannot contribute to rates and taxes revenue or pay for any other services rendered to them. This leads to compromised infrastructure development in the poor residential areas although National Treasury disseminates an equitable share which is meant to make up for the deficit. The process is not well managed. In Stellenbosch, water management in general is further complicated by water-intensive industrial activities such as agriculture and manufacturing, contributing 4.9% and 22.4%, respectively, to the regional economy. Some of these

industries discharge non-compliant effluents into water-receiving bodies [25]. In addition to the importance of Stellenbosch as a contributor to the economy is that several South African company headquarters are situated in Stellenbosch [17]. Hence, the availability of adequate clean water quantities and the availability of quality clean water are of great importance for the sustenance of such a phenomenal economic hub of the region.

G. Annual Rainfall Patterns of Stellenbosch

The average annual rainfall over the 1880 to 1985 period was 713 mm and the average over the 2005 to 2017 period was 693 mm as depicted in Table III. Therefore, there is a negligible difference in the average annual rainfall over the years. However, a reason for concern is climate change and the rapid population growth, particularly resulting from rural- to-urban migration. These two factors induce significant water stress on the municipal waste water management and provision of adequate clean water to Stellenbosch. Table III indicates that 2015 and 2017 were amongst the driest years, while the last year the town had a good rainfall was in 2013. The annual rainfall analysis is troubling to water managers. The situation is exacerbated by climate change which complicates the process of predicting future rainfall. This is unmistakable evidence of a need to manage the available fresh water innovatively and with the best available scientific practices.

H. Impact of Climate Change on Rainfall Patterns in the Western Cape Province

To comprehend the reality of climate change on rainfall in the Western Cape, this study explored Wolski's analysis of rainfall patterns in the province. Reference [46]'s findings using data collected from the South African Weather Service and the Western Cape Water Supply System (WCWSS) indicated that the period 2015 to 2017, 2017, was the driest period since 1933. This kind of drought occurs once in 311 years [47]. Fig. 6 depicts some of the charts on weather patterns from [47]. Fig. 6

also indicates the magnitude of rainfall trends is 17 mm per ten years in the WCWSS over 84 years. The recorded rainfall trends, according to [47] may have been precipitated by anthropogenic effects on climate changes, resulting in a severe

drought in 2017. Currently predictions of future rainfall quantities have become complex since previous records have no bearing on the future rainfall predictions. Fig. 6 shows the regional rainfall patterns for the past 84 years.

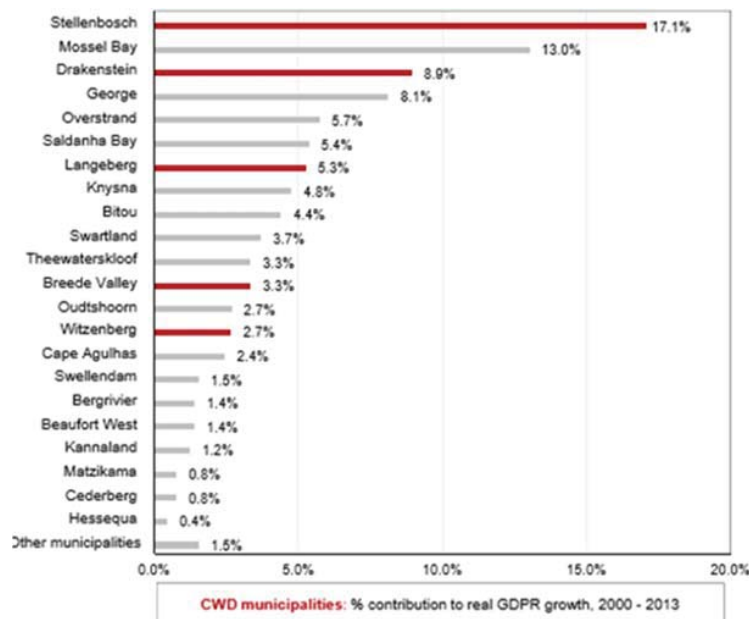


Fig. 5 Contributions to real GDP growth by non-metropolitan municipalities in the Western Cape Province, relative to their sizes [23]

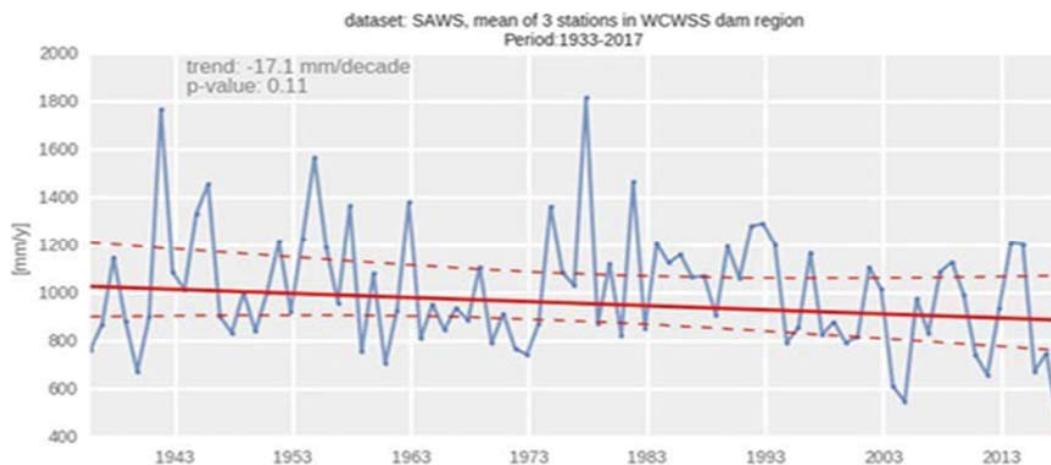


Fig. 6 Rainfall trends in the WCWSS over the past 84 years [47]

VI. STELLENBOSCH MUNICIPALITY WATER CYCLE

The Stellenbosch Municipality UWS comprises freshwater sourced from natural water bodies managed by a water infrastructure designed to supply clean water to urban centers. Two-thirds of the fresh drinking water are supplied by the City of Cape Town, which in turn draws the raw water from the Theewaterskloof and Wemmershoek dams. The remaining portion is either supplied as raw water by the Department of Water and Sanitation or drawn from underground sources through boreholes and treated within Stellenbosch at the Paradyskloof water treatment plant after which the clean water

is fed into the network for clean water consumption. The waste water from urban centers is piped by sewers to a central waste water treatment plant (WWTW) where it is treated and fed into a natural receiving water body. Fig. 7 depicts the current Stellenbosch water cycle.

Fig. 8 shows water consumption per utility in a typical South African household which includes Stellenbosch. Only 3% is utilized for the most important aspect of life which is cooking and drinking. Sixty-two percent of the water, which is used for toilet, laundry and bathing, can be recycled creating a high volume of surplus of water entering the water supply network,

while reducing the amount of water drawn from natural water sources. The strategy of recycling the waste water involves extensive adjustments to the current developed infrastructure. In the following subsection, the fresh water and waste water infrastructures are considered.

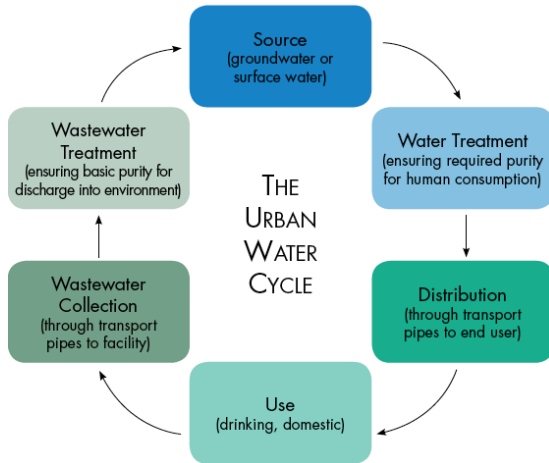


Fig. 7 Stellenbosch municipality urban water cycle adapted from Sowby National Geographic [1]

A. Water Usage by Utility in a Formal Household in Stellenbosch

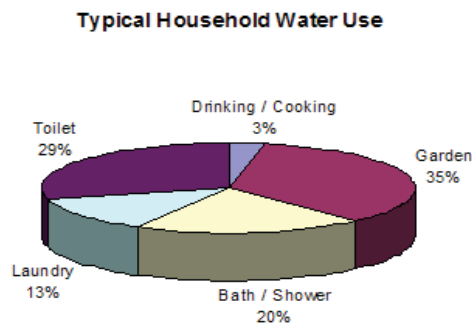


Fig. 8 Typical household water consumption by utility in South Africa [18]

B. Stellenbosch Water Infrastructure

Concerning water infrastructure development in general, the national government is responsible for major water infrastructure projects and the provincial government plays the oversight and supporting role in ensuring that municipalities are compliant in the execution of their water services mandate. Funding of major projects is provided by the national government through municipal infrastructure grants. The operations and maintenance are the responsibility of the municipality and are funded from rates and taxes, and national operational and capital grants.

In 2012 the Sustainability Institute reported most of Stellenbosch's key water supply infrastructure to be in a dire state, exacerbated by a backlog in maintenance and repair of the existing infrastructure. Due to population growth, the demand has surpassed water infrastructure development, thus impacting

negatively on the municipal water supply services [33]. The water infrastructure was estimated to have depreciated by 52.3% [41]. This has resulted in reactive rather than preventative measures to ensure efficient delivery of water services. To bolster the continually degrading infrastructure, Stellenbosch Municipality has drafted a water master plan which is outlined in the following subsection.

C. Drinking Water Infrastructure

The Stellenbosch Municipal Water Master Plan of 2011 strategized to improve the bulk water infrastructure by upgrading bulk fresh water supply systems, pertaining to WTP, water pump stations and reservoir infrastructure [33]. In the Annual Report of 2015/16, Stellenbosch Municipality articulated various water conservation and demand management initiatives. These included water pipe replacements through water pipe leakages. Attention was paid to indigent water supply systems in light of the fact that 25% of the water fed into the supply system is unaccounted for [33]. According to the report, efforts towards improvement of the collection of revenue include the implementation of meter audits aimed at improving billing accuracy. According to the master plan, the strategy for secure fresh water supplies in the UWS entails the construction of large-volume reservoirs in Kayamandi, Groendal, Franschhoek, Klapmuts, Cloeteville and Idas Valley [33].

It can be deduced from the above account that water conservation and water demand management are linear and follow an engineering approach. Concerns around such a water management approach is that the region is currently confronted with a severe drought. Due to climate change, there is no certainty on whether the region will continue to receive the quantities of rainfall which the region has received in previous years. New methodologies of managing the available fresh water supply, which take cognizance of the multiple challenges described in Section I, are needed. This type of management can be achieved by placing more emphasis on shifting from a "government" paradigm to a "governance" water management paradigm, because the areas falling under Stellenbosch Municipality require 29.92ML/d. In the near future, this volume may not be available from fresh water sources alone and may hamper the most important activities in Stellenbosch Municipality's jurisdiction, for example agriculture. Table III details fresh water supplies in the Stellenbosch network for the past three years.

TABLE III
QUANTITIES OF FRESH WATER SUPPLY INTO THE STELLENBOSCH WATER NETWORK

Year	Total water into the system (MI)	Total water sold (MI)	Un-accountable water losses (MI)	Un-accountable water loss
2013/14	14 027	10 456	3 572	25%
2014/15	14 571	12 443	2 129	15%
2015/16	13 639	10 509	3 139	25%

There was a decrease of fresh water supply fed into the Stellenbosch municipal network in 2015/16 while the daily demand was 29.92 ML/d. Due to ongoing drought conditions,

Stellenbosch Municipality had to draw additional raw water from reservoirs such as the Kleinplaas Dam to supplement intake from Jonkershoek. There are plans to intensify borehole drilling as a means of drawing more water from underground sources to reduce the water deficit [32]. This strategy threatens the ecological reserve, as humans intensify the drawing of fresh water from groundwater resources while there is limited rainfall to replenish the natural water resources. The water management principle proposed by the present study seeks to manage water in a sustainable manner through the reduction of volumes of water extracted from natural sources by encouraging recycling of water in the system as many times as possible.

D. Waste Water Infrastructure (WWTW)

The Stellenbosch WWTW was commissioned in 1924 and was built to have a hydraulic capacity of 20 ML/d and conventional activated sludge treatment technology. However, rapid population growth coupled with aging infrastructure has contributed to the plant operating under capacity and a sewerage system beset by regular sewage spillages from WWTW into the Eerste River. The results are ground water pollution, eutrophication of the rivers, degradation of the ecosystem, and the spreading of water-borne diseases. In 2012, the Stellenbosch WWTW was documented as having the following attributes, a design capacity of 20.2 ML/d, with a plant utilization of 102.9%. At the time of assessment, the effluent quality compliance was at 65.8% and the waste water risk rating was 74.1% [37], placing the Stellenbosch WWTW in a high-risk category. As a result, inefficiently treated effluent

continued to be discharged into the nearby river, i.e. the Eerste River via the Veldwachters River, which impacts negatively on the irrigation and tourism activities downstream.

Currently, the Stellenbosch WWTW is undergoing upgrades and extension to increase the treatment capacity (hydraulic and process) to 35 ML/d and upgrades to the treatment process of the works to cater for future growth within the catchment area. A technical feasibility study of the project was conducted around data collection and design parameters. In addition, option analysis was considered for alternative process technologies. Elements such as capital and lifecycle costs, space requirements, ease of operation, treated effluent quality, potential for effluent reuse and sludge handling were considered. The treatment technology currently installed is the membrane bioreactor technology envisaged to produce high-quality recyclable effluent. These developments have also contributed to the motivation of this study, as the quality of effluent produced presents an opportunity for recycling. The following section provides the research findings and discussion.

VII. RESULTS AND DISCUSSION

Fig. 9 depicts the interpretive structural model of the qualitatively collected data from urban waste water experts described in Table I. Fig. 10 is a simplified version of the model. From the model, drivers in shifting the Stellenbosch municipal urban waste water management from a conventional government paradigm towards IUWM governance paradigm could be ascertained.

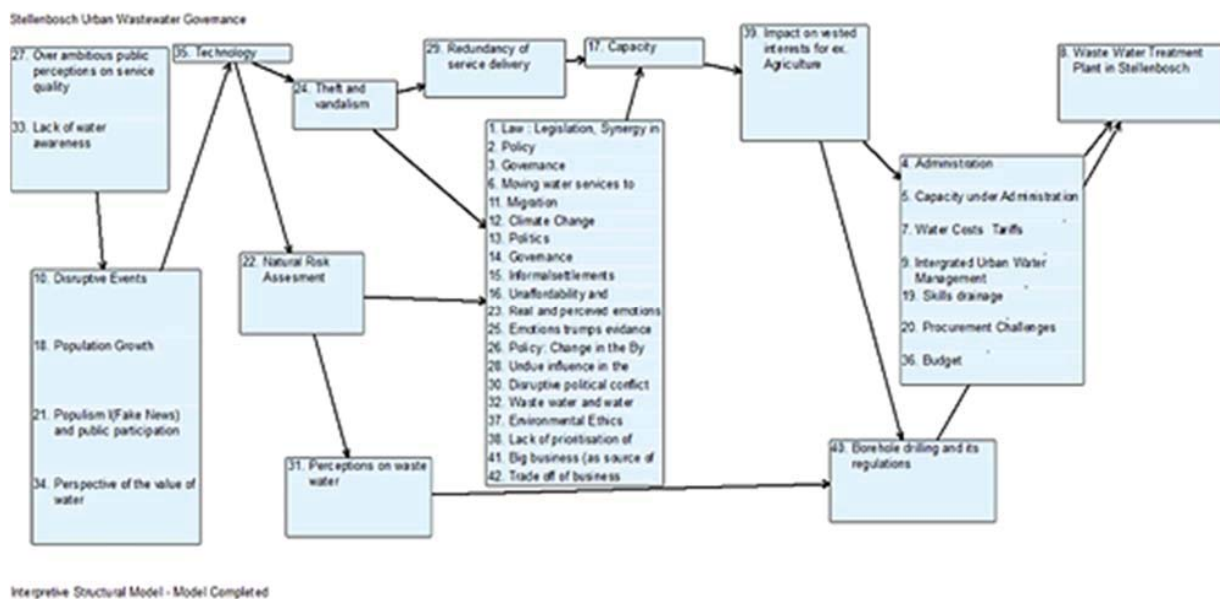


Fig. 9 Interpretive Structural Model (ISM)

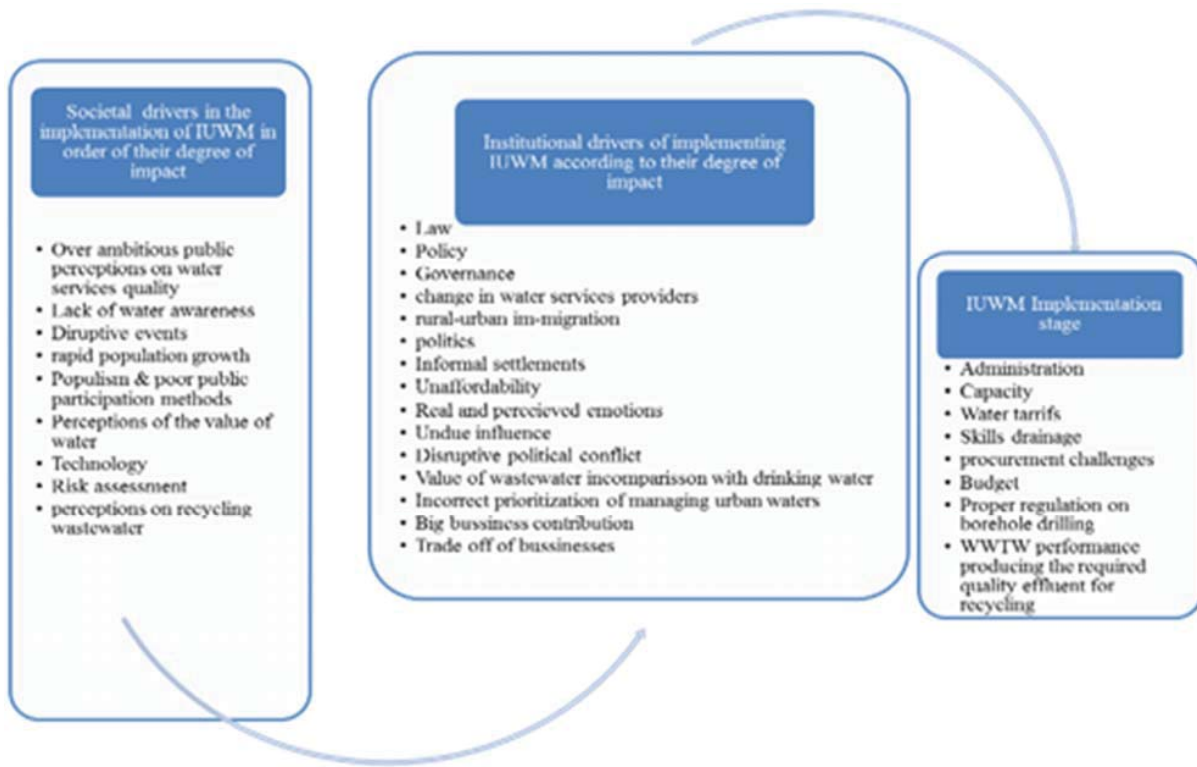


Fig. 10 Interpretation of ISM

These drivers are interconnected and interdependent. The strong drivers are on the left-hand side of the model. The social element of urban waste water governance plays a pivotal role in the implementation of the IUWM principle. From the model, elements such as overambitious public perceptions of water service quality and water awareness were interpreted. On the one hand, the rich demand high-quality water services from the municipality because they pay their rates and taxes. On the other hand, the poor's perceptions are influenced by the South African Constitution which stipulates in the Bill of Rights that access to water is a human right. As a result, they believe that the Water Service Authority must provide them with water and sanitation without fail. The Indigent Policy further exacerbates the poor's philosophy on water and sanitation services in that they do not have to pay for water and sanitation services, thus creating a culture of entitlement and irresponsible water and sanitation behavior. These two elements affect the process of addressing disruptive events such as drought which may require IUWM to be implemented to augment the available water.

Rapid population growth and rural-to-urban migration have resulted in masses of despondent citizens housed on the

peripheries of the town. These citizens are prone to populism and would not be able to contribute significantly to public participation on water matters that are normally chaired by municipal officials. The poor will embrace a rhetoric which speaks to their concerns while the affluent would resist any populist message which seek to address the plight of the poor only. Considering that Stellenbosch society is rated as the most unequal society in South Africa [23], populism and skewed

public participation in the society will lead to incorrect messages on water issues. When the value of water is not known, the appropriate technology for the treatment of urban waste water will not be ascertained.

Inappropriate waste water treatment technology has a two-fold impact which comprises vandalism and theft. The poor may perceive it as a golden opportunity to steal products such as scrap metal which can be sold to earn an income. Another important element was found to be natural risk assessment of, for example, draught. Humans tend to only react when a life-threatening event is inevitable or when they are hurt. If these two elements seem far-fetched, convincing authorities and society to implement preventative measures is difficult.

After successfully addressing the social issues of implementing IUWM, challenges around water institutional arrangements may be considered these arrangements are listed in the second box of Fig. 10 according to their degree of impact which determines the order in which they should be addressed. Once social and governance issues have been resolved, the administration of IUWM is achievable through addressing the elements in the third box of Fig. 8 in the order in which they are listed. The performance of the WWTW forms the last part of the process. What is also fascinating from the perceptions on recycling waste water and the impact of vested interests, such as agriculture, predominantly the more affluent and those with vested interest in, for example, agriculture would directly influence the borehole drilling regulations, a characteristic unique to Stellenbosch. This indicates that the farming community of Stellenbosch will be the first group to be affected

by water shortages and may resort to underground abstraction. If this is not regulated, it will create permanent problems in the region for the survival of future generations. Reports exist of farmers resorting to drilling boreholes to supplement their water demands without considering the state of the aquifers that still need replenishment so that groundwater remains available in the future.

VIII. RECOMMENDATIONS AND CONCLUSION

From this investigation, it can be concluded that the main drivers for Stellenbosch Municipality to undergo a paradigm shift in their urban waste water management lie within Stellenbosch community. The point of departure is the mindset of different groupings in the communities of Stellenbosch, as it influences the perceptions that a person or community holds on a phenomenon. A correct mindset can be inculcated to facilitate any educational water programs, formulated by the municipal authorities, for both the rich and the poor. In Stellenbosch, there are incorrect perceptions that only the poor lack water awareness, mismanage water and do not understand the value of water. The model revealed that farmers may not understand why it is not the best solution to undertake uncontrolled drilling and have numerous boreholes in the same area. It is not affordability that matters but the ecological reserve should be maintained with consideration for future generations. Public participation emerges as a vital element in shifting public perceptions on water, ensuring that the communities fully understand the problems and have an idea of some of the solutions. The municipal authorities and water sensitive groups should participate in water management activities and promote dialogue and public participation within their groups. Municipal authorities may have to work across communities, disseminating information in the manner that is suitable to those individual communities while they guide the community in seeking to achieve sustainable urban waste water management. In addition, there is a need for the municipality to treat their communities as equal citizens with impartiality and without discrimination pertaining to water services and to earn their trust regardless of their status in the community. The scars of apartheid, a policy which had skewed water management practices favoring only the white community, are still well entrenched in the Stellenbosch society.

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