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Green Drop Programme in South Africa: The role of institutional commitment in sustainable water resources management: Western Cape, South Africa

By

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Declaration

I, Ntombizanele Mary Bila – Mupariwa, declare that the thesis, titled "Green Drop Programme in South Africa: The role of institutional commitment in sustainable water resources management: Western Cape, South Africa" is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources that I have used or quoted have been indicated and acknowledged by complete references.

Full name: Ntombizanele Mary Bila - Mupariwa Date: November 2022

Signature:

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For with God, nothing shall be impossible – Luke 1: 37

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Abstract

Incentive-based regulation is a key driver of change to improve wastewater management and sustainable water resource management. Although the Green Drop Certification program has existed since 2009, no academic studies have been done to determine its impact on the commitment, attitude and progress of participating in water services institutions. The objective of this study is to analyse the impact of Green Drop incentive-based regulation initiative on sustainable water resources management in South Africa since its inception in 2009. This is a case study approach and six municipalities in the western cape of South Africa were used to showcase the impact of the Green Drop incentive-based regulation programme. The objectives of the study were as follows: 1] To determine the contribution of water services institutions to water resources management; 2] To determine challenges of water services institutions for managing water treatment facilities; 3] To assess the current progress of the green drop certification program for practical management and 4] To examine scientific aspects of the green drop certification program for wastewater management.

The study had two research questions: What new scientific analysis can be applied on the existing drop program data for water services institutions to meet their intended plan or target? What new interpretation from the scientific data on green drop program can be derived to improve water services in wastewater treatment? The societal problem remains the lack of adequate water of good quality for irrigation and other purposes and whether or not the green drop program can discharge that type of water into the receiving environment.

The argument of the study is that the Green Drop Programme which is an incentive-based regulation initiative ensures improved water services to ensure sustainable water resources management, therefore, new scientific analysis and interpretation from such scientific analysis need to be supported by the institutional commitment to sustainable water resources management. If the water institutions are not committed to new initiatives to generate scientific data and apply new scientific analysis to provide new interpretations from such scientific data, sustainable water resources management can not be obtained via wastewater resources.

In this thesis, the impact of the Green Drop incentive-based regulation program on a target group of six municipalities in the Western Cape was investigated. South Africa, as a key player in the South African Development Community (SADC), is transforming the water sector, guided by the principles of progressive regulatory strategies coupled with integrated water resources management (IWRM). We argued in this thesis that the Green Drop Program creates substantial goodwill and scientific knowledge and provides a basis for improved water services provision whilst sustaining water resource management, and it requires sustained and committed institutional support as per the intent of the regulatory framework.

We used raw and published data from the regulator and the participating municipalities, as well as interviews with key actors in the water sector. Verification of the results was done by collecting data from the field during monitoring routine visits using an observation guide. We used sectoral approaches from various records. We compared our findings to such records and benchmarked results with similar regulatory approaches in other countries. We provided interpretations in the context of the available legislation and regulations in South Africa to conform to the regulatory framework in water services in the water institutions. We collected water quality data from the Integrated Regulatory Information System (IRIS), which is the centralized information management system that is used by all water services authorities and water services providers to log data monthly. Interviews were conducted at selected spheres of government - national, provincial, and local levels. Key informant interviews included the Water Research Commission (WRC), the Department of Science and Innovation (DSI), selected water boards, and other private institutions that participated in the program. Results from such analysis are presented in various tables and graphs in the thesis. The interpretation of results showed that the impact of the Green Drop Programme had short, medium, and long-term practical solutions, and the institutional commitment should follow a phased approach for the sustainability of wastewater services and water resource management. The current research was carried out at a case study level; therefore, it is recommended that the same argument should be tested at a national scale using more quantitative statistical techniques

Keywords: Incentive-based regulation, Green Drop, Water quality, Cumulative Risk Ratio, Berg River Water Quality Task Team

List of Abbreviations and Acronyms

BRWQTT	Berg River Water Quality Task Team
BRT	Berg River Partnership
CRR	Cummulative Risk Ratio
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Class/Category
EcoSpecs	Ecological Specifications
EIS	Ecological Importance and Sensitivity
ER	Ecological Reserve
EWR	Ecological Water Requirements
FHS	Fish Habitat Segment
FRAI	Fish Response Assessment Index
GAI	Geomorphology Driver Assessment Index
GPS	Global Position System
HAI	Hydrology Driver Assessment Index
IHI	Index of Habitat Integrity
ISP	Internal Strategic Perspective
IFR	Instream Flow Requirements
MCDA	Multi-Criteria Decision Analysis
NEMA	National Environmental Management Act (Act No 107 of 1998)
NEM:BA	National Environmental Management: Biodiversity Act (Act No 10 of 2004)
MIRAI	Macro Invertebrate Response Assessment Index
MIG	Municipal Infrustructre Grant
RBIG	Regional Infrustructure Grant

(N)FEPA	(National) Freshwater Ecosystem Priority Area
NWA	National Water Act (Act 36 of 1998)
NWRS I & II	National Water Resources Strategy I & II
PAI	Physico-chemical Driver Assessment Index
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RHP	River Health Programme
RQO	Resource Quality Objectives
RU	Resource Unit
RVI	Riparian Vegetation Index
SASS	South African Scoring System
TPC	Threshhold of Probable Concern
TWQR	Target Water Quality Range
VEGRAI	Riparian Vegetation Response Assessment Index
WQM	Water Quality Monitoring
WMA	Water Management Area
WSI	Water Services Institution
WUA	Water Use Authorisation
WULA	Water Use Licence Authorisation
WWTW	Wastewater Treatment Works

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Chapter 1: General introduction

1.1 Synopsis of the study

The focus of the present study is to determine the role of institutional commitment in sustainable water resources management using the wastewater programme known as the Green Drop Programme as a case study. Wastewater treatment works [WWTWs] in six municiplaities in the Western Cape of South Africa were used as examples. The argument of the study is that the Green Drop Programme which is an incentive-based regulation initiative ensures improved water services to ensure sustainable water resources management, therefore, new scientific analysis and interpretation from such scientific analysis need to be supported by the institutional commitment to sustainable water resources management. If the water institutions are not committed to new initiatives to generate scientific data and apply new scientific analysis to provide new interpretations from such scientific data, sustainable water resources management cannot be obtained via wastewater resources. In addition, we argued in this thesis that the Green Drop Program creates substantial goodwill and scientific knowledge and provides a basis for improved water services provision whilst sustaining water resource management, and it requires sustained and committed institutional support as per the intent of the regulatory framework. The Green Drop program is incentive-based regulatory tool for protecting water resources from waste and therefore, the presents study assess its relevance and impact on the receiving environment and society as well as the optimization of the wastewater treatment works [WWTWs] in the study area. It is a well-known fact in South Africa that the study area has rivers such as Berg River that are socially and economically important water systems within the Western Cape of South Africa and therefore the value of such water remains essential. Hence, the activities of the Green Drop program needed to be assessed to establish its relevance and impact on the socioeconomic environment. The Department of Water and Sanitation [DWS] created Berg River Water Quality Task Team [BRWQTT] that was later changed to Berg River Partnership [BRT] and the purpose was to investigate and propose potential interventions to improve water quality in the Berg River catchment (BRIP, 2009).

1.2 Overview on the Green Drop Certification Programme

The Green Drop program was initiated by the department of water and sanitation (DWS) as one component of the regulatory framework of the Department. The Green Drop Programme is the incentive-based program which promoted continual improvement toward excellence enjoyed enthusiastic support from all stakeholders including Water Services Authorities (WSAs) and Water Services Providers (WSP). Since 2013, due to internal capacity constraints, the Department has only been able to undertake desktop audits of WSAs with the last full assessment being conducted for wastewater in 2011. While this provides some indication of the performance of the WSAs and the treatment facilities, information required to inform the national water roadmap and optimise the use of limited resources has been limited. Institutions that are awarded Green Drop Certification status, achieved ≥90% and marked with, whereas Institutions that are identified to reside in a critical state with exceptional poor performance for <30% is marked with. The role of institution to support such a programme is critical.

1.3 The role of the national department and water services authorities

The role of the national government is to regulate water and sanitation services in terms of Section 155 (7) of the Constitution of the Republic of South Africa. One of the agreed sector goals is “the effective regulation of water and sanitation services. To identify, quantify and manage the corresponding risks according to their potential impact on the water resource (and human health) and to ensure prioritised and targeted regulation of Institutions. The regulator implemented the incentive-based regulation to address non-compliance, as well as to promote best practice management and good performance in wastewater and water systems, and enforce effluent quality standards following “Polluter Pays” (Waste Discharge Charge Strategy, 2010).

The water services authorities play an essential role in the sustainable implementation of best practice management of treatment facilities and compliance with the legal requirements. Based on the Green Drop reports and the experience of the regulator in implementing the programs, it is evident that the WSAs and WSPs that have performed well have been guided by the expertise and input from the water scientists, technical staff, and engineers. Where cross-pollination and sharing of skills and expertise are implemented, progress towards improved treatment has been observed in the supported municipalities.

1.4 The impact of the program and targeted audience/participants

Regulatory requirements include both legislated norms and standards and best practice guidelines. Publication of results ensures enhanced levels of accountability at all spheres of government - national, provincial, and local. It also ensures that the public has access to credible scientific information and does not have to rely on sensationalist reporting. Water services authorities, Catchment Management Agencies, Public Works, Private institutions, Water Boards, SALGA, CoGTA, and National Treasury.

1.5 Benefits through performance analysis

In launching an incentive-based regulatory program that was designed for the South African water sector, DWS chose a multi-faceted and programmatic approach to regulation. This enabled the progressive implementation of a regulation that was appropriate to the challenges of the sector while supporting the achievement of developmental local government objectives. This approach was discussed and debated with the entire sector and the resultant buy-in from the WSAs and other stakeholders was excellent, and the program progressed significant improvement in the level of compliance across WSAs was observed. This also introduced a level of competitiveness amongst the WSAs in the desire to achieve the highest score and the award of the coveted Drop Certificate (Green Drop Handbook, 2013).

1.6 Background to the study: Situation analysis

Historical trend on water service regulation with regards to the Constitution of South Africa assigns the responsibility for the provision of water services to the Local Government whilst oversight and performance monitoring duties are delegated to the Provincial and National Governments. The Department of Water and Sanitation is responsible for the regulation of water services by Section 62 of the Water Services Act (Act 108 of 1997). Traditionally, wastewater regulation was seen as only the monitoring of effluent quality and little or no attention was given to the actual service of wastewater collection, treatment and discharge as a part of water services. The discharge of the effluent (water containing waste) remains a Section 21 water as legislated in the National Water Act. The required process controlling, and supervisory skills are determined by requirements of (1) the Constitution of the Republic of South Africa, the Water Services Act, the National Water Act, and the Water Act 1956. In South Africa they are four regulatory approaches that are recognized and implemented: 1) Compliances Monitoring – Norms and Standards; (2) Punitive Regulation – Enforcement.(3) Risk-based Targeted Regulation and (4) Incentive-based Regulation (e.g. Green Drop Regulation). Water service regulation and in particular water and wastewater services carry huge economic and social importance as they are essential to the development and cohesion of society. The importance of this function is emphasized when following the international trend whereby new specialized agencies are created to provide for the regulation of their water utilities. In South Africa, this function is undertaken by the Department of Water and Sanitation, which introduced a robust Water Services Regulation Strategy for the water sector.

It clarifies the requirements and obligations placed on water services institutions, thereby protecting consumers from a potential unsustainable and unsafe service.

Regulation has the primary task to set and or interpret rules, standards, and, where relevant, grant approvals for the water sector. Regulation should monitor compliance, analyse and publish results to promote transparency and confidence in the actions of the Regulator. It should decide, enforce the decision, and intervene where necessary. In addition, the Regulator creates an environment that is conducive to sustainable investment and operation of this capital-intensive sector. Incentive-based regulation is one of the approaches which was introduced on 11 September 2008 to the water sector at the National Municipal Indaba in Johannesburg by the then Minister of Water Affairs. The concept was defined by the two programs: the Blue Drop Certification Programme for Drinking Water Quality Management Regulation, and the Green Drop Certification Programme for Wastewater Quality Management Regulation. (Green Drop, 2009). This study is informed by such a historical trend in managing wastewater.

The department has launched has chosen a multi-faceted and programmatic approach, which enables the progressive implementation of the regulation appropriate to the maturity of the sector while supporting the achievement of the development of local government objectives when a Regulatory Strategy that is appropriate for the South African Water Sector was launched. The Department of Water and Sanitation was cognisant of the need to develop a new regulatory approach upon the fundamentals of conventional regulation to ensure that credit was not compromised. Incentive-based regulation is a form of regulation and should not be perceived to be a weakened form of enforcement. The Green Drop Certification programs are based upon the core fundamentals of regulatory responsibilities and cannot be regarded as Municipal Support Programme. Hence the need to assess its impact and relevance.

1.7 Current discussion in peer-reviewed papers on water service regulation

Municipal compliance with water services policy: A challenge for water security; Development Bank of Southern Africa, Laila Smith (Mvula Trust) 2009, Series Editor: Andrew Paterson

The current debate globally is around challenges on water security, institutional arrangements, and amendments of the pieces of legislation related to water. To contribute to driving the country’s economy and reducing inequality on access to water for household and productive uses. to It is important to understand the current constraints on and opportunities for the South

African water sector. There are four pillars of water services regulation that form the basis of the National Water Services Regulation Strategy (NWSRS) and are viewed as working in harmony with one another to ensure the sustainability of water provision. (1) drinking water quality, (2) environmental regulation, (3) social responsibility, and economic regulation. Municipalities face several challenges in adhering to the set standards for the provision of water services. The main question is whether the current level of decentralisation in water services provision and local levels of regulation including the Green Drop incentive regulation is appropriate, especially given the enduring municipal capacity constraints.

This paper argues that the distorting of lines between the WSAs and WSPs at the local level has discounted the status of WSPs that are unable to explore external options to improve their performance. “The ineffectual interpretation and implementation of the Section 78 process has contributed to municipalities primarily keeping the provision function in-house, even when the capacity to do so adequately is lacking”. While the paper concludes by discovering the possible combination of WSA’s functions to the district municipal level, where appropriate, and the strengthening of governance mechanisms for citizens. This study builds on such argument.

“The United Kingdom and Australia both established independent regulators in the 1980s and 1990s as part of a package of reforms built around privatization or commercialization. Regulation of private utilities has existed for many decades in the United States, while contract regulation has historically predominated in France and Spain. These international reforms of WSS services often inspired similar models of regulation in LMICs”. Regulation of Water Supply and Sanitation in Bank Client Countries November 2018, Yogita Mumssen, Gustavo Saltiel, Bill Kingdom, Norhan Sadik, and Rui Marques. Yogita Mumssen, Gustavo Saltiel, Bill Kingdom, Norhan Sadik, and Rui Marques suggest that outcomes. Water supply and sanitation regulation in Low- and Middle-Income Countries specifically for regulations, the goals, form, and function should be aligned with the country’s established to be an effective institutional framework and should look at the realities of its political economy. To avoid merely create the illusion of reform. (Yogita Mumssen, Gustavo Saltiel, Bill Kingdom).

United Nations Economic Commission for Europe Organisation for Economic Co-operation and Development Integrated Water Resources Management in Eastern Europe, was launched at the World Summit on Sustainable Development in Johannesburg in 2002. The purpose of this report is to give an overview of the implementation of the IWRM principles and water sector reforms in the countries of Eastern Europe, the Caucasus, and Central Asia, with a focus on the development of institutional and legal frameworks. This report provides baseline data from countries of Eastern Europe, the Caucasus, and Central Asia (the target countries) as of late 2012. It was launched at the World Summit on Sustainable Development in Johannesburg in 2002. This discussion in peer-reviewed papers regarding water service regulation is informed by the instructional principle of the integrated water resources management. Therefore, using the Green Drop Programme in South Africa, this study assesses the role of institutional commitment in sustainable water resources management using six municipalities in the Western Cape, South Africa. Various data from such infrastructures are collected and analysed.

1.8 Current practice or projects on water service regulation

Water Services Local Regulation Case Study Report for the City of Cape Town (CCT), (SALGA, 2011). According to the report by SALGA, from a policy perspective, the CCT is compliant and has indicated that it has a budget allocated to most of its functional areas where this is considered necessary. The CCT views insufficient capacity as its major challenge, especially in by-law enforcement and WSDP information systems. There has been a significant loss of staff as part of the City's strategy to reduce the staff levels through natural attrition. For sanitation staff, staff capacity at the Wastewater Treatment Branch is a critical issue as staff levels have reduced from 449 in December 1997 to 279 in March 2007 – almost a 38% reduction. The WSDP highlights the urgent need to attract, develop and retain skilled staff in Water and Sanitation Services (SALGA, 2011).

These speak to aspects of water quality, operational efficiency, improving access levels, and financial viability. Among others below are the objectives or projects that the City of Cape Town prioritised to address issues related to the water services regulation: 1] Implementation of ISO 9001 for all our services in the next five years (2015/16); 2] Achievement of the Green Drop status for 60% of the wastewater treatment plants by (2015/16); 3] Achievement of 95% wastewater effluent quality; 4] To ensure the presence and dominance in Africa of the water, wastewater, and air pollution testing services; 5] Reduction of unaccounted for water to 15% in the next five years; and; 6] Provision of basic or emergency sanitation services to all residents to Cape Town City by 2015/16.

According to the report by (SALGA, 2011), few officials were interviewed on their understanding of regulation focussing on (Strategic Framework for Water Services, 2003) and the Water Services Act (1997) when asked about how they understand regulation. The report reveals that officials expressed a clear and comprehensive understanding of what regulation is, why it should take place, and the legal and policy requirements placed on the metro in this regard. In addition, specific reference was made the establishing the appropriate mechanisms for regulation including developing and enforcing by-laws, having a consumer charter in place, and ensuring regular reporting to the Department of Water Affairs and Forestry (DWAF) as the national regulator to ensure better regulation at entry-level or at the source will improve controls and prevent future costs. In conclusion, it was acknowledged by officials who were interviewed that there is always room for improvement concerning its roles as authority and provider. This background informed the Green Drop Programme and hence this study.

Water Services Regulation Board (WASREB) in Kenya, Created by WASREB under Section 47 (k) of the Water Act 2002 the purpose of these regulations is to provide the procedural and administrative framework for the Water Act 2002 to ensure that water services in Kenya are developed, conserved, managed, and controlled in. Compared to the South African Water Services Act, in the WASREB, any breach of the provisions of the set regulations shall:(1) Constitute a criminal offense punishable per the provisions of Sections 105 of the Water Act. (2) Constitute a wrong punishable by an award of penalties as against the offender by section 73 (3) of the Water Act; (3) Entitle licensee or its authorized Water Service Provider to disconnect services and to refuse to reconnect the same until a prescribed penalty is paid by the offending party. Any person who contravenes any provision of sub-regulation (a) is guilty of an offence and liable, on conviction, to a fine or imprisonment for a period prescribed under section 105 of the Act and any rules made thereunder. However, such regulatory provisions had no incentive hence the Green Drop program and, hence, the currency study.

1.9 Problem statement and unit of analysis

The societal problem is the poor management of wastewater. In addition, it is the lack of enforcing regulations for wastewater services to improve water quality. Water institutions lacked the commitment to support wastewater services and the role of such water institutions in sustainable water resources management was clear but not operational. Scientifically, the available data on wastewater lacked new analysis and new interpretation although the Green

Drop Programme was initiated. In other words, using the Green Drop Programme, the role of water institutions can address the challenges in the wastewater services if the available scientific data about the green drop program are analysed with new techniques and new interpretation are derived from such analysis. This is the argument of the current study.

1.10 Research question and thesis statement

In this study we argue that if the scientific data from the Green Drop Programme can be analysed and interpreted using scientific techniques then the commitment by the water institutions in sustainable water resources management can be demonstrated and thereby addressing the challenges in the wastewater services regulation. In other words, we are arguing that new scientific analysis is required on the existing green drop programme data for water services institutions to meet their intended target. Such information will solve the reported societal problem. In addition, a new interpretation of scientific data about the green drop program is required for wastewater services in wastewater treatment. Note that the Green Drop Programme is the incentive-based regulation accepted by the WSA, WSI/P and therefore it provides a paradigm shifts approach in the wastewater service provision field of study. In this study, we emphasize that new analysis and new interpretation need to be provided on the monitoring data, discharge data, and plant functionality data of the green drop program.

1.11 Study aims and study objectives

The aim of the study is the assess the role of water institutional commitment in supporting sustainable water resources management using the Green drop programme in six municipalities in the Western Cape of South Africa. To achieve such goal the current study:

1) Developed a conceptual model that describes the operational processes of incentive-based regulation of wastewater services and determine the contribution of the Green Drop Program/wastewater services institutions to water resource management
2) Assessed the relevance of incentive-based approaches by identifying challenges of wastewater services institutions to water resource management
3) Evaluate the impact or progress of incentive-based approaches (Green Drop Programme) for practical wastewater management

Results from this study provides present short-term, medium-term and long-term recommendations, that can be implemented by the wastewater services authorities and institutions to improve compliance with the green drop certification program. The department of water and sanitation remains the custodian of the information from the present study. Dissemination of the findings from the current study are presented in different forums.

1.12 Conceptualisation, scope and nature of the study

This study is informed by the Green Drop Certification Program, which is incentive base regulation which shows significance progress in managing the wastewater treatment inturns show potential towards sustainable management of water resources at a large scale in South Africa since its inception in 2009. As a case study, municipalities that own and operate wastewater infrastructure in the Western Cape are covered and the coverage remains constant until the 2011 audit cycle. The audit reports show that the Green Drop programme succeeds to act as a positive stimulus to facilitate improved performance and public accountability, whilst establishing essential systems and processes to sustain and measure gradual improvement. The current was conceived by the above-described context or situational assessment.

The scope of the current study is on the use of the green drop programme (the wastewater incentive-based programme) in South Africa to showcase the role or commitment or relevance or impact of water institutions in sustainable water resources management. Results from such case study are compared to what has been implemented in other countries in terms of managing wastewater treatment plants. The scope on green drop certification program highlights the water quality data that has been collected from 2013 to 2017 and reveals how the gap on tools to analyses such water quality data to inform practical recommendations. The study focuses on pieces of legislation that are being used to regulate the program.

In terms of the nature of the study, it follows a mix methodological approach where both quantitative and qualitative methods are used. The water quality data are sourced from the Integrated Regulatory Management System (IRIS) of the department of water and sanitation and western cape provincial department of environmental affairs and development planning where all information required for the green drop certification program is submitted by water services authorities and water services providers. In addition, interviews with representatives from the three spheres of government: national, local, and provincial are conducted. The interviews include representatives from the Water Research Commission, selected water board, and private institutions representing the farmers of the study area. The results of the data analysis are mapped provincially, and a national overview is presented for spatial visualisation.

1.13 Outline of the thesis

The thesis outline of this study is as follows: Chapter 1 provides a background on the Green Drop Programme, water service regulations in South Africa and a background on water regulation and water resource management. In addition, the research problem, research question, central argument, study aim, study objectives and study conceptualisation with scope and nature are stated. Chapter 2 presented the reviewed literature on the study to show what is known and not known from global to national context. The theoretical and conceptual frameworks that guide the study have been described. The description of the study area and its features are provided in chapter 3 of this thesis. Chapter 4 provides a discussion on research design and methods that were used to collect and analyse data. In addition, aspects of research integrity and limitations in the study have been described. Chapter 5 has presented and discussed results on 1] Developed a conceptual model that describes the operational processes of incentive-based regulation of wastewater services and determine the contribution of the Green Drop Program/wastewater services institutions to water resource management; 2] Assessed the relevance of incentive-based approaches by identifying challenges of wastewater services institutions to water resource management; 3] Evaluate the impact or progress of incentive-based approaches (Green Drop Programme) for practical wastewater management subsurface geophysical investigation. Finally, chapter 6 provides summary and conclusions on the study and recommendations for future work.

Chapter 2: Literature Review

2.1 Introduction

Chapter one has provided an introduction of the current study in terms of research overview, situational analysis, research problem, objectives, conceptualisation including the outline of the thesis. In this chapter two, previous studies have been reviewed in terms of what is known and what is not known about water services regulations and wastewater programme including the Green Drop Programme in South Africa. The reviewed literature has been presented systematically [objective by objective] and analytically [showing the gap in knowledge and practice] to show how the current study narrowed such gap. The general overview on water service regulation in South Africa has been presented. Principles and concepts that guide water service regulation including programmes and projects in the water sector areas are explained. In this chapter, the argument is that the use of the Green Drop Certification Programme provides a basis for improving water service regulation but water institutions need to be to provide tangible support such sustainability of such initiatives which in turn improves water resource management. The previous studies have been reviewed from global, regional, and national perspective to contextualise the current study at such three levels. The chapter ends with a review on frameworks that guide the current study such as theoretical, conceptual and interpretation frameworks for the study.

2.2 Previous studies on water service regulations

Section 2.2 provides the local, regional and global context of the current study. The argument in this section is that, it is important to position the current study into the local, regional and global context. That comparative analysis provides key insight on the current study.

2.1 Contextualisation of the current studies to previous studies in South Africa

"When I was appointed Minister of Water Affairs and Forestry in May 1994 I already had an appreciation for the immensity of the task ahead to provide even the minimum basic water and sanitation services to all our people, but the vastness of the task becomes more apparent day by day. I am inundated with appeals. I understand the growing impatience that I encounter but if we do not all gain an understanding of the task and how long it will take, we will land in a quagmire of panic-driven decisions. ...An equally hard reality is that not everyone's needs can be met at once. There are limits to our resources, both now and in the future."

Prof. Kader Asmal, MP: Minister of Water Affairs and Forestry (1994-1999)

This chapter presents an analysis of comprehensive approaches with respect to the water services regulation with respect to the provision of water services in South Africa compared to other countries, ranging from small wastewater systems to large systems servicing domestic and industries to the largest urban areas. It further outlines the changes of different incentive based regulation in order to improve water resources as well as the pieces of legislation goals. *In terms of the Republic of South Africa-Constitution Act, No. 108 of 199 section 24 .-Everyone has the right- (a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that- (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.* The current study is reinforced by these regulation pieces.

Water management in South Africa in particular waste water has undergone major challenges in the past decade in which integrated water resources management and the adoption of incentive-based regulation as the appropriate type of regulation to improve water quality in South Africa. The Green Drop certification is evidence to the manifestation of the idea and the inspiration that led to the development of the process and systems that made the Green Drop concept into the internationally applauded accolade that it is today. It is a constant reminder to the water sector of the focussed thought and creative energy that inspired a (wastewater) nation. In South Africa, water services refer to both water supply and sanitation services including regional water schemes, local water schemes, on-site sanitation, and the collection as well as wastewater treatment systems. (DWAF, SALGA, DPLG & NT, 2003). This study focuses on wastewater treatment systems. As indicated in the constitution of the Republic of South Africa that everyone has the right to live in an environment that is not harmful to their health or well-being, water and wastewater services are essential for health and life, businesses, industries, and as a result of the water services provision is efficient it can assist to promote economic development and eradicate poverty. This context clarifies the focus of the current study.

Table 1: Water institutions/ organisations currently involved in water services

Organisation	Role
DWS	Responsible for sector policies, support and regulate

Organisation	Role
WRC	Responsible for providing information that drives innovation within the water sector, informs water policy and decision-making, supports water services for socio-economic development, and empowers communities across the country.
WSA (Metropolitan municipalities and district and local municipalities	Responsible for ensuring the provision of water services within their area of jurisdiction
Municipalities	Responsible for the operation of some local water resource infrastructure (such as boreholes and dams) and bulk water supply schemes, supply water and sanitation to consumers and operate wastewater collection and treatment systems.
Water Boards	Responsible for operating some water resource infrastructure, bulk potable water supply schemes, some retail water infrastructure and some wastewater treatment systems.
CMAs	Responsible for the development of a catchment management strategy to investigate and advice interested people on the protection, use, development, conservation, management and control of the water resources in its water management area
Community – based organisations	Responsible for the management of some small water schemes in rural areas.
Publicly or privately-owned companies	Responsible for the provision of some water services.

“South Africa is an arid country with rainfall less than the world average very unevenly distributed across the country. With just over 1200 kl of available freshwater for each person each year at the present population of around 42 million, we are on the threshold of the internationally used definition of “water stress”. Within a few years, population growth will take us below this level. South Africa already has less water per person than countries widely considered to be much drier, such as Namibia and Botswana. The problems confronted in South Africa are not unique, although of the 149 countries for which data is available, South Africa is presently the 26th most stressed in terms of water availability per person." The information in the table above, shows that South Africa has water institutions/ organisations that are currently involved in water services, hence the need to encourage them to continue support initiatives such the Green Drop Programme for the improved water quality status.

During the 2011 Local Government Elections, the appalling management of water services and lack of dignified sanitation services in the Western Cape (Khayelitsha located within the City of Cape Town Metropolitan Municipality), made media headlines after a lodge of complaints by the political parties regarding failures in service delivery. Subsequent to the findings made by South African Human Rights Commission (SAHRC) on the Khayelitsha case, it was heard by the Cape High Court. Both the Cape High Court and the South African Human Rights Commission (SAHRC) made finding that the sanitation services (or inadequacy thereof) violated the right to human dignity, privacy and the right to a clean environment, and the City of Cape Town was ordered that the existing toilets be enclosed as a matter of urgency. To date, the Department of Performance Monitoring and Evaluation in The Presidency (DPME), in collaboration with the Department of Human Settlements (DHS), the Department of Water Affairs (DWA), the Department of Cooperative Governance (DCoG) and National Treasury (NT), undertook the task to establish "The quality of sanitation in South Africa" (DWA, DHS & DPME, 2012). This situation informs the current of the current research on water quality.

The South African government has since progressed in tackling both sanitation and water supply backlogs since 1994 (the backlog in terms of sanitation has been reduced from 52% in 1994 to 21% at the end of 2010) and managed to achieve the 2015 Millennium Development Goal for reducing the proportion of population without sustainable access to basic sanitation in 2008. South Africa set itself the target of achieving universal access to sanitation by 2014 (DWA, DHS & DPME, 2012). However, this thesis reveals that the trend of wastewater management has declined in South Africa and one of the courses is the poor performance by some of the municipalities and lack of regulation. It was concluded in the white paper to say that, it is crucial that the new approach to water management outlined in this White Paper must be pursued, if we are to build the South Africa of the next century, a South Africa based on democratic values, social justice and fundamental human rights, since this will enable us to achieve the protection of our environment to be enjoyed by future generations.

According to Banergee et al. 2009 the Namibian government spends about 3% of its gross domestic product on the operation expenditures of its water utilities. This is by far the highest percentage of all Sub-Saharan countries. Although efforts were made to improve access to safe water, it is said that Namibia is straggling in the provision of adequate sanitation UN News Centre, United Nations News Services, 11 July 2011. The lack or poor management of wastewater services has resulted in mortality of over 50% of child deaths are related to lack of water, sanitation, or hygiene; 23% are due to diarrhoea alone. The UN has identified a "sanitation crisis" in the country (Smith, Jana-Mari,12 July 2011, Arid Lands Newsletter No.56. Retrieved 11 June 2016). The Namibian situation is similar to South Africa.

There is evident that challenges on wastewater management is currently being experienced globally. The Namibian government acknowledged the challenges wastewater/sanitation services and developed a sustainable monitoring system to monitor on an ongoing basis after every process step to retain public confidence, water quality at the Goreangab Treatment Plant. "The citizens of Windhoek have over time become used to the idea that potable reuse is included in their water provision process. In fact, they have grown to harbour a fair amount of pride in the fact that their city in many respects leads the world in direct reclamation (" Petrus L. Du Pisani (November–December 2004). The upgrading of the plant was partly funded by the European Investment Bank (EIB) and Germany through KfW development bank (Retrieved 11 June 2016). The German situation provides a good context to water quality interventions.

AMCOW, 2015, reveals that for two decades from Zimbabwe's Independence in 1980, overall water coverage increased from 32 percent to 56 percent while overall sanitation access increased from 28 percent to 55 percent. The report further states that two Urban services had achieved excellent by more than 90 percent coverage by the late 1990s. However, since then there has been a decline in percentage, of which the exact extent is not known. The report by AMCOW further describe that Zimbabwe's practise of water and sanitation sector development is that of a model of African sector development, collapsing within a decade. The collapse of this suggests the vulnerability of sector service development built on state subsidies and donor finance, overlooking the focus on sustainability. However, given a favourable political environment (AMCOW, 2015) said, a large injection of finance, and prioritization of the sector may well be possible. The reports said they agreed to several priority actions to tackle these challenges, and ensure finance is effectively turned into services, among others is:
Urban sanitation and hygiene:

- Develop alternatives to high-cost sewerage-only policies.
- Develop a financing strategy for urban sanitation.
- Increase enforcement of environmental and public health controls.
- Attract or buy-in urban sanitation expertise.

2.2 Positioning the current study beyond South African studies

In this section, the current study is positioned into previous studies and statements about water services regulation carried out in South Africa. This context is important to the current study.

The OECD, (2009) articulated that the Netherlands Government is one of the most active participants in the development of EU-level Better Regulation strategies. With regards to the management of EU regulations they have well-structured processes that are in place and the framework is stronger on procedure however, more attention is needed to ensure the impacts of European Union [EU] regulations. This context is crucial to the current study.

In the Netherlands, compared to South Africa, provincial and municipal authorities have important implementation and enforcement (including inspection) functions, especially in physical and environmental planning, and licensing, based on regulations laid down by the central government. It is also the responsibility of the municipalities to implement certain measures laid down by the province to which they belong, and municipal authorities are responsible for water supply etc. With regards to matters that directly affect them directly, unlike in South Africa, provinces and municipalities also have limited powers to make their own regulations (by-laws), and they may also make additional regulations in areas that have already been regulated at national level. Provincial executives implement several central government regulations in joint governance. The Netherlands Constitution and the Municipal Act set the framework for local rule- making while the provincial authorities are responsible for environmental management, OECD, (2009). This is similar to South Africa context.

The president of EurEau, Bruno Tisserand, said "A lot has changed in the intervening eight years", just after the survey (on national technical and economic data, ranging from population connection rates to drinking water supply") was published. He further said, technology improved, innovation is increased and consumers are demanding more environmentally sound and cost-effective services." According to the Waterworld, 2017, data that was collected in total was from 29-member states across Europe, from Austria to Slovakia. The total length of the sewer network across the EU has been estimated at around three million kilometres. In total, there are more than 18,000 wastewater treatment plants across the continent they said. Remarkably, the level of wastewater treatment, across Europe a total of 3.1 percent of the load is treated at primary level while 28.5 percent at secondary level and 68.4 percent at a tertiary level, it's often used for "more stringent treatment than secondary treatment", yet tertiary treatment is not defined in the Urban Wastewater Treatment Direction (UWWTD) according to the report. In South Africa, wastewater treatment plants are well documented as well.

Reliable, high quality information about the environmental state of surface waters is essential for water management and for improving the environmental quality of Europe's waters, especially in relation to the Water Framework Directive. Monitoring and assessment of the environmental state of European waters are performed by numerous regional and national authorities. Results from national monitoring programmes and monitoring at river basin district scale under the Water Framework Directive are the most important ways of getting an overview of Europe's water quality and the pressures affecting the quality, (European Environment Agency Copenhagen, Hovedstaden, 07 Nov 2018). It can then be concluded that when data is collected during survey, by publishing the outcome of the survey with recommendations it does contribute to the improvement or changes thereof. In South Africa through the Green Drop Certification Programme, data on water quality among other parameters are available.

The Botswana National Water Policy elaborate the different roles of spheres of government as follows: The role of the Department of Water Affairs is to act as a Secretariat to the Board and provide technical expertise, to assess, plan, develop and maintain water resources for domestic, agricultural, commercial, industrial and other uses in the whole country for short-, medium- and long-term purposes. It may, when appropriate and so enabled, also administer the water law and other related legislations, and liaises with riparian users of national and international rivers regarding saving, conserving, and protecting water resources.

In Botswana, a Water Regulator is responsible to cover economic regulation of water supply and wastewater services. A Water Regulator role is to ensure that financial sustainability across the water sector, reducing wastage by facilitating the streamlining of operations, determining revenue requirements to inform regular tariff adjustments. When reviewing revenue requirements the regulator shall take account of Government guidance on service objectives, direct subsidy, and cross-subsidy, informed by affordability considerations. Unlike the management of regulation in South Africa, in Botswana, the regulator oversees compliance of service standards to ensure efficiency and protect consumer rights. This is highly commendable and South Africa is moving in that direction hence the need for institutional commitment.

The mandate for the Water Utilities Corporation was later amended to take responsibility as the water authority for cities and townships which have been declared waterworks areas under the Declaration of Waterworks Area Order, 1970, whereas it is original responsibility was for the supply and distribution of water within the Shashe Development Area. In terms of the Policy Statement: 13.1.1 the importance of water in the long-term sustainable development of Botswana requires continuous monitoring, regular review and evaluation of policy provisions in order to ensure that these remain relevant to national development goals. (Botswana National Water Policy, Ministry Minerals, Energy and Water Resources, October 2012).

Mitsumasa OKADA, January 25, 2016 emphasise the fact that "Regulations must be efficient, fair and feasible! "Mitsumasa explained that the uniform and national minimum criteria for effluent quality it does regulate effluent discharges into public water bodies from the specified facilities, this practise is similar to the one applied in South Africa by the National Government.

Linda S. Gaulke argued that the type of technology for treatment is dependent on the geographical location. Linda alluded to the fact that, In Japan it is apparent that many johkasou treatment methods need to be upgraded to ensure adequate protection of the environment. However, Japan is well known as the world leader in membrane technologies that allow for very high-quality effluent to be used as reclaimed water and having high skilled experts on technology. The unique history of on-site wastewater treatment in Japan demonstrates the many factors that must be considered when determining suitable technologies, (Linda S. Gaulke). By considering the type of technology for the wastewater treatment works as well as the location has some benefits in the long run such as improving water resources and allowing the system to operate optimally. Linda S. Gaulke, in the report Japan Wastewater said, acceptable wastewater treatment standards require an involved robust methodology and different types of technologies from the normal to advance technology. Hence the need for new analysis.

The report released by the UN Water UNESCO, on 22 Mar 2017 emphasised that Although wastewater is a critical component of the water management cycle, water after it has been used is all too often seen as a burden to be disposed of or a nuisance to be ignored. The results of this neglect are now obvious. The immediate impacts, including the degradation of aquatic ecosystems and waterborne illness from contaminated freshwater supplies, have far-reaching implications on the well-being of communities and peoples' livelihoods.

Continued failure to address wastewater as a major social and environmental problem would compromise other efforts towards achieving the 2030 Agenda for Sustainable Development. In this sense, wastewater is no longer seen as a problem in need of a solution, rather it is part of the solution to challenges that societies are facing today. Wastewater can also be a cost-efficient and sustainable source of energy, nutrients, organic matter, and other useful by-products. The potential benefits of extracting such resources from wastewater go well beyond human and environmental health, with implications on food and energy security as well as climate change mitigation. In the context of a circular economy, whereby economic development is balanced with the protection of natural resources and environmental sustainability, wastewater represents a widely available and valuable resource.

2.3 Synthesis on previous studies on water service regulations

In this section, the current study provides a synthesis on previous studies. The synthesis is provided systematically [objective by objective] and analytically where the gap is shown for the current study to fill such identified gap about water services regulations.

2.3.1 Operational processes of incentive-based regulation of water services

The first objective of the current is to develop a conceptual model that describes the operational processes of incentive-based regulation of wastewater services and determine the contribution of the Green Drop Program/wastewater services institutions to water resource management. The current study uses the Green Drop Programme in South Africa to explain the role of water institutions in sustainable water resources management. The incentive-based regulation initiative has gained significant momentum and support in the Water Sector, since its inception on 11 September 2008 (Minister of Water Affairs, National Municipal Indaba, Johannesburg). The concept was defined by two programs: The Blue Drop Certification Programme for Drinking Water Quality Management Regulation; and the Green Drop Certification Programme for Wastewater Quality Management Regulation. The Green Drop process measures and compares the results of the performance of Water Service Institutions, and subsequently rewards or penalises the institution upon evidence of their excellence or failures according to the minimum standards or requirements that have been defined. Awareness of this performance is obtained by pressure via consumers, the media, politicians, businesses, and NGOs. The strategy revolves around the identification of mediocre performing municipalities who consequently correct the identified shortcomings, as well as the introduction of competitiveness amongst the municipalities and using benchmarking in a market where competition is difficult to implement. (Department of water and sanitation Annual Report 2017/18). The current uses data from such a programme and provide new interpretation.

The Green Water Services Audit is the tool whereby incentive- and risk-based regulation is conducted in South Africa. Regulation is important to ensure effective and efficient delivery of sustainable water services and has been commended by South African authorities and accoladed by international peers. A good regulation approach is characterised by its ability to clarify the requirements and obligations placed on water service institutions, thereby protecting consumers from a potentially unsustainable and unsafe service. In 2009, 216 systems obtained Green Drop scores of ≥50% compared to 2011 whereby 361 systems and 415 systems obtained more than 50% in the 2013 Green Drop cycle. On a percentage scale this marked an increase from 44 to 50.4% for systems with >50% Green Drop scores. The average Green Drop score follows an equally impressive improvement trend from 2009 (37%) to 2011 (45%) to 2013 (46.4%), indicating an improvement in the average performance by municipalities. Overall, the above table is marked by an all-round which signifies an improvement trend in all performance areas. (Green drop report, 2013). The current study proposes application of analytical tools.

The most significant performance measure is, however, the National Green Drop Score, which applies weight per size of a system. The Regulator is satisfied with the increase in the national score from 71% in 2011 to 73.8% in 2013. The most impressive statistic is the number of Green Drop Certifications that were achieved in 2013, totaling 60 systems compared to only 40 systems in 2011 and 33 in 2009. What makes this figure remarkable, is that the 2013 Green Drop criteria were significantly more stringent than the 2011 criteria. A wastewater system that achieved ≥90%, can truly be regarded as 'excellent' and has achieved a level of mastery that will compete with the best wastewater systems in the world. The following is the scorecard that outlines the key requirements of the Green Drop assessment and indicates the Portfolio of Evidence that was required by each Water Services Institution to calculate a Green Drop score per wastewater system. However, this thesis will only be focussing on the details of Wastewater

Effluent Quality Compliance:) a] 90% Microbiological Compliance (e.g. E Coli; Faecal Coliforms); b] 90% Chemical Compliance (e.g., E- coli, COD, Ammonia, Nitrogen, Nitrate, Nitrite, Residual Chlorine, Orthophosphates, and c] 90% Physical Compliance such as pH, Suspended Solids, Electrical Conductivity, Soap, Oil or Grease, among other parameters.

The Western Cape province has 30 municipalities and one metropole or Category A municipality; five district or Category C municipalities – the Cape Winelands, Overberg, Central Karoo, Eden and the West Coast; and 24 local or Category B municipalities that are grouped within each of the five districts. Cape Town is the province's growth engine, generating 76,6 per cent of the Western Cape's total GDPR. The province has two further growth motors – the Eden node, which includes Mossel Bay, George, Knysna and Plettenberg Bay, and that of Saldanha-Vredenburg. The Western Cape economy has become increasingly service-dominated, driven by Cape Town, Cape Winelands, and Eden economic dynamics. The province has a growing and maturing population, leading to an increase in labour supply over time, helping to alleviate constraints in growing sectors should workers be appropriately trained and skilled. The local socio-economic profiles present six key areas of opportunity to achieving shared growth and development outlook in the province: 1] Thriving regional growth sources; 2] Competitive regional economies; 3] Maturing demographic profiles; 4] Reasonably skilled workers; 5] Considerable infrastructure and settlement investment opportunities; and 6] Relatively sound municipal finances. Therefore, understanding these local socio-economic profiles, provide analytical and interpretational platforms of the results from the current study.

2.3.2 Using incentive-based regulation approaches in wastewater service institutions

The second objective of the current is to assess the relevance of incentive-based approaches by identifying challenges of wastewater services institutions to water resource management. The Green Drop Certification Program in wastewater services institutions is used as an example in assessing such relevance towards sustainable management of water resources.

The Green Drop process has been developed against the philosophy that if the Department of Water Affairs as Regulator can inspire a path whereby disciplined, people, disciplined thought, disciplined action can be measured and reported, that the South African wastewater industry can build greatness to last. It is incredible to note the paradigm shift and behavioural changes brought about by this program in the water sector over the short space of 4 years (2009 – 2013). The positive impression left on the municipal, private sector, and the Department of Public

Works stands as evidence of the passion, enthusiasm, and commitment rekindled within those responsible for wastewater quality management. Furthermore, the Green Drop Report underscores the importance of Regulation as an instrument to ensure effective and efficient delivery of sustainable water services. The need for sustainable water services is recognized by South African authorities and internationally, and sets the standard requirements and obligations placed on water services institutions, thereby protecting consumers from potentially unsustainable and unsafe services. This shows the relevance of the programme.

When South Africa, department of water and sanitation adopted an incentive-based regulation, it was to identify, reward, ensure and encourage excellence in wastewater management. The program has raised the level of awareness on wastewater management in the municipalities. It has also resulted in the raising of the bar, especially for local government. There has been a contribution to skills and capacity building both within DWS and in WSIs through this regulatory program. In the critical look by the Council for Scientific and Industrial Research (CSIR), the paper, reveals that South Africa's Green Drop Programme (DWA, 2010) the two mechanisms i.e. the Enforcement Protocol and the Green Drop Programme generally reflects the current trend in international and domestic environmental regulation. In a nutshell, they encompass a hybrid of the traditional approach to regulation (command-and-control) and the more contemporary alternative approach (incentive-based). It was further argued in the paper that the non-publicity releasing of the Green Drop report is symptomatic of the generally decreasing levels of transparency and accountability in the South African State (DWA, 2010). In short, the description shows that using this incentive-based regulation approaches [Green Drop Certification Programme] in wastewater service institutions remains relevant.

The relevance of using the Green Drop Certification Programme in wastewater sector to promote sustainable water resources management is demonstrated in various sources. For example, the CSIR, (2016), provides evidence that the Green Drop Programme has been effective since its inception and resulted in a significant improvement in wastewater treatment nationally, even though there is still a substantial improvement of South African water resources enforcement must be pursued, "We believe that overcoming the challenges presented in this paper brings South Africa considerably closer to having an effectively functioning wastewater services sector" CSIR, 2016. Therefore, the use of the Green Drop Certification Programme in wastewater sector has the possibility to address challenges in the wastewater and thereby contributing significantly towards sustainable management of water resources.

2.3.3 Evaluating the impact and progress of incentive-based regulation approaches

The third objective of the current is to evaluate the impact and progress of incentive-based approaches for practical interventions in wastewater services institutions towards sustainable management of water resources. The Green Drop Certification Program in wastewater services institutions is used as an example in evaluating the impact and progress. The steady increase in the number of municipalities that have been awarded the Green Drop Certificates over the years is indeed a testimony of the hard work that we have all put, to ensure that wastewater management becomes an indispensable cog in safeguarding the health of our communities and facilitating economic growth. The success story of the Blue and Green Drop programs could not have been possible without the support of decision-makers and water services authorities/institutions as well as officials who worked tirelessly to collect the information that we used to assess the Water Services Institutions. As an African proverb says "If you want to go quickly, go alone. If you want to go far, go together". This show that a journey of the collective nature will take the water sector to new levels in our quest to ensure access to quality water and healthy environment for our communities. This description shows that there is progress in using the Green Drop Certification Programme in wastewater sector.

In the first years of democracy from 1994, the priority regarding water in South Africa was a major drive to ensure that as many people as possible get access to water. As good progress was made, and the program delivered and the department said: "...what about the quality of water that was being provided?" So, the regulation of drinking water quality started and still later the wastewater quality followed. The concept of incentive-based regulation (IBR) was developed as punitive regulation did not work. Green Drop programs were born which is a proudly South African first. The biggest impact these programs have achieved is the buy-in from municipalities. This shows that the "carrot" was more effective than the "stick". The program has raised the level of awareness on wastewater management in the municipalities. It has resulted in the raising of the bar, especially for local government. There has been a contribution to skills and capacity building both within the department and WSAs/WSI/Ps through this regulatory program. In summary, the Green Drop Programme has positive impact.

2.4 Frameworks for the current study

The current research is guided by the concept of water services regulation

South African water problems are clearly defined in the water and sanitation master plan. “South Africa is a water-scarce country and has lost over 50% of its wetlands, and of the remaining, 3.2 million hectares (approximately 30%) are already in a poor condition. Approximately 56% of municipal wastewater treatment works and approximately 44% of water treatment works in the country are in a poor/critical condition and need urgent rehabilitation, with some 11% completely dysfunctional which is having a significantly detrimental impact on the environment and driving up the cost of water treatment. Responsibility for water supply and sanitation (constitutionally) lies with 144 municipalities that are Water Services Authorities (WSAs). At least a third of these are regarded as dysfunctional and more than 50% have no, or very limited, technical staff. Twenty-seven priority districts have been identified as being particularly dysfunctional and requiring specific intervention (though not all are WSAs). The reliability of services that have been provided since the advent of democracy is declining, with only 64 % of households having access to a reliable water supply service. The institutional landscape of the water sector is also overly complex and not sufficiently transformed, which is impacting the value chain” (Stats SA General Household Survey 2018).

Since the preparation of the Master Plan the IMTT on Basic Services has identified 57 Municipalities which account for over 87% of all households living in informal settlements or backyard dwellings, constitute over 50% of all backlogs, and are the epicentre of recorded public service delivery protests (DWS Masterplan, 2017). “Water is a scarce and unevenly distributed national resource which occurs in many different forms which are all part of a unitary, interdependent cycle” (National Water Act, Act No 36 of 1998). Groundwater either seeps (discharges) into streams, rivers, and oceans or is released back into the atmosphere through plant transpiration. Water quality is a significant challenge in most countries including South Africa. Pollution-induced quality deterioration not only reduces the benefits of available supply but also leads to harmful environmental and health hazards. Some parts of South Africa are currently facing water-related natural disasters such as droughts which as a result are potential threats to human life, both directly and indirectly. Over and above the human costs, there are also economic losses from crop and property damage. South Africa has low levels of rainfall relative to the world average with high variability and extremely high levels of evaporation due to hot climate and increasing challenges from water pollution. All the above pose constraints on the amount of water available for use. One of the significant water quality challenges in South Africa among others is the untreated or poorly treated wastewater that severely affects the quality of water in many areas (DWS Masterplan, 2017). This concept aligns with the situation that “South Africa is a water-scarce country and has lost over 50% of its wetlands, and of the remaining, 3.2 million hectares (approximately 30%) are already in a poor condition. Approximately 56% of municipal wastewater treatment works and approximately 44% of water treatment works in the country are in a poor/critical condition and need urgent rehabilitation, with some 11% completely dysfunctional which is having a significantly detrimental impact on the environment and driving up the cost of water treatment.

2.5 Chapter summary: Gap analysis for the current study

In summary, the current study tries to address the following challenges in the wastewater sector by highlighting some of the identified practical tools that need to be applied: To enhance the effectiveness of the Green Drop program on the progress made to date in terms of the regulation of the wastewater services sector, DWS must address the following whilst overcoming the found challenges: Firstly, strengthening the capacity within municipalities to draft and implement relevant and substantive ratification plans as required by the Green Drop Programme. This capacity includes addressing the need for relevant expertise as well as for the necessary resources to draft and implement these plans (CSIR, 2016). Secondly, Green Drop report findings need to be mainstreamed in the municipal financial year to allow proper planning, decision-makers to be aware of the findings related to the improvement of water quality into the water resources and implementation thereof within the water services authorities. This will allow the decision-makers to budget for WWTWs that require efficiently upgraded and maintained by ring-fencing budgets especially set aside for delivering effective wastewater services. These gaps make the current study relevant, timely, and appropriate.

Thirdly, the planning and budgeting processes of municipalities must be adapted so that municipalities can engage in long-term planning, ideally more than one year in advance, when it comes to wastewater treatment. As a result, WSAs will implement preventative measures and monitoring and evaluation–focused approaches, rather instead of implementing reactive activities. Fourthly, National Treasury must be engaged in the procurement of goods and services within the WSAs to assist them in maintaining and repairing their WWTW effectively. Fifthly, the political leadership between DWS and WSAs needs to address institutional challenges. The paper further reveals that interviews conducted, reveal that solutions include ensuring that municipalities receive more support from DWS is required to effectively implement the Green Drop Programme. There is a need to address the capacity and cooperation challenges within DWS. It also refers to the changing of the Green Drop criteria on an annual basis, since it does not allow the WSAs to plan financially and implement findings from the previous assessments. Hence, the need to assess the impact of the programme.

The relationship between WSAs and DWS is the considerable challenge that DWS faces in holding municipalities accountable in terms of wastewater treatment management. “This can be attributed especially to the principle of cooperative governance. It is critical to find a way to continue upholding the ethos of this principle, while at the same time overcoming the limitations it imposes upon the ability of organs of state to hold each other accountable. Furthermore, it is important to better coordinate the Green Drop Programme and the Enforcement Protocol’s implementation processes. Such improved coordination would contribute to enabling DWS to move away from a situation of fragmented and poorly co-ordinated regulatory functions and to work towards a consolidated and continuous regulatory cycle” CSIR, 2016. Sixthly, vandalism and misuse of wastewater treatment infrastructure must be addressed immediately, which can lead to costly damage. Interventions in this regard may require a mix of better policing by the Department and the South African Police Service (SAPS) and raising awareness amongst water users. Lastly, not releasing the full green drop report by the department in the public domain since the 2012 progress report has done considerable damage to the credibility of the Green Drop Programme, the DWS, and municipalities. Therefore, the need to evaluate the progress of the programme using scientific methods as proposed in the current study remains fundamental to restore the dignity of the programme.

Chapter 3: Description of the study area

3.1 Introduction

This chapter 3 provides a description of the study area and its features where the study was carried out to show relations of the features and the research objectives in addressing the identified societal using results obtained from the scientific problem. The location, topography, climate, and water quality characteristics of the study area has been described.

3.2 Reasons for conducting the current study in the chosen area

South Africa is a water-stressed country receiving an average rainfall of 450mm per year, with high temporal and spatial variation in rainfall, and high evaporation which reduces the levels of runoff and availability of surface water. The Berg Water Management Area (WMA) is situated in the extreme southwest corner of South Africa and falls entirely within the Western Cape Province. It is said that the name Berg River originates from the largest river within its boundaries, namely the Berg River and it borders on the Atlantic Ocean and Indian Oceans to the west and south respectively (Berg WMA Internal Strategic Perspective, 2004). Generally, the water situation of the Berg region is no different from the national perspective, with a varying annual rainfall between 300mm on the west coast to 1400mm in the folded mountains of the region. The water demands differ across sectors, water users, and ecological requirements. The pressures and impacts associated with water use are also diverse in composition and intensity, affecting the resilience and availability of the province's water resource situation and subsequent management (Collins and Herdien 2013).

The National Water Act (Act No 36 of 1998) recognizes the fundamental importance of protecting the nation's water resources and is a consistent theme throughout the integrated management ethos it has inspired as mandatory. Specifically, Chapter 3 of the Act makes provision for the supply of water for basic human needs together with the need to maintain water supply for the sustainability of the aquatic environment. This recognition is based on the global realisation that a healthy and optimally functioning aquatic ecosystem needs several different components to ensure its ability to provide valuable ecosystem services for human use. The study that was conducted in detailed for limnological and chemical by A.D. Harrison and Elsworth in the beginning in May 1950 for 3 years, reveals that the Berg River was the first river in South Africa on which an (RHP, 2004)

The Berg River is the largest catchment compared to other catchments in the western cape., which also includes several smaller catchments such as the Diep, Kuils, Eerste, Lourens, Sir Lowry's, Steenbras, as well as various small catchments on the Cape Peninsula and along the West Coast. (Berg WMA Internal Strategic Perspective Report, 2004).

Due to increasingly serious challenges regarding the degradation of water quality in the Berg River, and as a result, the agricultural export market was under a tremendous threat such that they were unable to export their products. Pollution from urban settlements, wastewater effluent discharges, agricultural runoff, and alien invasive flora in catchment areas were identified to be most of the factors that contributed to the pollution of the water quality. The Department of Environmental and development planning: Western Cape government commenced with the implementation of the Berg River Improvement Plan (BRIP) in 2013. Notably, BRIP has made a great improvement in implementing effective water quality monitoring upstream and downstream of the Berg River WMA. (Impact and Implementation Evaluation of the Berg River Improvement Plan, WC: DEA&DP, April 2009)

3.3 Physiographic features of the study area

The natural geology (shales) and agricultural return flows introduce elevated salinity in the middle and lower reaches of the Berg River and the Diep River. The ISP report reveals that many of the urban rivers of Cape Town serve as conduits for discharging treated effluent to and whilst they cannot be rehabilitated, their condition should at least be maintained at levels that will not introduce adverse health and social impacts. The exposed underlying geology of the Berg WMA is largely comprised of Table Mountain Sandstone formations. The Table Mountain and the Cape Peninsula's Mountain range reside in the southwest; the Kasteelberg and Piketberg to the north (isolated sandstone outcrops); and the Cape Flats and West Coast flats characterised by alluvial deposits in the form of sand dunes and sandy soils underlain predominantly by shales. The geology in the Berg WMA is dominated by sandstones and quartzites of the Table Mountain Group, Malmesbury shales, and quaternary sediments along the West Coast and Cape Flats area. Soils from this region are thus limited in the mountain areas and become significant sandy deposits as one move to the flats and coasts. Where shale outcroppings occur, a higher clay and loam content in soils will be evident (agricultural belts). Being agricultural based area, the presence of wastewater is expected to be available hence the need to implement an intervention that manages such wastewater and the Green Drop Certification Programme was found to be appropriate to evaluated in such an area.

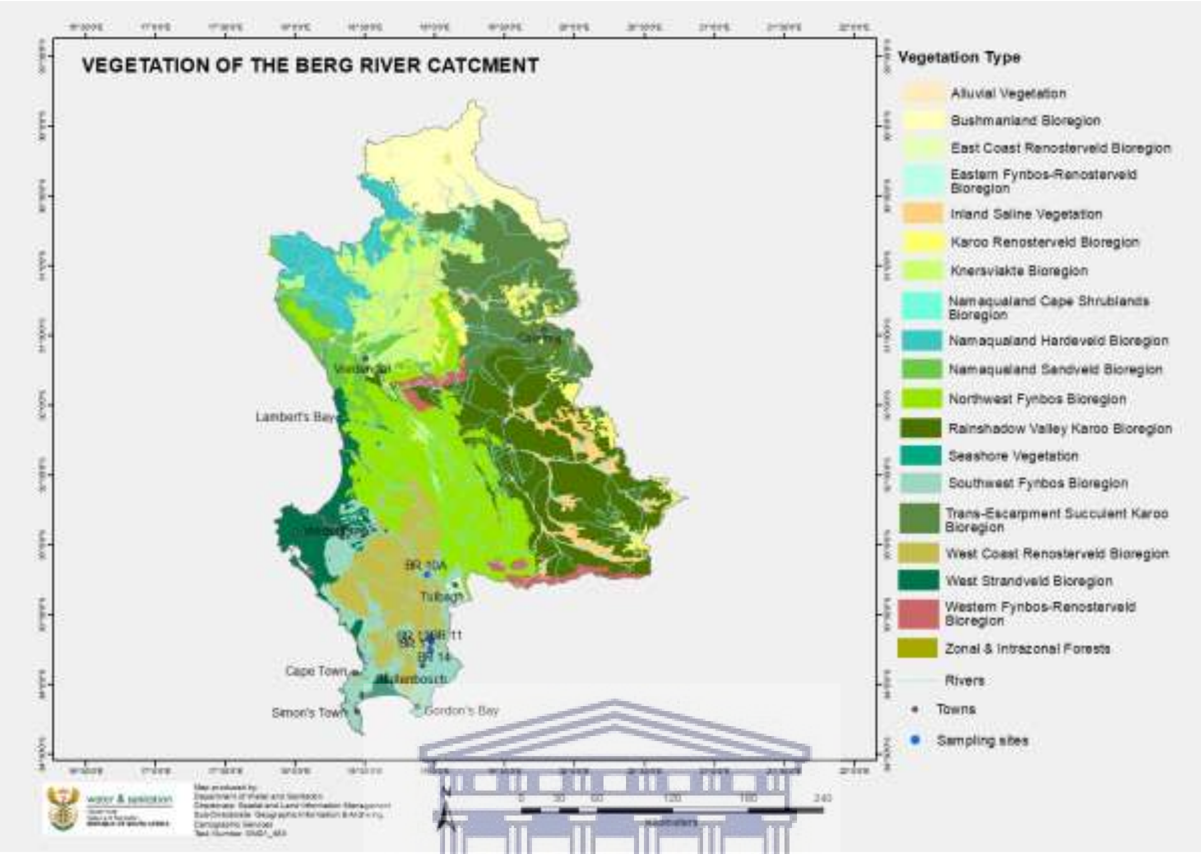


Figure 1: Vegetation Map of the study area, the Berg River DWS, GIS Section, (2011)

3.4 Socioeconomic features of the study area

The Berg River is a socially and economically important water system within the Western Cape Province. There are many agricultural-based activities that range from farming, livestock, fishing, slaughtering, winery processing which tend result into wastewater as by-products. Note that these are unintended consequences of agriculture and manufacturing activities. These activities show that factors that influence the water quality in the study area. The availability of wastewater treatment plants is not a new thing in the study area. Point and no-point sources pollution from urban settlements, wastewater effluent discharges from WWTWs, agricultural runoff, and alien invasive flora in the catchment areas are many. Flow alterations through dam construction among others and abstraction of water for agricultural use have further degraded water quality and quantity in the study area. However, the focus of the current study is the assess the relevance and impact and progress of the incentive-based regulation, the Green Drop Certification programme, in managing wastewater towards sustainable management of water resources. But it is vital to describe activities in the study area as a case study for the research.

3.5 Location of the study area: The Berg water management area

The RHP, 2004 report reveals that the Berg River drains an area of approximately 8 980 km² and has a total length of about 285 km. The RHP, 2004 report further concludes that Berg River has nine major and seven minor tributaries, six of which were naturally perennial, namely the Franschhoek, Wemmershoek, Dwars, Klein Berg, Vier-en-Twintig and Matjies rivers. According to the National Water Resource strategy, the Berg River WMA is subdivided into three subdivisions and eight management units as revealed on the figure shown below sourced from the (Berg WMA Internal Strategic Perspective, 2004).

The Upper Berg River (UBR) sub area constitutes of eight quaternary catchments (G10A – G10H) This area extends from the source of Berg River in the Franschhoek mountains to Misverstand Dam, south of Piketberg. The UBR originates in the Drakenstein Mountains at an altitude of 1500m above sea level but drops steeply at the confluence with the Franschoek and Wemmershoek Rivers. The Berg and Wemmershoek Rivers have dammed in their upper reaches and above these dams, the rivers are in their natural states. Interbasin Transfer Schemes also occur in this study area. Some parts of this area are protected to protect the yield and water quality of the Berg River Dam, as a result, there are no land use activities taking place. The SASS results indicate that this site is still in a Natural condition. (RHP, 2004).

The Lower Berg (LBR)Sub-area constitutes of ten quaternary catchments (G10K – G10M, G21A, G21F and G30A). It follows that this area includes the Berg River catchment between misverstand Dam and the Berg River mouth. The Lower Berg area tributaries include the Matjies, Boesmans, Platkloof and Sout Rivers, which originate in the Olifantsrivier and Piketberg Mountains. The Sout River drains the southwest portion and has a lower gradient. The Matjies River is the only perennial tributary and the underlying Malmesbury Shale geology of these rivers results in high salinities (RHP, 2004). Lastly the Greater Cape Town sub-area: The Cape Town metropolitan area is the Eerste Kuils, Lowrens and Sir Lowry's Pass Rivers including the Steenbras River. There are many wastewater treatment plants in this catchment.

Rivers in this study area are characteristically short, originating in the steep Cape Peninsula Mountains and flowing over the flat coastal areas before draining into False Bay and the Atlantic Ocean. The Westlake, Diep/Sand and Keyser rivers have been modified in various ways and all drain urban areas before entering Zandvlei. The Big and Little Lotus rivers flow through densely areas of the population before entering Zeekoevlei. They have been modified by canalization. The Salt and Hout Bay rivers are the major rivers in the central area of the City of Cape Town. The Elsieskraal, Black, and Liesbeek rivers are the major tributaries of the Salt River which originates from the Tygerberg Hills, the northwest side of the Cape Flats, and the eastern slopes of Table Mountain respectively. The lower reaches of all these rivers have been canalised and diverted (River Health Programme, 2005).

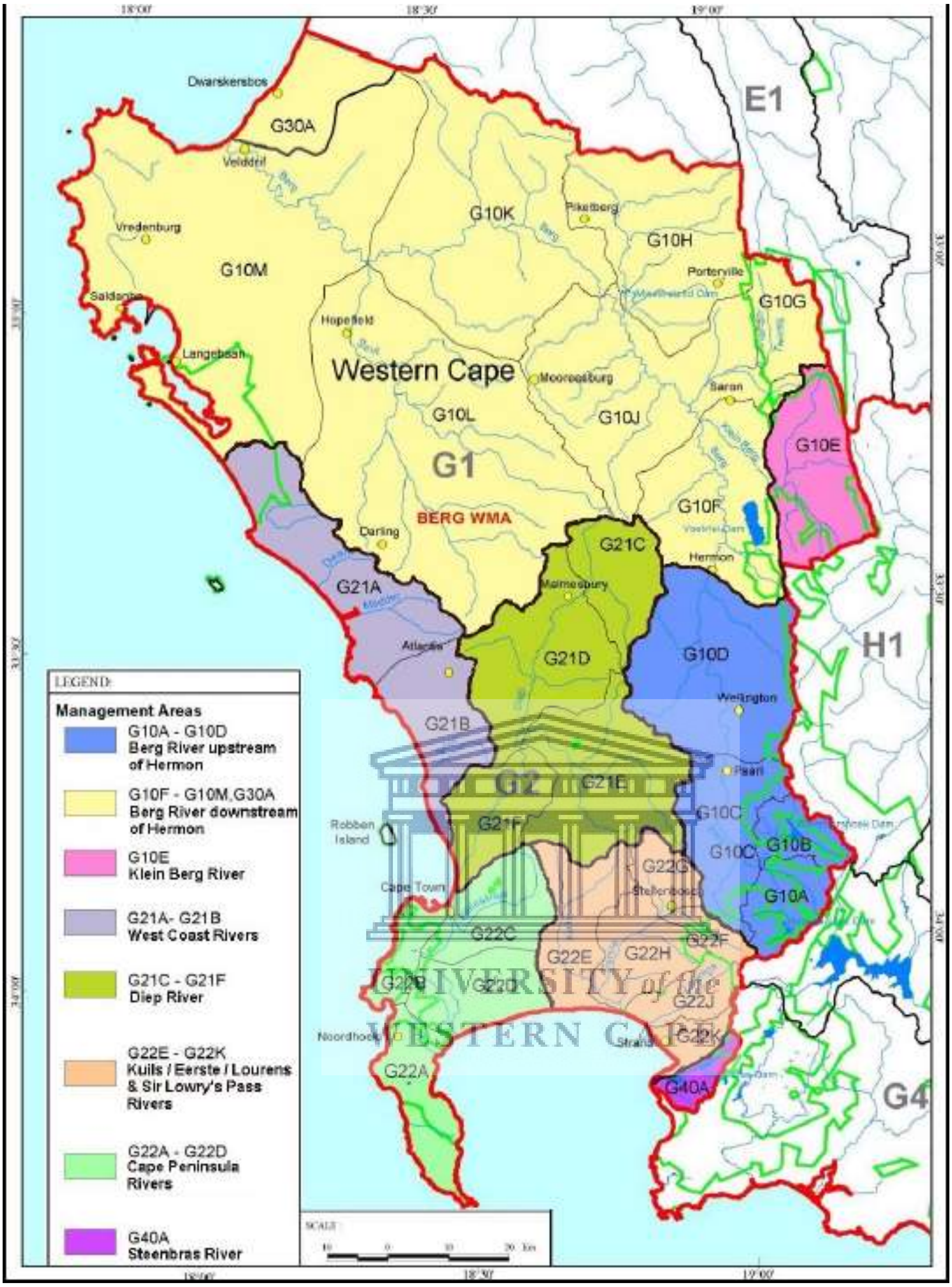


Figure 2: Eight management units of the Berg water management areas

3.6 Climate and rainfall of the study area: The Berg water management area

The temperature and climatic differences throughout the Berg River WMA have the mean average temperature that ranges between 16°C in the central east, to 18°Calong the west coast, and 16°C for the whole WMA. The highest temperature is experienced during January, while the lowest temperature is experienced during July. The rainfall regime within the Berg River

WMA is during winter, with maximum rainfall occurring during May to September months. (River Management Strategy for the BERG Water Management Area of the Western Cape, January, DWAF Project No. 2006 -462, 2008). Rainfall within the Berg WMA differs spatially. The large spatial variation results in the highest mean annual precipitation of more than 3200 mm in the high–lying areas of the Hottentots Holland Mountains in the south-east to less than 500 mm in the -west. The average potential mean annual evaporation (measured by Symons-pan) ranges from 1700 mm in the north to 1400 mm in the southern parts (DWAF, 2004, Gorgens and de Clercq, 2005) The climate is a Mediterranean and rainfall is receiced in winter one. The more the rainfall the area has the more dilutaion effect on the wastewater status. The higher the temparatures that area has, the more concentration levels of the contaminants. Thus, it is important to be familairs on the rainafall and temperayutre pattern in the study area.

3.7 Ecological and management perspective for water use in the study area

Ecological perspective and management perspective provide the change on water qualuty over time and over space. Such assessment informs the investigations on the cause for such changes. For examples, the present and desired health of the river conditions were assessed and results were categorised as per river health categories presented in the Table below:

River Health Category	Ecological Perspective	Management Perspective
Natural N	No or negligible modification	Relatively little human impact
Good G	Biodiversity and integrity largely intact	Some human-related disturbance but ecosystems essentially in good state
Fair F	Sensitive species may be lost, with tolerant or opportunistic species dominating	Multiple disturbances associated with the need for socio-economic development
Poor P	Mostly only tolerant species present; alien species invasion; disrupted population dynamics; species are often diseased	High human densities or extensive resource exploitation

"The present health of a river is a measure of the present ecological state of the river during the time of the survey and is presented in terms of the river health categories given below. The desired health of a river is the envisioned future ecological state of the river. It is based on ecological considerations, the need for sustainable development and management actions concerning the river environment". The water quality in the Berg River has changed considerably over time, with the major impactors being agricultural return flows, irrigation releases, urban and industrial runoff and wastewater discharges. Temporal trends in water quality in the Berg River catchment can be summarised as follows: (River health program, Berg River system, 2004). The Green Drop Certification Programme considers the water quality changes in the study area over time and over space. Such spatiotemporal assessment is vital in assessing the impact and relevant of the Green Drop Certification Programme.

The Berg River catchment starts from the mountains in the Franschhoek which is situated on the north of Cape Town in the Western Cape. From the north-westerly direction, it enters the sea at St. Helena Bay at Velddrif on the west coast. The resilience of the economy for the Berg River catchment is the Cultivation of various fruits and the largest once are grapes. Some of the major industries found in this catchment practice agricultural activities include food processing factories. As the catchment stretches towards the report reveals that the North of Wellington, dryland grain farming and sheep farming predominate as well as commercial pine forests that consume a lot of water occur in the headwaters, around Franschhoek. (RHP, March, 2005). The 1999 ecological status classes from DWAF (1999) provides a benchmark or a reference point for spatial temporal assessment of water quality in the study area.

Table 2: Berg River Baseline Monitoring Programme Final Report, (2007)

Ecological Status Class	Description of General Conditions
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota can take place but the ecosystem functions should essentially be unchanged.
C	Moderately modified. A moderate change in natural habitat and biota can take place but the basic ecosystem functions should still predominantly be unchanged.
D	Largely modified. A large change in natural habitat, biota and basic ecosystem functions can occur.
E	Seriously modified. The losses of natural habitats and basic ecosystem functions are extensive
F	Critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat.

From the table 2 above, it is clear that irrigation activities in the Berg River catchment are ongoing to support the economy of the country and therefore, there will always be wastewater from such activities and the way forward is the implement an incentive-based programme for sustainable management of such wastewater. The impact on the export fruit industry has emerged as a major threat. In an article published in the Cape Times on Wednesday, 23 February 2011, Peter Lukey (Department of Environmental Affairs, Acting Director: Climate Change) comments that "global climate change could bring about the horror story of the end of the wine industry in the Western Cape". Wine is produced using specific cultivars of grapes. The cultivars are specific to climatic regions and geographic locations. Changes in climate will lead to "re-location" of cultivars and development of new cultivars and wines which may impact on existing reputations (Status Quo Report, DEADP, 2011).

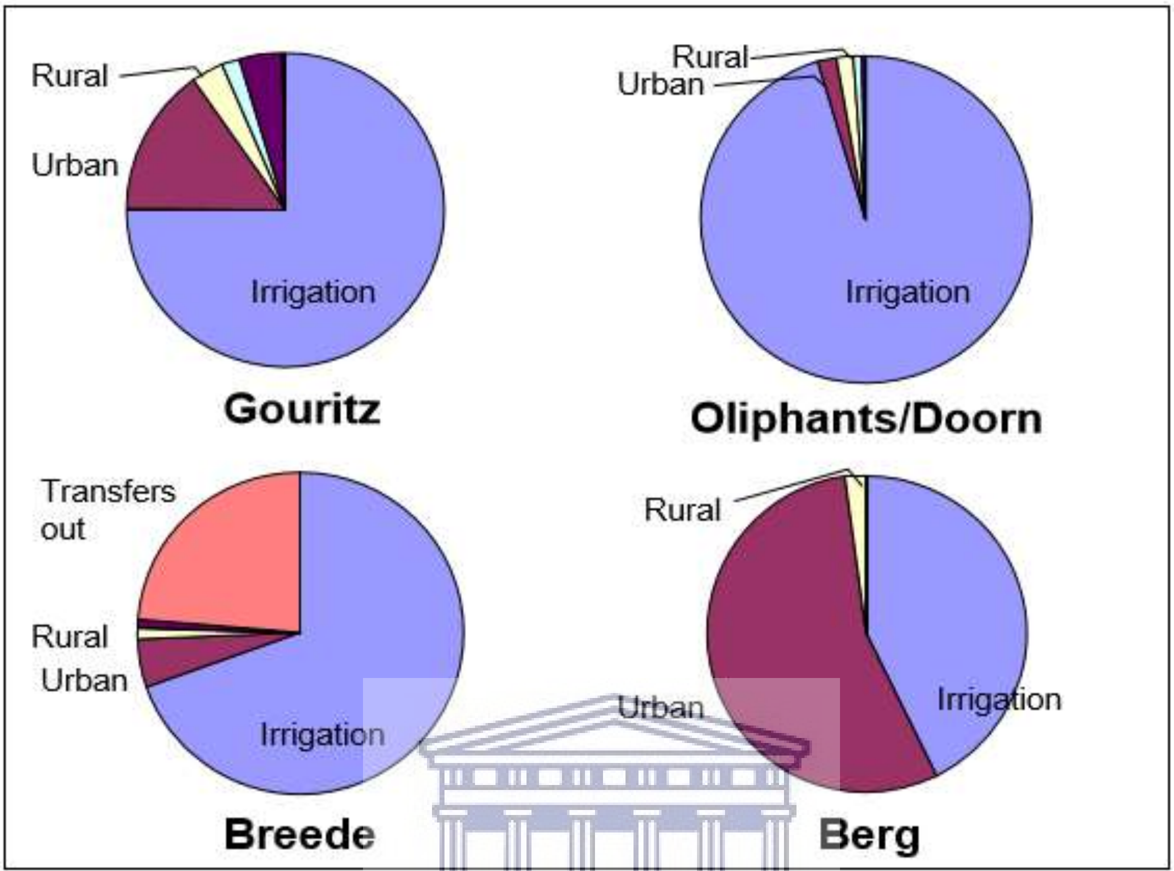


Figure 3: Water use by sector for the four water management areas, Western Cape (Midgley, et al 2005)

3.8 Summary chapter about the study area

The chapter on the study area has provided the context or situation where the project was implemented It is evident from the (RHP, 2004) report that effluent from the wastewater treatment works is not the only pollutants into the Beg River. Pesticides and fertilisers are heavily utilised to optimise the production of grapes, deciduous, and citrus fruits. Normally these chemicals land into rivers via vapour/spray drift, surface runoff, spills or through leaching into groundwater. The RHP, 2004 confirms that the water quality state in the Berg River has changed significantly over time, with the major impactors being agricultural return flows, irrigation releases, urban and industrial runoff, and wastewater discharges. Temporal trends in water quality in the Berg River catchment remain variables due to the changing rainfall and rainfall pattern. The main argument in this chapter was that the conditions where a researcher implement his/her project can positively or negatively influence the outcome/results and therefore it is important to describe the features and activities in the study area for the project.

Chapter 4: Research design and methodology

4.1 Introduction

The chapter one provided the general introduction to the current study highlighting the problem statement, research question and study aim and objectives that needed to addressed. In chapter 2, the reviewed literature sources provided the context and synthesis of the previous studies in line with the current study, in addition to providing the frameworks and gap analysis for the current study. Chapter 3, provided a description or the prevailing conditions of the study area where the study was implemented which were thought to have positive or negative influence on the findings of the current study in the study area. The current chapter 4, explains methods that were used to collect and analyse data in addition to presenting the research design that was followed to answer the research question and the set objectives in chapter one. Therefore, this chapter four covers the research design approach, methods for data collection and analysis, quality assurance measures for the results, research integrity and limitations of this study.

4.2 Research design of the current study

Leady (1997) defined research design as a study scheme that provides the overall framework for data collection while MacMillan and Schumacher (2001) defined research design as a subject selecting plan, research sites and procedures for data collection in answering the set research question(s). The authors further stipulated that the goal of a sound research design is to provide results that are considered credible hence the choice to characterise the aquifer with the chosen methods which are appropriate for the study in ensuring that the set question of this research is answered, and the identified problem is bridged. A detailed description of the design employed in this study is provided in this chapter. Any type of research that employs numerical information to explore individuals or group characteristics to produce findings is termed a quantitative research methodology. The data used for this type of research are in form of numbers hence it is an empirical research. Keskinocak and Tayur (2001) stated that data required for this type of research includes experimental designs and non-experimental designs and the sources of data includes: surveys, observations and secondary data while qualitative research methodology allows the researcher to get close to the data thereby developing the categorical, analytical or conceptual components of explanation from the data itself. Berrios and Lucca (2006) stated that the data required for this type of research methodology includes narrative research, phenomenologies, ethnographic methodology, grounded theory and case studies and the sources of data includes: interviews, postcards, secondary data, and observations. The mixed research methodology refers to a developing methodology of research that advances the formal integration or mixing of quantitative and qualitative data within a single study. Quantitative and qualitative type of data are both collected and analysed. Data are mixed in different forms and priority is given to one or both forms of data. Creswell (2017) stated that the mixed methodology can be used in a single study or in multiple phases of a study. The current research project used both quantitative and qualitative methods and data.

The current study followed a mixed methodology which is also called an integrated approach which. Some preliminary ideas about wastewater services in the study area were established and this was done with the aim of improving understanding on the role of water services institutions for wastewater services regulation in the study area. A desk study was done to review the available records, information, and data on the operations and performance of the Drop Programme and the role of institutional commitment in sustainable water resources management. This was conducted so that the current and appropriate methods for collecting and analysing information were identified, selected, and used in the study in a proper manner. A record review method was also used to identify other wastewater services institutions and information about water services institutions in the study area, and this formed the basics of selecting the appropriate methods for data collection and data analysis and interpretation.

4.3Research methods for data collection and analysis

In this section, methods that were used to collect and analyse data to achieved the set objectives in chapter one and to answer the research question and to produce results to support the set argument for the study were discussed and the appropriate methods were selected for the present study. The discussion is presented objective by objective in this section 4.3. Before data collection began, permission from the department of water and sanitation was granted to use data that appeared in the department's reports and IRIS and from the six respective municipalities within the Berg water management area including the River catchment data.

4.3.1Contribution and challenges of water services institutions

The first objective of the current was to develop a conceptual model that describes the operational processes of incentive-based regulation of wastewater services and determine the contribution of the Green Drop Program/wastewater services institutions to water resource management. The current study used the Green Drop Certification Programme in South Africa to explain the role of water institutions in sustainable water resources management. The focus was on assessing the contribution of water services institutions towards sustainable management of water resources using various methods.

The second objective of the current was to assess the relevance of incentive-based approaches by identifying challenges of wastewater services institutions to water resource management. The Green Drop Certification Program in wastewater services institutions was used as an example in assessing such relevance towards sustainable management of water resources. The focus was on determining challenges of water services institutions for managing water treatment facilities using various methods. Methods that were used to collect and analyse data for objective one and two were similar and the discussion on them are provided below:

Data analysis task was carried out on primary and secondary data. Primary data sources included data from key informant interviews with key informants involved in the Berg River catchment and one informant from a water board outside of the western cape province but have tremendous experience in the water quality discharged into the receiving environment. These were submitted in writing and some were done through virtual meeting due to time constraint. Several informal interviews and discussions were held with officials and researchers. I differentiate the responses by these informants in terms of 'interview' (where it was informant interview and ' personal communication' where I needed to gain more clarity on a particular matter). Analysis was undertaken of existing raw data on receiving environment in the study area that was collected by the Western Cape provincial government, Department of Environmental Affairs and Development Planning (DEA&DP) from 2013 to 2020 as well as analysis data conducted by the six municipalities in the study area. With regards to the secondary data sources, official and non-official government documents such as development plan, strategies, GIS from the department, pieces of legislation, study reports were read as well as assessed and interpreted in the study. Qualitative data were used to calculate the trend of CRR within the WWTWs in the study area. Other secondary data for Biomonitoring were consulted to provide the relationship between the chemical and microbiological with biomonitoring in the study area. Secondary data from internet were used on an *ad hoc* basis.

Informant Interviews: Situation analysis of the situation in the Berg water management area or River catchment regarding challenges within the water services institutions was developed before interviews were carried out to illuminate the issues involved. Informant interviews were conducted with key informants from various spheres of government and expertise.

Interviewees selected were key personnel in the water sector and were experts. An Informant Interviews for this study were constructed in terms of the three objectives. These questions had strategic questions of which the answers determined the level of risk that the wastewater treatment plants impart to the receiving environment and human health. Due to pandemic Covid-19, there were no face-to-face interviews, some interviews were conducted telephonically and some completed a list of questions provided. Interviews conducted vary from municipal, the department, water board, water research, representatives of the farmers around the entire Berg Water Management Area. I administered a research instrument to allow all interviewees to have sufficient time to respond to the questions as honestly as they should. I further asked direct questions requiring yes, no, or I don't know. I acknowledged the fact that this nature of matter has been politized for some time and in most cases, scientists, officials, and representatives of the farmers around the study area might not want to be definitive but remain ambiguous. Some of the questions had a follow-up question to clear the ambiguity.

Another method that was used is called Case study analysis. This was undertaken to find what the new scientific analysis which was required on the existing drop program data for water services institutions to meet their intended plan or target. The aim was to addresses the reported societal problem. This method helped to explore the new interpretation of scientific data about the green drop program which was required for water services in wastewater treatment. Interview participants in the progress thus far since the inception of the Director General of the department of water and sanitation to establish whether there has been a paradigm shift and improvement of the Berg River and from the WSIs WWTWs, the difference between the initial scorecard and the current one. Lastly interview provided the required clarification.

4.3.2 Impact and progress of Green Drop Programme for practical management

The third objective of the current was to evaluate the impact and progress of incentive-based approaches for practical interventions in the wastewater services institutions towards sustainable management of water resources. The Green Drop Certification Program in wastewater services institutions was used as an example in evaluating the impact and progress. The focus in the third objective was on assessing the impact and progress of the Green Drop Certification Program for practice management, and examining scientific aspects of the Green Drop Program for wastewater management in the water resource management sector. This section explains the methodology that was followed to obtain a systematic description of how the CRR data relevant to the study was collected. It included data collection, and analysis of the water quality data for analysis that was collected by the municipal officials and analysed at various laboratories, and submitted to the DWS as part of their water use authorisation obligation as part of this study. Approaches and techniques that were employed to collect data that provided a representative and accurate picture with respect to water and sanitation programmes in South Africa over the past 15 years were clarified and followed. A detailed procedure on trend analysis of applicable indicators and evaluation of impact across the various Water Services Authorities in the country was provided and was followed.

4. 4 Research quality assurance for the study

One of the main requirements of any research process is the reliability of the data and findings. Reliability deals with the consistency, dependability, and replicability of "the results obtained from a piece of research" (Nunan, 1999). Obtaining the similar results in quantitative research is rather straightforward because the data are in numerical form. To ensure adequate validity and accuracy of results, some measures were put in place to checkmate the estimated errors. There are quality control (QC) and quality assurance (QA) measures. QC/QA control measures are those activities one undertakes to demonstrate the accuracy (how close to the real result one is) and precision (how reproducible results are). Quality assurance generally refers to a broad plan for maintaining quality in all aspects of a program while quality control consists of the steps taken to determine the validity of specific sampling and analytical procedures. Quality assessment is assessment of the overall precision and accuracy of one's data, after the running of the analysis. The aspects were implemented in the present study and reported in this thesis. In this study, since secondary data were used alongside primary data sets for triangulation. Field observations were used alongside Key Informant Interviews for triangulation. Data gaps were filled using missing data methods from the hydrology field. Errors in data sets were checked and corrected using statistical techniques. The reliability in the water quality data was achieved using the charge balance error techniques in the water quality discipline. The aim of a quality assurance was to make sure the data/research were free from errors hence having a data set that is reliable and valid which was achieved after carrying out the quality assurance process in this study. This is how reliability and validity of the data were achieved for the study.

4. 5 Research integrity for the study

According to Singapore statement on research integrity, the integrity of any research should be based on four principles: Honesty in all aspects of research, accountability in the conduct of research, professional courtesy, and fairness in working with others and good stewardship of research on behalf of others (Resnik and Shamoo, 2011). Access to the data that was used for this research was granted, the principle of honesty was applied because the data and findings were shared openly to the research team. The principle of integrity was also applied here as the interpretations of data was completed to answer the stated objectives. Everyone associated with the different aspects of this research were all treated with dignity and respect, and everyone was duly informed on the research procedures. The matter of wastewater management and pollution of the receiving environment in South Africa at large is a very sensitive matter in all spheres (National, Provincial and Local) of government spheres, therefore, assurance was given to all interviewees that the purpose of this investigation was for academic purpose only. I managed to maintain an ethical conduct. I verified the accuracy of statements I received. I obtained verbal permission to chat with key information interviewees from the selected departments in the water sector. Their names were not recorded for confidentiality.

4.6 Limitation of the study

This section presents the challenges that were encountered in the course of implementing the current study and it explain how such challenges were managed so that the set objectives were achieved. The first challenge was the restrictions and lock downs that were encountered due to COVID-19 and movement restrictions. Collecting all the planned primary data was not possible that would have enhanced the interpretation of the results obtained. However, the available secondary data sets were collected and the few primary data that were collected were used to validate the secondary data sets. Adequate, reliable and valid results were obtained. A second limitation encountered was the break in the operational activities of the Green Drop Programme which provided gap in the data sets about wastewater services and performance of the Green Drop Certification Programme. This challenge was addressed by using the historical trend alongside data filling gaps method which were borrowed from the field of hydrology. Lastly, this study was only focused on the Green Drop Certification Programme in the wastewater services without comparing with the Blue Drop, No Drop and Grey Drop Programmes in the water services institutions. This does not provide a full picture of the water services institutions in the water resource management. However, lessons learned from the Green Drop Certification Programme provided a basis for conducting a similar research with a focus on other Drop Certification Programmes in the water service sector.

Chapter 5: Results and discussion of the current study

5.1 Introduction

This chapter presents and discusses results obtained from the study that assessed the role of institutional commitment in sustainable water resources management where the Green Drop Certification Programme in the Western Cape of South Africa was used as a case study. Mixed methods were used to collect and analyse secondary and primary data. The reliability of validity of results were achieved by using various quality assurance methods as described in chapter 4 of this study. The first objective was to determine the contribution of the Green Drop Program/wastewater services institutions to water resource management. The second objective was to identify challenges of wastewater services institutions to water resource management. The third objective was to evaluate the relevance, impact and progress of incentive-based approaches for practical interventions in the wastewater services institutions towards sustainable management of water resources. In this study, the Green Drop Certification Program in wastewater services institutions was used as an example in assessing relevance, impact and progress of programme towards sustainable management of water resources. In this chapter, results are described and discussed from comparative analysis perspective. Implication of the results are highlighted before providing the summary chapter on key findings.

5.2 Determining contribution of Green Drop Certification Program in wastewater services institutions towards sustainable management of water resources

The first objective of the current was to develop a conceptual model that describes the operational processes of incentive-based regulation of wastewater services and determine the contribution of the Green Drop Program/wastewater services institutions to water resource management. The current study used the Green Drop Certification Programme in South Africa to explain the role of water institutions in sustainable water resources management. The focus was on assessing the contribution of water services institutions towards sustainable management of water resources using various methods. The conceptual model was not developed but it was reviewed and described in the chapter 2 of this study. However, contribution of water services institutions to water resources management where the results from the Green Drop Certification Programme were identified, presented and such contribution was demonstrated. The results of the descriptive analysis were reported in the tables and graphs to follow in this chapter. Chemical and microbiological analyses of the surface water upstream and downstream of the Berg River during summer and winter periods were collected, analysed and were presented to show the contribution of the programme. The study sites where data were collected are presented and the water characteristics upstream and downstream of the WWTWs are also presented as end member and for comparative analysis purposes.

The analysed data presented below are secondary data that were sampled by the Western Cape provincial government, Department of Environmental Affairs and Development Planning (DEA&DP) from 2013 to 2020 of the DEA&DP of the following B10A (1km d/s of the confluence of Klein-Berg River), B 11 (D/ of Wellington WWTW discharge) B12 (D/s of Mbekweni/Newton informal settlements & stormwater canals), B13 (D/s of Paarl WWTW discharge), B 14 (Berg River at Paarl Arboretum d/s of farms) sites.

The correct sampling technique was used whereby at river sampling locations, the samples were taken as close to mid-stream as possible either by the sampler or through an extension pole depending on accessibility. The bottles were steriled with added thiosulphate to neutralise possible residual chlorine in the water, for example, downstream of WWTWs. The bottles were rinsed before sampling with the same water that were sampled to avoid contamination of the sample. Samples were immediately put on ice in a cooler box until delivered at the laboratory within six (6) hours. The accredited chromogenic agar method was used to test E. coli in water samples and full counts were carried out. Samples were analysed at the CSIR laboratory. The key informant interview with Ms. M Kunneke [Personal communication] provided the described sampling procedure thereby providing quality assurance of the sampled water.

Table 3: Description of sampling sites in the study area

Site name (location order)	ID#	Lat	Long
1km d/s of the confluence of Klein-Berg River	Berg River 10A	-33.207516	18.943699
D/s of Wellington WWTW discharge	Berg River 11	-33.656089	18.9666
D/s of Mbekweni/Newton informal settlements & stormwater canals	Berg River 12	-33.666963	18.974949
D/s of Paarl WWTW discharge	Berg River 13	-33.690526	18.975228
Berg River at Paarl Arboretum d/s of farms	Berg River 14	-33.755509	18.972616

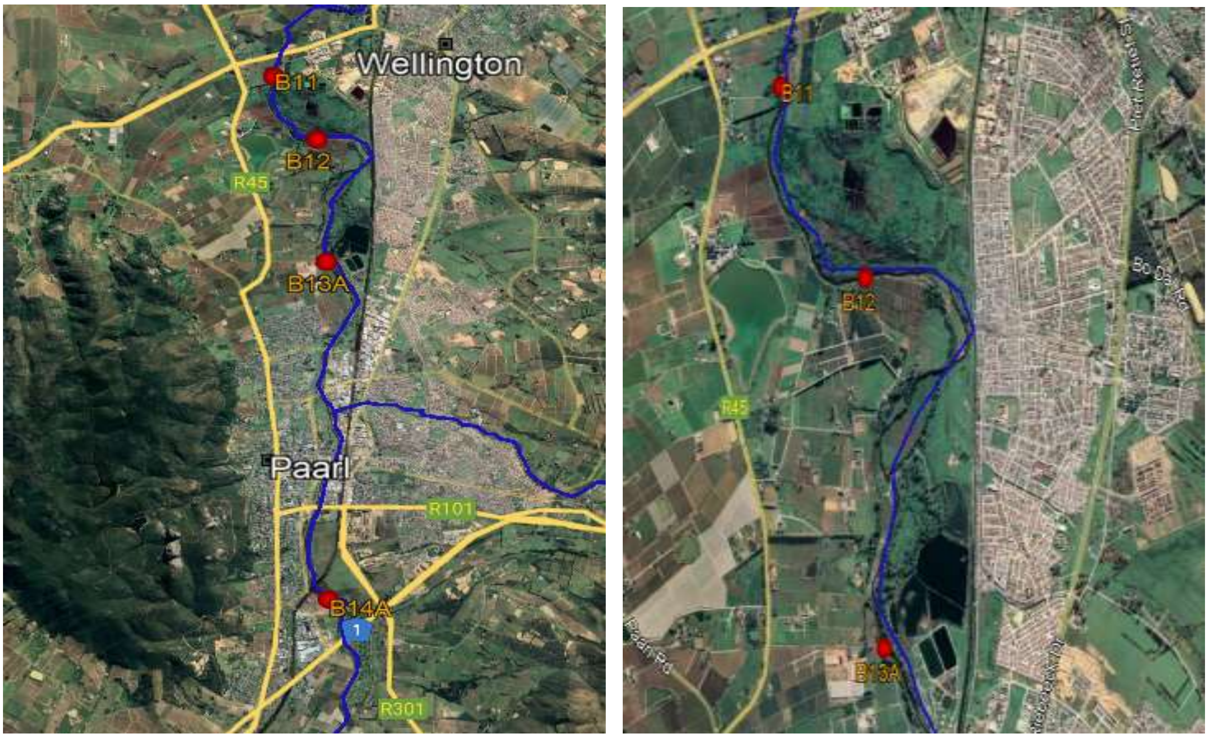


Figure 4 presents the visualisation of the sampling sites in the study area

Table 4 shows limit of wastewater applicable for discharge into a water resource

SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (per 100 ml)	1000	0
Chemical Oxygen Demand (mg/l)	75 (i)	30(i)
pH	5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)	6	2
Nitrate/Nitrite as Nitrogen (mg/l)	15	1,5
Chlorine as Free Chlorine (mg/l)	0,25	0
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	50 mS/m above background receiving water, to a maximum of 100 mS/m
Ortho-Phosphate as phosphorous (mg/l)	10	1 (median) and 2,5 (maximum)
Fluoride (mg/l)	1	1
Soap, oil or grease (mg/l)	2,5	0
Dissolved Arsenic (mg/l)	0,02	0,01
Dissolved Cadm ium (mg/l)	0,005	0,001
Dissolved Chromium (VI) (mg/l)	0,05	0,02
Dissolved Copper (mg/l)	0,01	0,002
Dissolved Cyanide (mg/l)	0,02	0,01
Dissolved Iron (mg/l)	0,3	0,3
Dissolved Lead (mg/l)	0,01	0,006
Dissolved Manganese (mg/l)	0,1	0,1
Mercury and its compounds (mg/l)	0,005	0,001
Dissolved Selenium (mg/l)	0,02	0,02
Dissolved Zinc (mg/l)	0,1	0,04
Boron (mg/l)	1	0,5

Table 4 shows general limit and specific limit of each water quality parameter. Table 4 provides the limit for wastewater applicable for discharge into a water resource. The objective of this assessment is to assess the contribution of the WSI to the water resource management of the Berg River catchment since the inception of the green drop certification program in 2009.

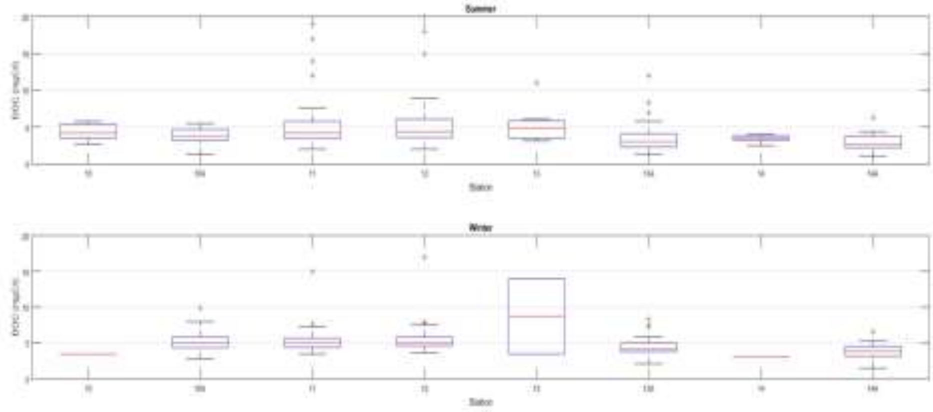


Figure 5 shows dissolved oxygen (DOC) concentration at various points along the Berg River

The DOC concentration in unpolluted water is typically less than 5 mgC/R, but in waters receiving organic wastes from runoff, significantly higher concentrations may be encountered. COD and BOD determinations are normally carried out on unfiltered water samples and thus are measures of both dissolved and suspended organic matter. The TOC is the sum of both dissolved and suspended organic carbon (South African Water Quality Guidelines, 1996). Figure 4 shows specification for sampling points (B10A in winter and B11, B12, B13, and B14) for both seasons summer and winter.

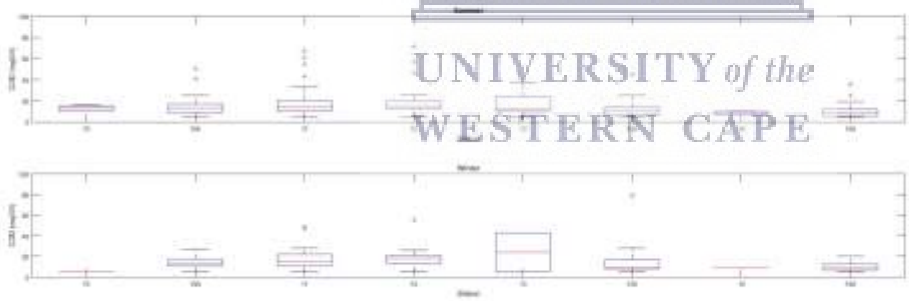


Figure 6 shows Chemical Oxygen Demand (COD) concentration at various sampling points

The acceptable limit for COD in the Berg River is 75 mgO/l as per the DWS standards. Results presented in Figure 6 for the COD of samples were taken in summer and winter from points B11 and B12 fall outside of the specification in terms of the DWS standards. The observed trend is used as the basis to show whether there has been an improvement in the Berg River catchment since the inception of the Green Drop assessments. (South African Water Quality Guidelines, 1996). One notes that there is a tendency to right (higher value) tailing in summer, suggesting a flow-related impact. Unfortunately, the impact of reduced data numbers is also evident in the winter data. The need for more data is evident for better visualisation.

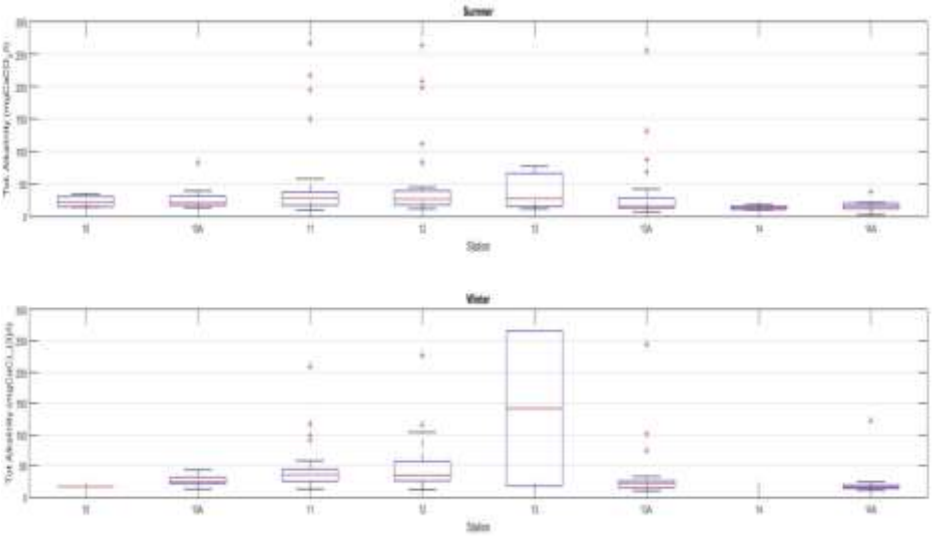


Figure 7 shows Total Alkalinity concentration at various points along the Berg River

Based on the interpretation of the aggressiveness index, it can be concluded that AI falls within the highly aggressive water property. There was tendency of water to form a scaling film on plumbing fixtures and particularly in hot areas until it becomes slightly undersaturated concerning the calcium carbonate. Aggressiveness Index (AI) formulated for evaluating corrosion in an asbestos cement pipe, is defined as" (South African Water Quality Guidelines,1996). AI = H + $\log_{10}$ (AH), where; A = total alkalinity in mg Ca CO_3/R, and H = calcium hardness as mg/R Ca CO^3. The following is the data interpretation of the aggressiveness index:

Aggressiveness Index (AI)	Water property
$12	Non-aggressive
10.0 to 11.9	Moderately aggressive
#10	Highly aggressive

(South African Water Quality Guidelines, 1996)

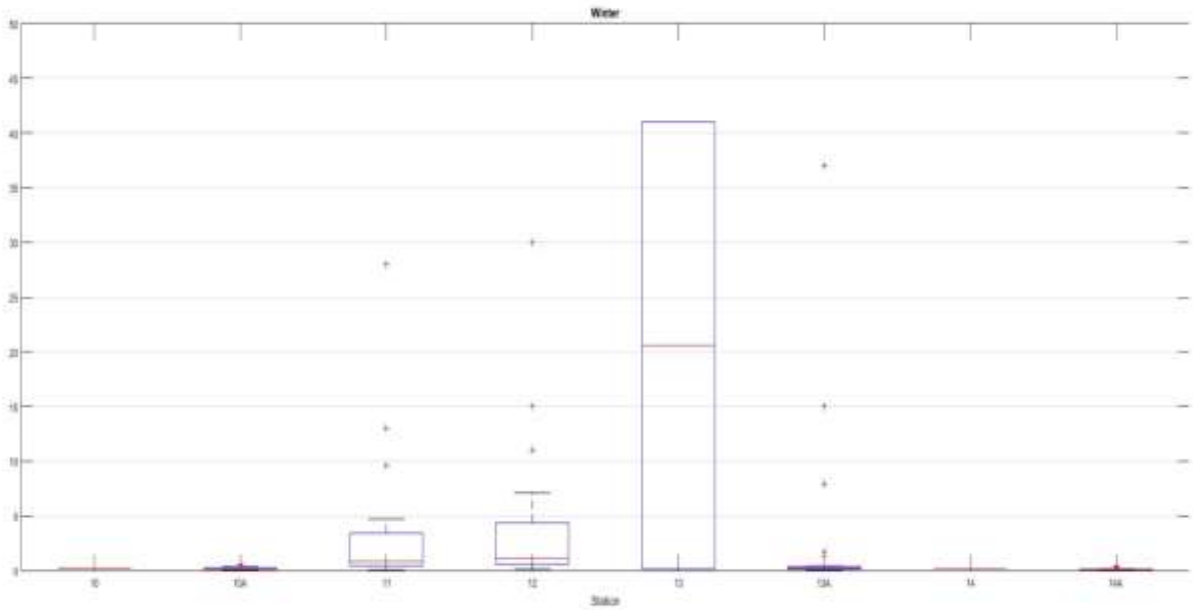


Figure 8 shows the Ammonia (NH4-N) concentration at various points along the Berg River

Ammonia as NH4-N concentration in the receiving environment should not increase beyond 6mg/l. Given the results above sampling points in winter B 11, B12, B13 showed that there was a tendency to exceed specification limits. (South African Water Quality Guidelines, 1996). Receiving environments that are contaminated with organic waste or raw untreated sewage had a high ammonia nitrogen concentration exceeding 6 mg/l if it is not contaminated the ammonia value was less than 0.2 mg/l. The presence of ammonia in the receiving environment was the result of runoff from agricultural lands whereby ammonium salts were used as fertilisers. Acidic conditions presented very low toxicity of ammonia while alkaline conditions presented toxic ammonia. Results showed that there was a close relationship between chemical reactions and toxicity effects of ammonia and pH. (South African Water Quality Guidelines, 1996).

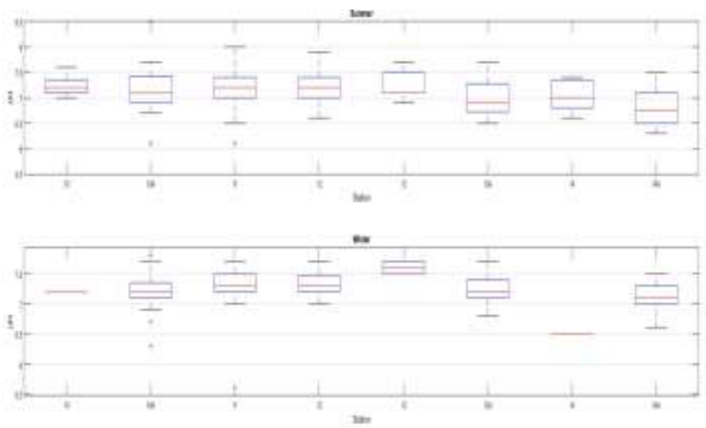


Figure 9 shows the pH concentration at various points along the Berg River

In terms of the department of water and sanitation requirements, wastewater pH limits values applicable to the discharge of wastewater into the water resource, it should range between 5.5

and 9.5. Both summer and winter results showed that there were within specification. At pH less than 7 is acidic, while a pH greater than 7 water is alkaline. The pH of a solution is the negative logarithm to the base ten of the hydrogen ion concentration, given by the expression: $pH = \log_{10} [H^+]$, where $[H^+]$ is the hydrogen ion concentration. Results for all the sites B10 to B14 above showed that in summer pH exceeded 7 meaning that the water is more acidic unlike in winter where the pH concentration fluctuates between acidic and alkaline. (South African Water Quality Guidelines, 1996). These results are show that the water was fresh.

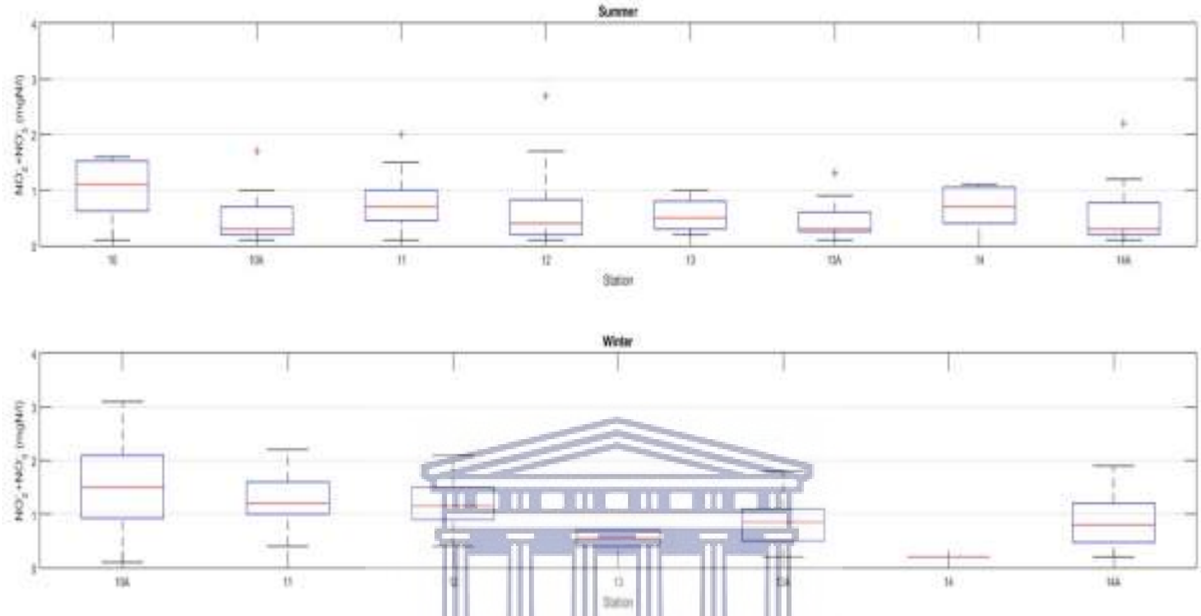


Figure 10 shows the Nitrate and Nitrite concentration at various points along the Berg River

The trend for nitrate and nitrite indicated that it was within the specification for not greater than 15 mgN/l. Interactions with nitrate are present with all conditions associated with the presence of breakdown of organic matter. For example, enrichment of waters with dissolved organic carbon can increase the rate of denitrification by providing an energy source for the denitrifying bacteria. The processes of nitrification, denitrification and the active uptake of nitrate by algae and higher plants are regulated by temperature and pH (Bain and Engelhhardt (1989).

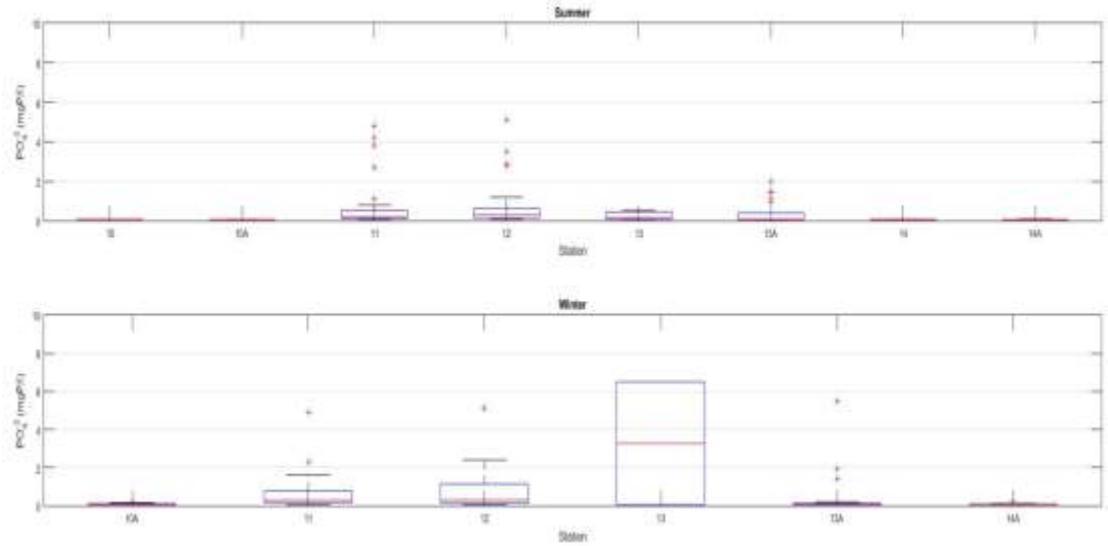


Figure 11 shows Ortho- Phosphate concentration at various points along the Berg River

Sites B11 and B12 showed a high concentration of all the constituents meaning there were out of specification. Miró, Frenzel emphasized that "Determination of orthophosphate is of great importance in water-quality surveillance since this compound is regarded as the best indicator of the nutrient status of natural waters. (Determination of orthophosphate is of great importance in water-quality surveillance since this compound is regarded as the best indicator of the nutrient status of natural waters", M. Miró, W. Frenzel, in Encyclopedia of Analytical Science (Second Edition), 2005). Such assessment was viewed as a good practice in water quality.

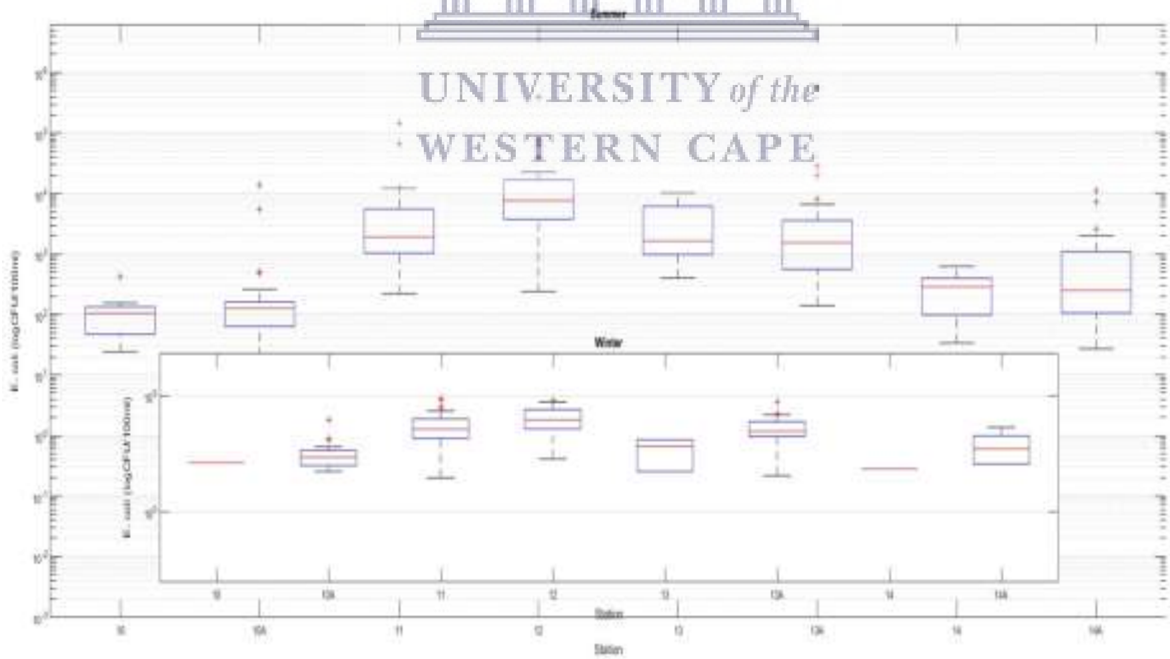


Figure 12 shows E- coli concentration at various points along the Berg River

The presence of the E- coli concentration in fresh water is unwanted and it shows presence of fresh human waste in the water body hence poses risk to human health in the ecosystem.

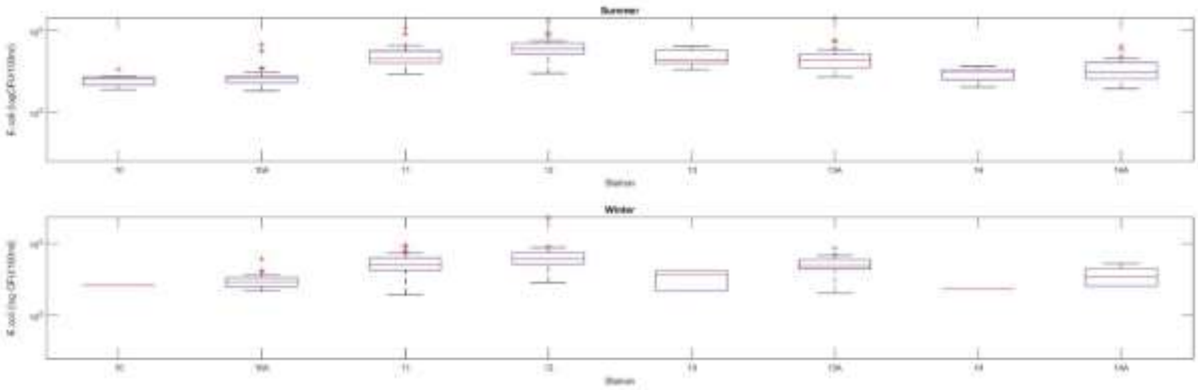


Figure 13 shows E- coli concentration at various points along the Berg River

The results on E-coli showed that the concentration was rising for the years which posed a risk to human health and the environment. It was resulted into suggesting that effectiveness of sewage treatment processes to remove faecal pathogens and antibiotic residues required more advanced techniques as the existing technologies seemed not working. However, this was beyond the scope of the presented study's objectives. However, these finding provided insight for further microbiological studies. Ishii [2008] argued that Escherichia coli is the preferred microbial water quality indicator and current guidance upholds that it indicates recent faecal contamination. (Microbes and Environment, Michael Sadowsky Satoshi Ishii May 2008).

The River Eco status Monitoring Programme (REMP) involves monitoring several biological (macroinvertebrates; fish; riparian vegetation) and physical (habitat integrity; geomorphology) components. Each of these components has an index model designed for it, which once completed, produces an Ecological Category (EC) also confirms the chemical and biological monitoring that was sampled in the Berg River catchment. The ECs range from A (natural) to F (critically modified) and are used to describe the ecological state/health/integrity of a river site or reach (Table). The ECs represent the Present Ecological State (PES) of the individual components. It can be concluded that the wastewater treatment works that are discharging final effluent into the Berg River are contributing to the pollution of the receiving environment. Due to aging and overloaded sewer infrastructure, the sewage is partially treated to reach the Department of Water and Sanitation's water quality standards. This often results in inadequately treated sewage discharged into rivers. This has a negative water quality impact, causing algal and reed growth. Rivers such as Eerste, Kuils, Black River in Athlone, Sout River in Melkbosstrand, Diep River in Malmesbury are highly impacted by WWTW. Upgrades of WWTW are recommended, as it is often a matter of aging and overloaded treatment infrastructure that is a problem. The riparian zones must be rehabilitated by stabilizing the riverbanks, taking into consideration the original slopes and shapes of the rivers in question. Indigenous plants must be planted when rehabilitated areas are vegetated. Clearing of aliens should be done constantly, followed up regularly and there must be co-operation across government so that landowners can clear aliens on their properties.

Table 5 shows generic ecological categories (Kleynhans and Louw, 2007)

ECOLOGICAL CATEGORY	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota, and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota, and basic ecosystem functions is extensive.	20-39
F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances, the basic ecosystem functions have been destroyed and the changes are irreversible	0-19

It was decided that in the interest of not causing statistical bias, not to replace non-detects with half detection limit. Although it was expected to lead to medians higher than those that would be statistically representative of the given data set, the effect was expected to be relatively small. At any rate, for this study where upstream/ downstream comparisons are all that was required, this should be sufficient. It was appreciated that the process of replacing left-censored data (non-detects) was fraught with difficulties and the subject of controversy (Bain and Engelhardt, 1989). It was also recognised that in the case of comparison of data sets, a quantitative statistical test would add to scientific credibility. The proposed null hypothesis was that there was no difference between the downstream and upstream sites. A two-tailed t-test for equal means and unknown standard deviation was applied. Here the power of the test is strongly dependent on the number of data in each group. This test could not realistically be applied when summer and winter data. sets were separated. The data were split into winter data (May to October) and summer data. The comparisons are presented as box and whisker plots in the figures below using the Matlab 2015, Statistics toolbox. The red lines represent the median values, the box represents 25th and 75th percentiles, and whiskers the 90th percentiles. Crosses above and below whiskers represent outliers (Bain & M Engelhhardt (1989).

It was appreciated that, to assess the impact of point sources, one should use pollutant loads. In the absence of flow data, it was decided to look simply at concentrations. But it is recognized that pollutant loads (or more accurately, mass flux) may present a slightly different picture.
The informant interview method was used to collect data from various individuals that vary from academics, technical managers from the WWTWs, researchers, representatives of the BERG River farmers, experts who worked in Berg River, officials, and scientists. The results of the informant interview were used to validate the results from analysis of secondary data.

5.3 Identifying challenges of wastewater services institutions to water resource management: Relevance of Green Drop Certification Programme

The second objective of the current study was to assess the relevance of incentive-based approaches by identifying challenges of wastewater services institutions to water resource management. The Green Drop Certification Program in wastewater services institutions was used as an example in assessing such relevance towards sustainable management of water resources. The focus was on determining challenges of water services institutions for managing water treatment facilities using various methods. Methods that were used to collect and analyse data for objective one and two were similar and the discussion on them are provided below:

Studies on Municipal CRR profiles shows the risk-based regulation in South Africa. For example, the full *Green Drop assessment* focuses on the entire value chain (reticulation, pumping, treatment, discharge) of the wastewater business within the municipal (or other) wastewater services business, the *Cumulative Risk assessment* focuses on the wastewater treatment function specifically. The latter approach allows the Regulator to have insight into the treatment component of the municipal business, which is one of the high-risk components within the wastewater value chain. Risk-based regulation allows the municipality to identify and prioritise the critical risk areas within its wastewater treatment process and to take corrective measures to abate these. Risk analysis is used by the Department of Water and Sanitation to identify, quantify and manage the corresponding risks according to their potential impact on the water resource and to ensure a prioritised and targeted regulation of high-risk municipalities (GD Report 2013).

In this study, it was discussed that the regulator should make sure that other pollutants such as microplastics are tracking all over and check where the sources are, they are not taking samples of what you do not know what damage you are causing if you are not looking. It was further said that alternative ways of treating effluent from the wastewater treatment work the WSI before discharge to the receiving environment. It was found out that biomonitoring and adhering to the RQOs upstream and downstream WWTWs discharge points were not happening. Setting trends and mitigation plans, penalties for Green Drop assessments were not prioritized. Continual sampling and capturing of data did not bring solutions but only results. Results need to feed solutions but this was not happening and it remained a challenge.

Risk is defined and calculated by the following formulae: Cumulative Risk Rating (CRR) = A x B + C + D

Where the weighting factor is based on:

A = Design Capacity of the plant which also represents the hydraulic loading onto the receiving water body

B = Operational flow exceeding-, on- and below capacity.

C = Number of non-compliance trends in terms of effluent quality as discharged to receiving water body

D = Compliance or non-compliance i.e. technical skills (management, operation, maintenance)

Where each risk element carries a different weight in proportion to the severity of the risk element: A CRR value is calculated for each municipal wastewater treatment facility in South Africa, as provided in this chapter. Water quality compliance focus on the following parameters: (1) E. coli / Faecal coliform, (2) pH, (3) Electrical Conductivity, (4) Suspended Solids, (5) Ammonia as Nitrogen, (6) COD (7) Nitrate/Nitrite as Nitrogen, (8) Ortho-Phosphate as Phosphorus

A: Design Capacity (Ml/d)		WF
Design Capacity Rating	> 400	7
	201 to 400	6
	101 to 200	5
	51 to 100	4
	21 to 50	3
	20 to 5	2
	<5	1

B: Capacity Exceedance (%)		WF
Capacity Exceedance Rating	> 151 %	5
	101 – 150 %	4
	51 – 100 %	3
	1 1 – 50 %	2
	0 – 10 %	1
	< 0 %	0

C: Weighting Factor (WF) for the Technical Skills		WF
Technical Skills Rating	Superintendent + Process Controllers + Maintenance Team	1
	Superintendent + Maintenance Team but no Process Controllers	2
	Process Controllers + Maintenance Team but no Superintendent	
	Process Controllers + Superintendent but no Maintenance Team	
	Superintendent but no Maintenance Team & no Process Controllers	3
	Process Controllers but no Maintenance Team & no Superintendent	
	Maintenance Team but no Superintendent & no Process Controllers	
	No Superintendent + No Process Controllers + No Maintenance Team	4

D No of Non-Compliant Parameter Failures	WF
Effluent Failure Rating	8
	7
	6
	5
	4
	3
	2
	1
	0

(Snapshot, Greendrop Handbook, 2013)

Records review showed that since the inception of the Green Drop certification programs in 2008, the department and sector at large have passionately put shoulders to the wheel and can look back at the achievements with pride knowing fully that the future holds exciting possibilities for this incentive-based regulation system. Over the years, the sector has gradually seen a remarkable increase in the number of systems that were assessed bi-annually and a corresponding increase in the Green Drop Certificates. In 2008/09, 444 wastewater collector systems were assessed, whilst in the 2012/13 assessment year, 963 wastewater collector systems were assessed, representing a whopping increase of 118%. This exponential increase in the systems being assessed is not only an indicator of how serious the sector takes the issue of waste management, but also a commitment that there is leading awareness to conserve and manage our water resources in a manner that strikes a balance between the need for economic development and environmental sustainability. The challenge was that such a passion never continued with the support and commitment that were required over the years.

The steady increase in the number of municipalities that have been awarded the Green Drop certificates over the years was a testimony of the hard work that we have all put in, to ensure that wastewater management becomes an indispensable cog in safeguarding the health of our communities and facilitating economic growth. The success story of the Green Drop programs could not have been possible without the support of the qualified specialists, the inspectors, who worked tirelessly to collect the information that was used to assess the water services institutions. As an African proverb says "If you want to go quickly, go alone. If you want to go far, go together". I believe that ours is not a quick and lonely journey, but a journey of the collective that will take the water sector to new levels in our quest to ensure access to quality water and a healthy environment for our communities. "a better life for all our people". (Molewa, 2013). The challenge was to sustain the support and commitment of such progress.

In general, records showed in the first years of democracy from 1994, the priority for water in South Africa was a major drive to ensure that as many people get access to water. As good progress was made, and the program delivered what it was aimed to deliver and then later the department said "...what about the quality of water that was being provided?" (Personal interview Helgard Muller, 2013) So the regulation of drinking water quality (Blue Drop) commenced and still later the wastewater quality (Green Drop) followed. As punitive regulation did not work and the concept of incentive-based regulation was developed. The biggest impact these programmes have achieved is the buy-in from municipalities Helgard Muller, (2013). Sustainable commitment for water services institutions was short lived.

The program has raised the level of awareness on wastewater management in the municipalities. There has been a contribution to skills and capacity building both within DWA and in municipalities through this regulatory program. DWA as a regulator enforced compliance. The Civil Society organisations partnered with DWS. An empowered society was thought useful in addressing non-compliance issues. Technological research was opened up from learning institutions, there were various research institutions like the CSIR and WRC that are currently involved in research and work closely with the Department of science and technology. It was agreed useful to use appropriate technology in all instances because there can be no one size fits all and the users were encouraged to have adequate skills to operate and maintain the systems to ensure sustainability of water resource management (Personal interview Mochotlhi, 2013).

5.4 Evaluating impact and progress of incentive-based initiative for practical interventions in wastewater service institutions for water resource management

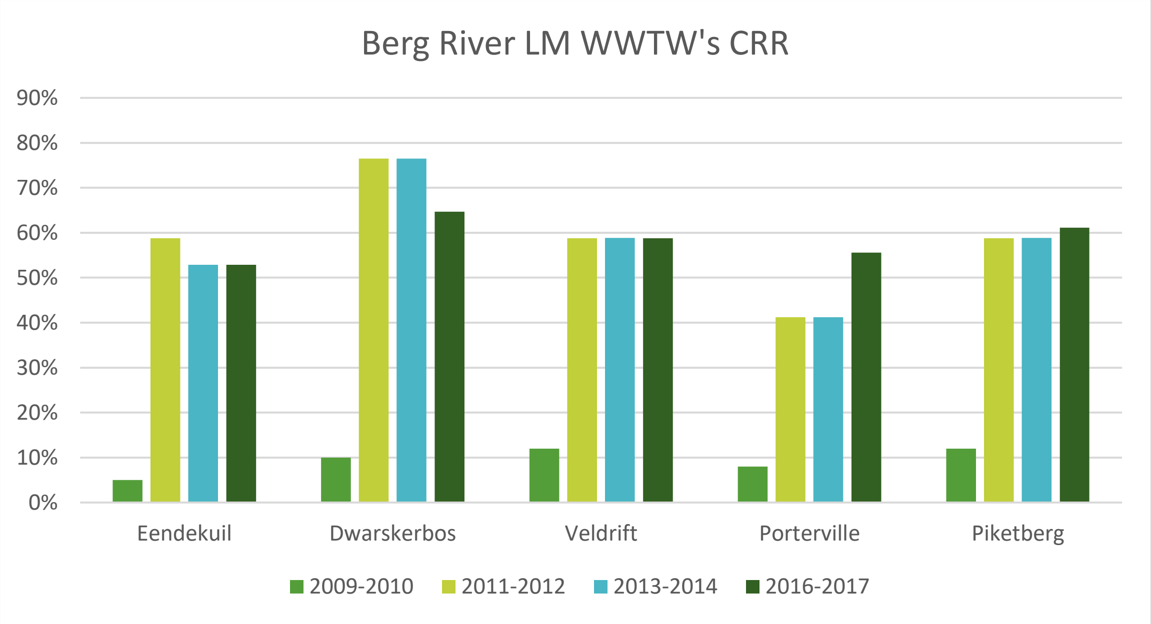
The third objective of the current was to evaluate the impact and progress of incentive-based approaches for practical interventions in the wastewater services institutions towards sustainable management of water resources. The Green Drop Certification Program in wastewater services institutions was used as an example in evaluating the impact and progress. The focus in the third objective was on assessing the impact and progress of the Green Drop Certification Program for practice management, and examining scientific aspects of the Green Drop Program for wastewater management in the water resource management sector. This section explains the methodology that was followed to obtain a systematic description of how the CRR data relevant to the study was collected. Results are presented in tables and graphs. The key message in this section is to show if the current implementation of the green drop certification program and best practice management approach is an effective regulatory tool.

Green Drop Key Performance Areas

GD # Key Performance Areas	KPAs 2009-2010	KPA 2012-2013	KPAs 2021 -2022
A	Process control, maintenance and management skills;	Process Management & Control	Capacity Management
B	Wastewater quality monitoring	Wastewater Quality Compliance	Environmental Management
C	Credibility of wastewater sampling and analysis	Risk Abatement & Management	Financial Management
D	Submission of wastewater quality results	Local Regulation	Technical Management
E	Wastewater quality compliance	Management Accountability	Effluent and Sludge Quality Compliance
F	Management of wastewater quality failures	Asset Management	Green Drop Bonuses
G	Storm-water and water demand management		Green Drop Penalties
H	By-laws		
I	Capacity and facility to reticulate and treat wastewater		
J	Publication of wastewater quality performance; 11 Wastewater asset management		

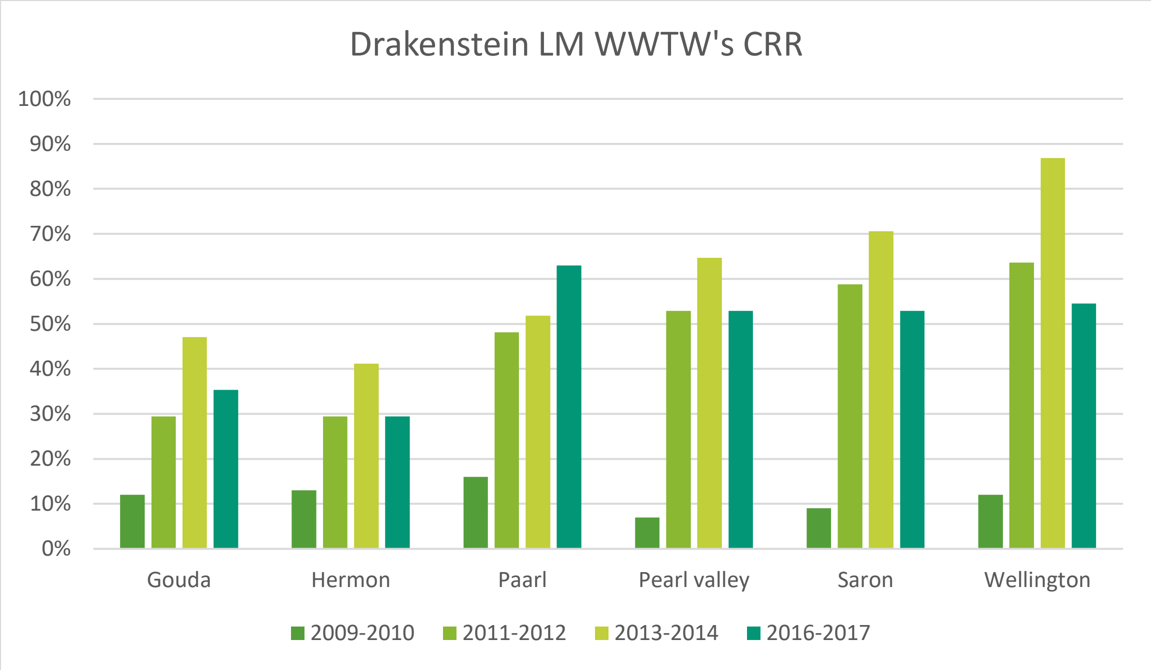
% Deviation = CRR/CRR(max) TREND			% Deviation = CRR/CRR(max) TREND	
	90 – 100% Critical risk			90 – 100% Critical risk
	70 - <90% High Risk			70 - <90% High Risk
	50-<70% Medium risk			50-<70% Medium risk
	<50% Low Risk			<50% Low Risk

Snapshot from the GreenDrop report, 2013

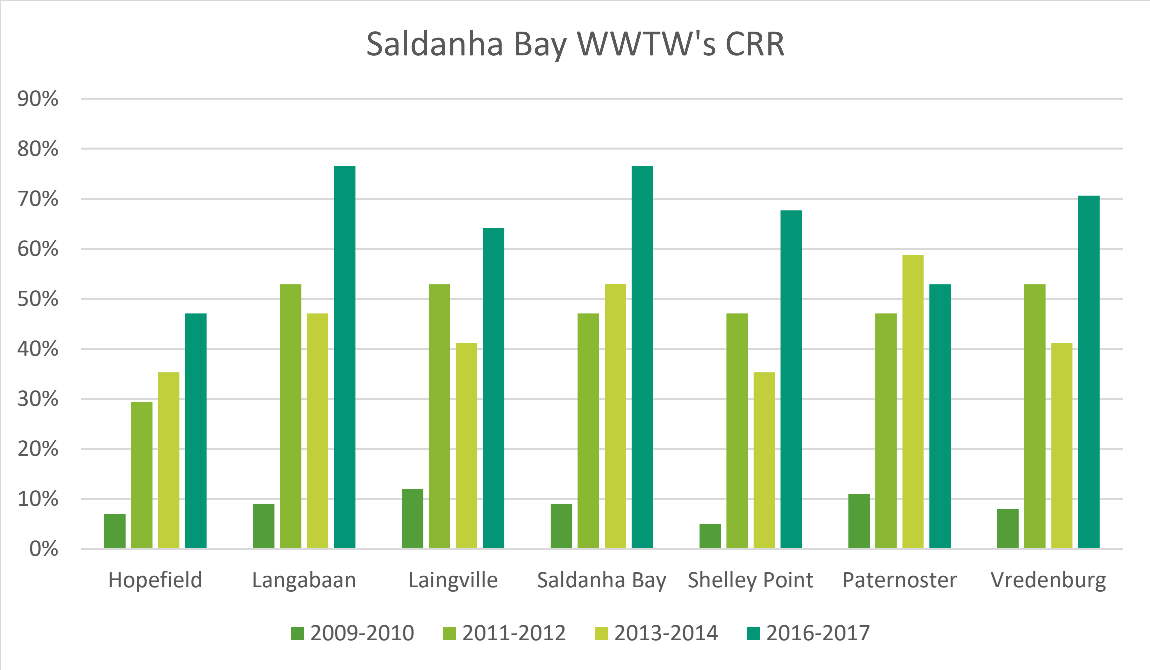


The Bergrivier municipality water compliance remains a challenge even though there is a slight improvement on the CRR % for the two WWTWs Eendekuilis and Dwarskerbos WWTWs are Oxidation ponds which does not discharge directly into the Berg River. Eendekuilis complies Nitrate/Nitrite as Nitrogen >90% remain the medium CRR % >50% and Dwarskerbos WWTW shows improvement from high to medium risk and is within specification with Orthophosphate as Phosphorus>90%, and while other WWTWs are activated sludge plants for Veldrft WWTW the CRR remains at medium risk <70% WQ compliance (E-coli >90%, pH>90%, Nitrate/Nitrite as Nitrogen >90%). Porteville WWTW's CRR% has increased but remains in the medium risk WQ compliance (pH>90%, Nitrate/Nitrite as Nitrogen >90%, Electrical Conductivity >90%, Ortho-Phosphate>90%) and Piketburg WWTW's CRR % is at medium risk, WQ (pH>90%, Nitrate/Nitrite as Nitrogen >90%, Suspended Solids>90%, Ortho-Phosphate>90%)   The overall CRR for the entire WSI is medium risk <70% and this is due to non-compliance on effluent water quality. The WSI has a highly skilled technical staff to operate the plant and all WWTW s are operating within the average dry weather flow.

% Deviation = CRR/CRR(max) TREND	**90 – 100% Critical risk**	
	70 - <90% High Risk	
	50-<70% Medium risk	
	<50% Low Risk	

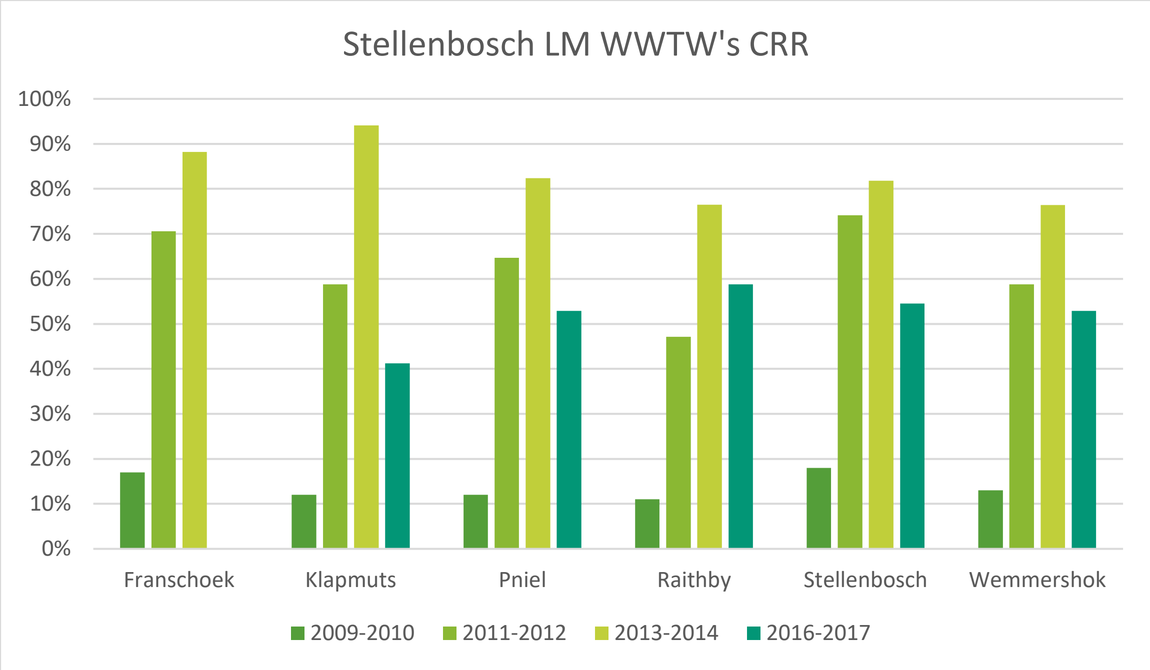


The overall CRR % for the WWTWs for the municipality shows a great improvement that ranges between low (Gouda and Hermon) and medium risk. (Paarl, Pearl Valley, Saron, and Wellington) water compliance remains a challenge even though there is a slight improvement in the CRR %. Even though the two WWTWs Gouda (oxidation pond) and Hermon WWTW evaporation pond still managed to reduce the risk and remain at low risk, while other WWTWs (Pearl Valley, Saron & Wellington) that are activated sludge plants their CRR% reduced slightly and remains at medium risk. Paarl is the only WWTW for Drakenstein WSI that the CRR has increased, however, the CRR% remains at medium risk. The overall CRR% for the entire WSI is at medium as a result of non-compliance on effluent water quality of some of the parameters. The WSI has a highly skilled technical staff to operate the plant and all WWTW s are operating within the average dry weather flow. Even though the water quality requires further improvement, the following are observed: For Paarl WWTW (pH>90%, Nitrate/Nitrite as Nitrogen >90%), Wellington WWTW (pH>90%, Nitrate/Nitrite as Nitrogen >90%, Electrical Conductivity >90%, Ortho-Phosphate as Phosphorus>90%), Pearl Valley WWTW (E-coli>90%, Electrical Conductivity >90%, Suspended Solids >90%), Saron WWTW (E. coli >90%) and Hermon (E-coli>90%, Electrical Conductivity >90%, >90%)



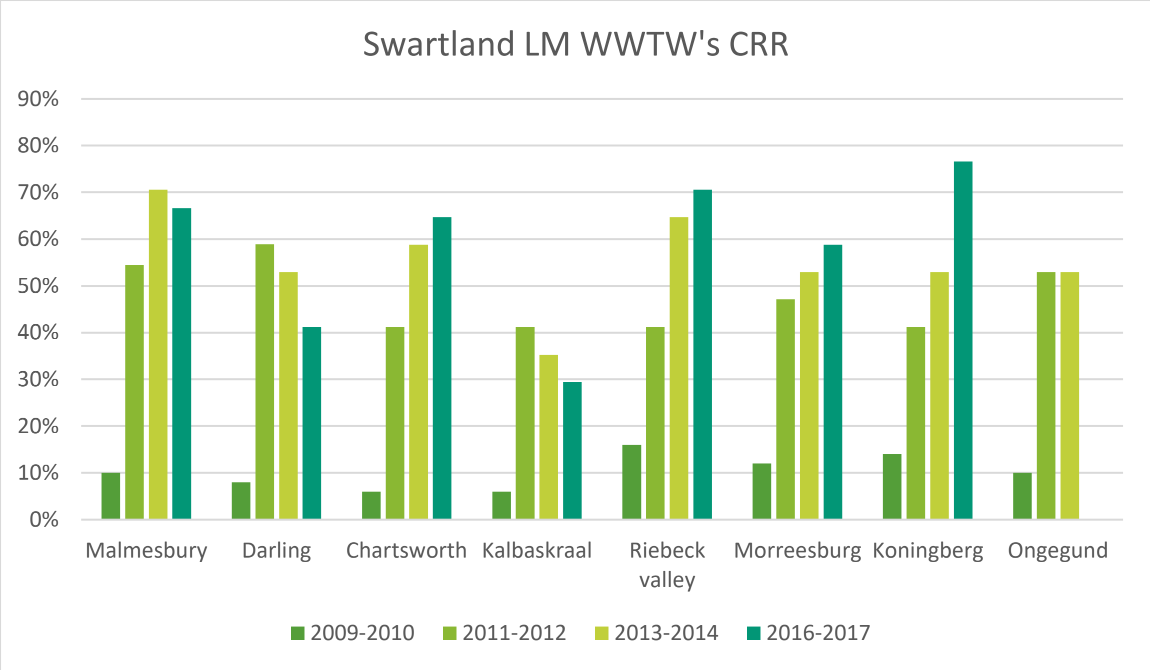
The overall CRR % for the WWTWs for the municipality shows an increase residing between low, medium, and high risk. It must be noted that 5 of the WWTWs in this WSI (Vredenburg, Langebaan, Hopefield, Shelly Point, and Laingville) do not discharge their treated effluent directly into the Berg River but rather use it for irrigation. Effluent compliance remains a challenge. The two WWTWs (Paternoster and Saldanha Bay) discharge their treated effluent into the stream and eventually lands in the Berg River, Vredenburg WWTW. CRR % for Saldanha Bay WWTW shifted from medium to high risk with WQ compliance (E-coli>90% and Ortho-Phosphate as Phosphorus>90%)Vredenburg WQ (pH>90%, COD>90%, and Ortho-Phosphate as Phosphorus>90%), Langebaan WWTW WQ (E-coli>90%,pH>90%, Nitrate/Nitrite as Nitrogen >90% & Ortho-Phosphate as Phosphorus>90%), Hopefield WWTW WQ (E-coli>90%,COD > 90%, pH>90%, Nitrate/Nitrite as Nitrogen >90% & Ortho-Phosphate as Phosphorus>90%), Paternoster WWTW WQ (E-coli>90%,pH>90%, Ammonia>90% & COD>90%), Shelly Point (pH>90% &COD>90%) and Laingville (pH>90%, Nitrate/Nitrite as Nitrogen >90%, Electrical Conductivity >90%, Ortho-Phosphate as Phosphorus>90%). The non-compliance of the technical skills, design capacity, and some of the plants exceeding the design capacity is contributing to the increase of the CRR %.

% Deviation = CRR/CRR(max) TREND	90 – 100% Critical risk	
	70 - <90% High Risk	
	50-<70% Medium risk	
	<50% Low Risk	



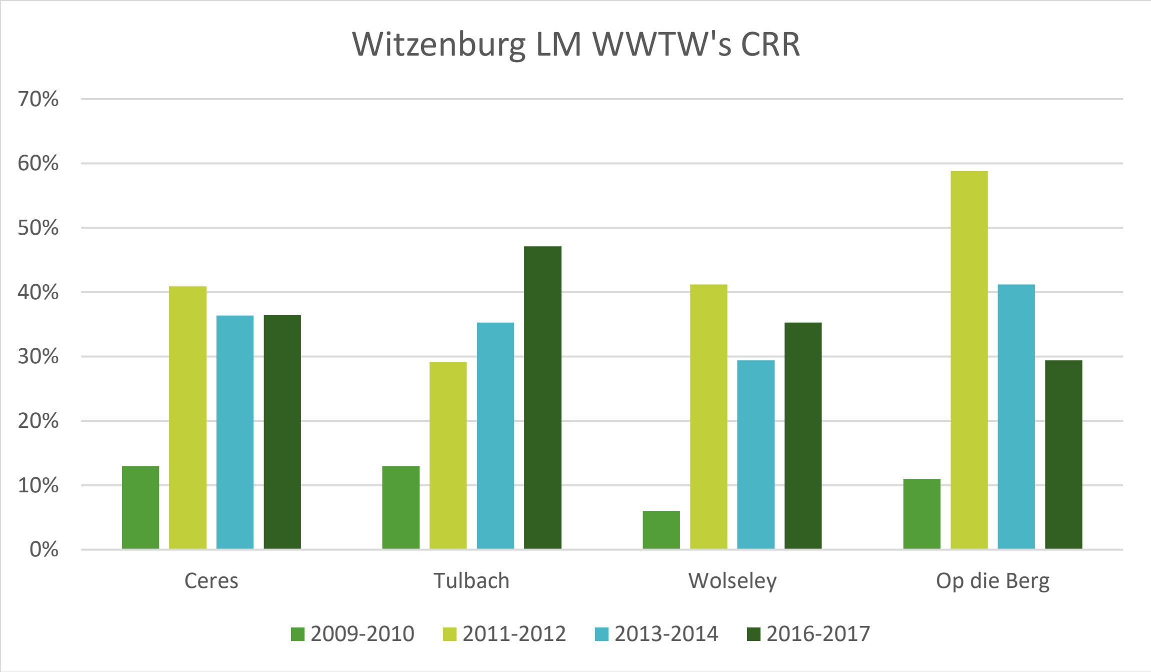
Franschhoek WWTW has been decommissioned hence there is no latest CRR %. The overall CRR& for Stellenbosch WSI shows an improvement ranging from critical to low risk. There are no WWTWs that fall within the high-risk area. The overall CRR % for the WWTWs for the municipality shows an improvement from all the WWTWs residing between low, medium, risk) Effluent compliance requires an improvement. Klapmuts WWTW. CRR % is low with WQ of (pH>90%, COD>90%, and Electrical Conductivity >90% and Ortho-Phosphate as Phosphorus>90%), Pniel CRR % is medium with WQ (pH>90%, Nitrate/Nitrite as Nitrogen >90%, Electrical Conductivity >90%), Raithby WWTW CRR is medium with WQ compliance of (COD>90%, Electrical Conductivity >90% and Nitrate/Nitrite as Nitrogen >90%), Stellenbosch WWTW's CRR has improved even though is still resing under medium rate, WQ: (pH>90%, Electrical Conductivity >90% and Nitrate/Nitrite as Nitrogen >90%) and Wemmershoek WWTW CRR's % is showing an improvement in the trend and still residing under medium risk, WQ: (pH>90%, Electrical Conductivity >90% and Nitrate/Nitrite as Nitrogen >90%

% Deviation = CRR/CRR(max) TREND	**90 – 100% Critical risk**	
	70 - <90% High Risk	
	50-<70% Medium risk	
	<50% Low Risk	



Ongegund WWTW has been decommissioned hence there is no latest CRR %. The average CRR% for the WSA is ranging from low to high risk. Malmesbury WWTW is remaining at high risk with the following parameters being compliant (Ammonia, pH, Electrical Conductivity, Suspended Solids, COD > 90%), Darling WWTW's CRR% is medium with WQ (pH, > Nitrate/Nitrite as Nitrogen 90%), Kalbaskraa WWTW's CRR % is residing under low with WQ of (pH>90%, E-coli>90% and Suspended Solids>90%), Chatsworth CRR % is medium with WQ (pH>90%, Nitrate/Nitrite as Nitrogen >90%, Electrical Conductivity >90%), Koringberg WWTW's CRR is high with WQ compliance of (Nitrate/Nitrite as Nitrogen >90% and pH>90), Riebeek Valley WWTW's CRR has improved even though is still rising under medium rate, WQ: (pH>90%, Electrical Conductivity >90% and Nitrate/Nitrite as Nitrogen >90%)

% Deviation = CRR/CRR(max) TREND	90 – 100% Critical risk	
	70 - <90% High Risk	
	50-<70% Medium risk	
	<50% Low Risk	



Witzenburg LM all WWTWs CRR % remain at low risk. The average CRR% for the WSA is ranging from low to high risk. Op Die Berg WWTW improved from a medium to low-risk rating. Witzenburg LM effluent compliance at all WWTWs and monitoring compliance 100%. With all the parameters. In a nutshell, the areas where further improvement is needed are under technical management. The third objective in impact and progress was well achieved.

5.5 Summary chapter: Practical implication of results from this study

Results showed that 5 of the WWTWs in this WSI (Vredenburg, Langebaan, Hopefield, Shelly Point, and Laingville) did not discharge their treated effluent directly into the Berg River but rather use it for irrigation. Using treated effluent for irrigation showed that that programme was relevant and had a positive impact. It provided nutrients for farming activities thereby reducing the cost of buying fertilisers for farming activities in addition to increasing water availability for farming activities through the reuse approach. Secondly, overall results showed an improvement in wastewater management which ranged from critical to low risk. Thirding the Greend Drop Certification Programme had a highly skilled technical staff to operate the plants and all WWTWs were operating within the average dry weather flow. These findings lead to achieving the third objective of evaluating the impact and progress of incentive-based approaches for practical interventions in the wastewater services institutions towards sustainable management of water resources. The Green Drop Certification Program in wastewater services institutions was used as an example in evaluating the impact and progress. Results showed positive impact and positive progress of the Green Drop Certification Program for practice management [operating WWTWs]. Scientific data the study WWTWs were scientifically measured, analysed and presented in graphs as shown in this section. In short, scientific aspects of the Green Drop Certification Program for wastewater management in the water resource management sector were addressed. This section explained the methodology that was followed to obtain a systematic description of how the CRR data relevant to the study were collected. Results were presented in tables and graphs and a brief description on each table and graph/figure was provided. The key message in this section was to show the impact and progress of implementing the green drop certification program and best practice management approach (scientific approach) in operation to feed into effective regulatory tool.

It was argued that the regulator should make sure that other pollutants such as microplastics are tracking all over and check where the sources are, they are not taking samples of what you do not know what damage you are causing if you are not looking. It was further said that alternative ways of treating effluent from the wastewater treatment work the WSI before discharge to the receiving environment. It was found out that biomonitoring and adhering to the RQOs upstream and downstream WWTWs discharge points were not happening. Setting trends and mitigation plans, penalties for Green Drop assessments were not prioritized. Continual sampling and capturing of data did not bring solutions but only results. sampling results need to feed solutions but this was not happening and it remained a challenge.

It was observed that if the goal is to improve the status quo of the water quality in the Berg River, it is crucial to understand the problem which was not the priority. This is achieved through continuous monitoring of problematic and common pollutants but such activities are not consistent. Once this is established, preventative measures of pollution and remedial actions can be investigated and implemented to address the problem but this was not happening by the time this study was carried out. Furthermore, research on emerging pollutants (those currently not part of the compliance regime) is necessary to develop an improved understanding of the true quality of river water. This was a challenge as studies on emerging pollutants remain critical to the wastewater service regulation. This then requires the development of advanced tools to measure and monitor these emerging contaminants such as pharmaceuticals, among others. During interviews, it was reported that the need for a position papers on water quality such as re-use, upgrades of the refurbishment of plants was important. Predictive water modelling as a new management tool was not there yet. Alternative ways of treating effluent coming from wastewater treatment plants before discharge to the receiving environment was started but not rolled out to other WWTWs. Advanced treatment methods of effluent were not practiced but were needed. Upgrading of the decommissioned wastewater treatment plants was reported as urgent action. Revision and development of stricter effluent discharge standards were discussed but interviews suggested wider adoption of such suggestion by authorities.

The examination of the scientific aspects of the green drop certification program for wastewater management showed that new and advanced scientific analyses were required on the existing data of the Green Drop Certification Programme to provide information required to sustainable improvement of the water services institutions. Such services will address the reported societal problem about water resource management. Professional trainings on advanced technical skills remain critical for new interpretation of scientific data of the Green Drop Program in the water services in wastewater treatment for practical and sustainable water resource management.

Chapter 6: Conclusion and recommendation

In summary, the current study was set to determine the contribution of water services institutions to water resources management; to determine challenges of water services institutions for managing water treatment facilities and to assess the current progress of the green drop certification programme for practical management. The main focus was to assess the role of institutional commitment in sustainable water resources management where the Green Drop Certification Programme in the Western Cape of South Africa was used as a case study. The reviewed literature of previous studies provided a context and synthesis to the current study in addition to providing gap analysis. The study area where the current research work was carried out was described to highlight features and conditions that would have influences the outcome of the current research. The study followed mixed methodological approach where mixed methods were used to collect and analyse secondary and primary data. The reliability of validity of results were achieved by using various quality assurance methods as described in chapter 4 of this study. In this study, the Green Drop Certification Program in wastewater services institutions was used as an example in assessing relevance, impact and progress of programme towards sustainable management of water resources. In this chapter, summary on results, conclusions and recommendations are provided.

In summary, section 5.2 outlines the challenges of water services institutions for managing water treatment facilities, section 5.3 outlines the current progress of the green drop certification program for practical management and section 5.4 outlines findings on scientific aspects of the green drop certification program for wastewater management. Sub-section 5.4.1 answers the research question on what new scientific analysis is required on the existing drop program data for water services institutions to meet their intended plan or target to solve the reported societal problem. What new interpretation of scientific data about the green drop program is required for water services in wastewater treatment? It is important to repeat that the current study investigated (1) the determination contribution of water services institutions to water resources management (2) challenges of water services institutions for managing water treatment facilities (3) current progress of green drop certification program for practical management and scientific aspects of green drop program for wastewater management.

The following summary, conclusions and recommendations from the 3 objectives:

Ammonia, E. coli, orthophosphate, and COD are showing an increasing tendency in concentration while DOC and total alkalinity show little or even decreasing tendencies. The overall hazard and probably the cumulative risk in the Berg River are likely to increase significantly in the next 2 years if the root cause of these challenges is not addressed enforcement in the regulator or if regulations are not strengthened. The frequency of water at the selected sampling stations has been consistent since 2013. The current level of data appears to be adequate to support the broad conclusions presented. This reveals that most constituents follow increasing trends in summer (dry season) although very few show trends significantly different from zero during winter (wet season) – phosphate being the exception. Most constituents that do show trends significantly different from zero in winter show declining trends. It can be concluded that there is an increase in the concentrations of water quality drivers in the downstream direction of the 5 selected sites in the Berg River catchment.

It was found out that water services institutions are currently facing many challenges in providing effective water services among others are the management of WWTWs. Most WWTWs that are not operating optimally discharges partially treated effluent into the receiving environment and cause water pollution. The Green Drop program aims to create a paradigm shift by which wastewater operations, management, and regulation are approached. (Burges, 2014). Conditions for regulatory intercession: The responsible authority fails to prove capability to provide water services as per regulatory requirements. In both instances the Water Services Authority will remain responsible for the governance function; however, the provisioning function will be taken over by the Minister (or representative of the Minister). Financing of the service should be primarily sourced from existing revenue sources and grants. It is paramount that the Department should strive to ensure that cost-reflective tariff structures are implemented to finance adequate maintenance and effective operations. Provisioning should also be made for rectifying capital projects where so required. To achieve this target all, grant funding needs to be re-aligned towards a comprehensive Programme for the achievement of reliability of services. All funding mechanisms such as MIG, RBIG, WSIG, equitable share, revenue from water sales, private sector contribution, and NGOs contributions should have one funding model that covers governance, functionality, water security, and new infrastructure developments. Proposed Representatives (WSP) to investigate the extent of non-compliance and required steps towards rectification and to formulate a Rectification Plan of Action. DWS and WSI to scrutinise the proposal and make comments. Use proposal to draft the Ministerial Intercession Instruction. Agree with WSI on conditions for intercession (including revenue channelling and financing); 3-way signatory agreement. Issue intercession Instruction/Directive and monitor implementation.

Further research is required to understand the relationship between biomonitoring and surface monitoring. The following are made based on the findings acquired during the study: The implementation of the RQOs as gazetted for the Berg River catchment, after experiencing drought in the western cape, using wastewater for groundwater recharge is another alternative way for seasonal storage and additional water quality improvement through a soil-aquifer treatment. Introducing emerging pollutants like microplastic monitoring is what should be pursued as lessons learned during the Covid -19 pandemic. Industrial effluent being discharged into the receiving environment. The impact of oxidation ponds on controlled activities such as recharge of groundwater and irrigation with wastewater discharged from the oxidation ponds.

References

Berrios, R., & Lucca, N. (2006). Qualitative methodology in counseling research: Recent contributions and challenges for a new century. *Journal of Counseling & Development*, *84*(2), 174-186.

Bruntland, G. (1987). Our common future. *The World Commission on Environment 1 and Development*, 45-65.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Government of South Africa. (2016) "Water and Sanitation." Water and Sanitation Reports.
Gringarten, A. C. (2008). From straight lines to deconvolution: The evolution of the state of the art in well test analysis. *SPE Reservoir Evaluation & Engineering*, *11*(01), 41-62.

Hay, ER, K Riemann, G Van Zyl, and I Thompson. (2012) Ensuring water supply for all towns and villages in Eastern Cape, Western Cape Provinces in South Africa. *Water SA* 38, no. 3.

Keskinocak, P., & Tayur, S. (2001). Quantitative analysis for internet-enabled supply chains. *Interfaces*, *31*(2), 70-89.

Bain L.J. and M Engelhhardt (1989). Introduction to Probability and Mathematical Statistics. 565pages. ISBN 0-87150-067-1. PWS-Kent Publishing Co. Boston, Massachusetts, USA

Merriam, S. B. (1998). *Qualitative Research and Case Study Applications in Education. Revised and Expanded from" Case Study Research in Education."*. Jossey-Bass Publishers, 350 Sansome St, San Francisco, CA 94104.

River Management Strategy for the BERG Water Management Area of the Western Cape, January, DWAF Project No. 2006 -462, 2008,

Berg WMA Internal Strategic Perspective Report No. P WMA 19/000/00/0304

National Water Resource Strategy, 2013 (NWRS2)

South African Water Quality Guidelines, Voi. 1: Domestic Water Use, Second Edition, 1996

M. Miró, W. Frenzel, in Encyclopedia of Analytical Science (Second Edition), 2005)

South African Green Drop Certification for Excellence in Wastewater Treatment Plant Operation, Water Research Commission of South Africa, Jo Burges

Department of water and sanitation Annual Report 2017/18

South African Local Government Association, 2011

Mvula Trust, 2009

Green Drop Reports, 2009

Water Services Act, 1997 (Act 108 of 1997)

Green Drop Handbook, 2013

Waste Discharge Strategy, 2019

Department Water Affairs and Forestry, South African Local Government Association, Department of Local Government and National Treasury, 2003

Department of Water Affairs, Department of Human Settlement, DM PME 2012

The Economic Research, Banergee etal 2009

Sanitation crisis in the country, Smith, Jana-Mari, 2011

Alliance, the African Ministerial Conference on Water (AMCOW), 2015

Organisation for Economic Co-operation and Development (OECD), 2009

Green Drop Report, 2013

Department of Water Affairs, 2010

Council for Scientific & Industrial Research (CSIR), 2016

Statistics South Africa General Household Survey, 2018

Department of Water and Sanitation, Master plan, 2017

Berg River Water Management Area, 2004

International Journal of Water Resources, Collins, Herdien, 2013

River Health Program, 2004

Department of Environmental Affairs and Development Planning (DEA&DP), 2009

River Health Program, 2005

Swiss public health measures associated with reduced SARS-CoV-2 transmission using genome data

Wikipedia, the free encyclopedia Leady, 1997

The case study as research method: A practical handbook MacMillan, Schumacher, 2001

The Singapore statement on research integrity, Resnik, Shamoo 2011

South African Water Quality Guidelines, 1996

IEEE Transactions on Reliability, Bain, Engelhhardt 1989

Green Drop Report, Mochitlhi, 2013

Green Drop Report, Halgard Muller, 2013

Microbes and Environment, Michael Sadowsky Satoshi Ishii, 2008